

REPORTS

CORRESPONDENCE AND ORIGINAL PAPERS

ON

VARIOUS PROFESSIONAL SUBJECTS

CONNECTED WITH THE DUTIES

OF THE

CORPS OF ENGINEERS

MADRAS PRESIDENCY

ARRANGED AND PRINTED FOR PRIVATE CIRCULATION

BY

CAPTAIN J. T. SMITH, F. R. S.

ASSOC. MEM. CIV. ENGRS. INSTITY.

VOL. I.

MADRAS:

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KNOWLEDGE.

1839.

TO
THE RIGHT HONORABLE JOHN LORD ELPHINSTONE G. C. H.

&c. &c. &c.

WHOSE CORDIAL ANXIETY

FOR

THE ENCOURAGEMENT OF EVERY USEFUL UNDERTAKING

AS WELL AS EMINENT STATION

Constitute Him

THE NATURAL HEAD AND PATRON OF THE CORPS

WHOSE LABOURS ARE HERE COMPILED.

THIS VOLUME

IS IN THE NAME OF HIS BROTHER OFFICERS

MOST RESPECTFULLY INSCRIBED

BY HIS OBLIGED

AND

OBEDIENT SERVANT,

THE EDITOR.

P R E F A C E.

The object proposed in the compilation of this volume will be readily acknowledged by every Officer of the Corps to be one of universal and permanent interest—that of providing a record, for the benefit of all, of the experience of its several members, and thus preventing the fruits of costly experience, or anxious study, being lost with the individuals by whose exertions they have been obtained.

It was under this impression, added to the feeling that the establishment of a free communication on scientific subjects would tend to encourage and keep up a more lively interest in our duties, and promote the real efficiency of the Department, that the commencement of a first volume was attempted; and the result of the experiment has I hope been such, as to hold out every encouragement for the future.

The arguments which apply in recommendation of such a work as this in Europe, plead with tenfold force in this country. Cut off as we are, both from examples for imitation, and authorities for reference, the practical Engineer is at this remote distance thrown entirely upon his own resources in regard to every new undertaking; and in the direction of a difficult enterprise, wherein he alone is called upon to supply information, from the most important principles in theory, down to the minutest particulars in detail, must often feel the want of that readiness of invention, or fertility of resource, which can be acquired only in the hackneyed paths of familiar practice and long accustomed routine.

In the absence of a mutual interchange of the experience which each may laboriously acquire on these occasions, and while a record is still wanting of such information as new circumstances give birth to, or new opportunities of observation discover, it cannot fail to be a source of regret to all, that the same obstacles should oppose themselves with fresh hindrance to each in turn, and that each should have to tread the same path of difficulty and doubt, to arrive at the region already explored by the many who have gone before him.

Instead of enlarging the boundaries of our practical knowledge by our united labours, we have, in fact, all to set out from the same point, and toil up the same rugged ascent often mastered before; and the waste of time and opportunities thus lost in the unnecessary acquisition of known truths puts a complete check to the extension of our labours, and damps the energies which might have been devoted to higher and more important research.

The proposition, therefore, which calls upon every individual member of our service to perform his part in a work of this kind, by communicating the results which his opportunities of experience afford, for the benefit of the rest, meets him in the shape of a duty which he owes to his brother Officers, followed by a recompense which he himself reaps in return; whence it may be confidently assumed, that the emulation which prompts each to aim at the most satisfactory discharge of his own peculiar duties, will stimulate him also to lend his aid, to the utmost of his ability, in raising the standard of professional knowledge, by which may be regulated the general efficiency of the Corps.

It will be observed that a change has taken place during the progress of the volume, in the selection which has been made for its contents. In first commencing to print for private circulation, it appeared to me, that it would have been sufficient to have collected together such public documents as would have given a complete history of the undertakings to be described, and would have embodied all the opinions and facts collected respecting it; but on proceeding to carry this into execution, I found, that so much irrelevant matter was thus necessarily included, and the papers were thus rendered so bulky and tedious, that a perseverance in that principle only, would have defeated both the usefulness, as well the interest of the volume.

With the exception of two or three subjects, therefore, that feature of the original plan has been modified by the substitution of papers expressly written for the occasion; and I am glad to have an opportunity of here expressing my sincere thanks to those friends, by whose kind exertions I have been enabled successfully to make a change involving so much additional labour.

An advantage attends this substitution which more especially marks it as the most suitable course for a collection of this kind—an opportunity is thus afforded for the insertion of minor details which it is the chief object of the volume to record; and the minutiae of practical difficulties, with the methods of surmounting them, which, though perhaps not the most interesting, are by far the most useful results of experience, can thus be communicated along with the accounts of the difficulties themselves. It is with a view to the encouragement of such detail, and with the desire also, that the authors should aim more at making their communications practically instructive, than popularly pleasing, that it has been judged expedient to make the present circulation a private one; and thus, while none may be restricted by any fear of deficiency from free contribution, those who have any further objects may still preserve the copy right of their communications, and after subjecting them by this “rehearsal” to the indul-

gent criticism of their brother Officers, make such further use of them as they may afterwards think proper.

In regard to the nature of the papers of which the work ought to consist, one rule only has been assumed, which it is hoped will be found a sufficient guide in all cases; and this is, that the communications submitted shall be the results of real experience, and therefore relate to some work or experiment *actually* executed; by this means it is hoped that the statements submitted will contain a valuable collection of *facts*, and that whatever information may be offered will be free from those delusive errors, which are too apt to pervade mere opinions, however carefully formed.

It has also been considered advisable that no definite periods should be fixed for the successive appearance of different volumes. In fact, the necessary advantages of position and opportunity are too rarely enjoyed by any member of the Corps, and the frequent mutations in our service render the liabilities to deprivation of them too numerous and sudden, to admit of the possibility of any prospective pledge being undertaken or fulfilled; moreover, the unremitted and overwhelming demand which almost all are subject to in their professional labours, leaves to but few the capability of assisting in a work of this nature, except by occasional efforts.

While, however, a desire shall continue to be felt by all for the encouragement of this endeavour towards our mutual improvement, it may be trusted that individual exertions will not be relaxed; and as long as the supply from the original sources shall continue steady and copious, we need not fear that their united streams will ever be long retarded by the want of an appropriate channel.*

J. T. S.

* It is requested that contributions for an ensuing volume may be addressed to the Secretary to the Engineer's Library.

NOTICE.

The Editor is not to be considered responsible for any of the opinions or statements contained in this volume, with the exception of such as may appear under his own signature.

The following papers are not to be published, or used as the materials for publication, without the express permission of their authors.

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REPORT BY CAPTAIN COTTON ON THE PROPOSED BREAKWATER AT MADRAS.

To

The Secretary to the

Breakwater Committee.

SIR,

I have at different times done myself the honor to send several Communications to the Committee on the subject of the Breakwater. I have now had some further opportunities for examining the question, and having ascertained the progress which has been made in the subject by the Committee, it seems to me that it may be useful to draw up a short report, containing the substance of my former papers, with such further information as I have obtained while at Madras.

From what has passed in Committee and what I have heard from different quarters, it appears to me, that the following points are now so generally allowed, that they do not require to be particularly remarked upon.

1st. That the work best calculated to counteract the surf should be unconnected with the shore.

2nd. That its shape should be a straight line parallel with the Coast.

3rd. That it should be of rough stone, and

4th. That it should be not within, nor much beyond, the outer line of the surf.

By making it entirely unconnected with the shore, there is the least danger of the formation of sand banks around it, both because the Current will be less interrupted by it, and also because the sand in its neighbourhood will not be disturbed by the surf. That the Current may be as little interrupted as possible, it is also necessary that it should be a straight line parallel with the Coast, or in the direction of the Current; if it is intended to be a permanent work, it must of course be of stone, or of large masses of old brick masonry; and the former is best, because it can be got near at hand in any quantity, and of any size that may be required. By putting it beyond the outer line of surf there is less danger of the sand around it being disturbed, and the communication will be kept open at all times when a Boat can live in the roads; and also it will be in such a depth of water, (about 20 feet), that any Dhoney that comes into the roads might anchor within it; and by placing it not much beyond the outer surf it will be in as shallow water as the other objects to be attained will admit of, which will both make the section as small as possible, and will also cause it to be exposed to less heavy seas than if further out; the height of the seas under similar circumstances, increasing and diminishing with the depth of water, when the depth does not exceed a few

fathoms. By placing it near the outer line of surf it will be out of the way of the shipping, for in stormy weather a ship could hardly come into 20 feet water, and within so short a distance of the shore, without being lost, whether there was a Breakwater there or not. The distance from the shore at which the outer surf breaks in stormy weather, has been ascertained to be within 300 yards, and the distance from shore settled by the unanimous vote of the Committee was 350 yards, where there is about 20 feet of water at spring tides.

The points next to be considered are those about which there still exists considerable difference of opinion, the principal of them seem to be—

1st. What is to be the length.

2nd.....height.

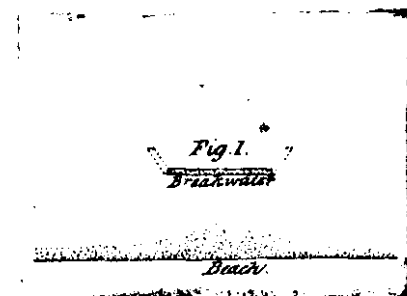
3rd.....form of section.

4th. Size of Stones.

5th. Expense.

It was upon the length required that the Committee were most divided, the two lengths mentioned at the meeting of the Committee were 200 and 350 yards, and the former was carried by a majority of one only. After much consideration on this point, I feel more confident than at first that 200 yards will be found sufficient. At the distance proposed, viz. 350 yards, it is evident that no heavy surf can form within the Breakwater, if the swell is fairly broken upon it, except by means of the waves which come round the ends of the work. If the work be too short, it is evident, that the swells from each end, inclining inwards as they approach the shore, will meet and form a fresh surf, though a slight one, and probably only immediately on the beach; and the height of this surf will not depend so much upon the proportion between the length of the work and its distance from the shore, as upon the proportion between the length of the work and the height of the swell. It must be remembered, that in whatever direction the wind is, the direction of the swell does not form a large angle with the beach at the distance of 350 yards from the shore; that is, at that distance the line of the swell is always not far from parallel with the Coast, as may be observed at any time when the wind is southerly or northerly; and hence it will be always nearly the same point of the beach that is most sheltered by the work. But whether the swell comes from rather to the Northward or rather to the Southward of East, the extent of beach sheltered will not be less than when it comes direct from the eastward. It is not necessary that the same point of the beach should be always sheltered, it is only necessary that some point should be, unless a slight timber jetty is constructed, as at first proposed, (which would

be very convenient for loading and unloading Boats,) and then it would not be necessary to bring the Boats to the beach. I think the opinion, that a longer work will be necessary, is chiefly owing to the very peculiar circumstance of the situation not being sufficiently considered. The Coast extending almost perfectly straight both North and South, with a shallow water all along it, effectually prevents any swell getting up in those directions; and the work being in only 20 feet water, the swell that comes round the ends from the eastward cannot be of such a height as that which rolls round the Plymouth or other Breakwater, placed in 8 or 10 fathom water. From these circumstances I conclude, that a greater length than 200 yards will not be required; but should it be found insufficient, two remedies may be applied, both of which will be a question of expense and not of practicability. First, it may be lengthened, or secondly, a timber jetty may be extended from the beach towards the Breakwater, which would not be at all an expensive work, because it would be effectually protected from any severe blow of the sea, by the Breakwater; either would be easily executed, but probably the latter would be the cheapest, and most convenient. But I must here mention that it is probable that one effect of the Breakwater will be, that sand will accumulate on the beach opposite to it, in this form.



It is to be observed that the Current alone, being very moderate, would have little effect upon the sand, if it remained undisturbed by the surf; it is the combined actions of the surf and Current, which cause such rapid changes in the sands, the surf keeps the sand suspended in the water, and the Current then carries it with it. Hence, when the beach is sheltered from the swell, I conclude that there will be an alteration in the line of the beach, as shown in the sketch; this, if it does not extend too far, will be a great advantage; both by carrying the beach nearer to the Breakwater, and also by increasing the space in front of the Custom house; but should it appear to be extending too far, and to be likely to continue to advance till it meet the Breakwater, the remedy must be, either to keep the Breakwater so low, as that a slight surf will occasionally force on the beach, (over which a jetty must be carried,) or to extend the Breakwater at each end by lines carried in a N. E. and S. E. direction, so as to contract the Current between the Breakwater and the shore. On these and many other points I do not conceive that it is possible to form any certain judgment now, but the effects should be carefully watched as the work proceeds, and from thence certain conclusions can be drawn, by which the further proceedings may be regulated.

The height of the work was determined in the Com-

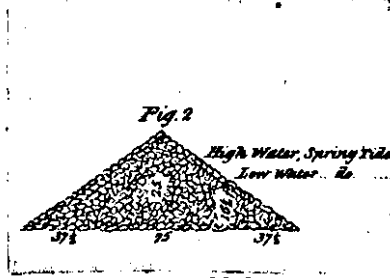
mittee, by a large majority, to be 5 feet above high water, that is, that it should be about 25 feet in total height.

There are two ways, in respect of the height, in which the work may be secured from much injury, first, by making it so high that the top, where the stones have nothing but their own weight to keep them in their places, may be out of reach of the main force of the sea. The blow given by the top of the wave is of course very weak, and it gradually increases down to the level of the hollow of the sea, where it is greatest; supposing that the mean level of the sea in a Hurricane is 2 feet above the ordinary mean level at spring tides, and the waves are 10 feet high, or 5 feet above the mean level at the time; the tops of the waves will be two feet above the top of the work, if the height is made as proposed; the top stones will then be exposed to a much less severe blow than if the work is made lower, and consequently they will be less liable to be displaced.

The other plan, in respect of height, for diminishing the injury in storms, is to make the top not much above the hollow of the sea, below which level the force of the sea is greatly diminished. Thus, if the mean level was 2 feet above the ordinary mean level, and the waves were 10 feet high, the hollow of the sea would be 3 feet below the ordinary mean level; and hence if the top of the work was made 1 yard below the mean level at spring tides, it would be below the level of the mean force of the sea, and I believe that little injury could be done beyond that point. But as respects the shelter, it is evident, that completely to keep the sea from breaking over in moderate weather, the work must be made two or three feet above the mean level; I am not however at all sure that it will be found necessary completely to stop the wave from rolling over the work, for wherever there are banks or reefs from 3 to 6 feet below water, the force of the swell is almost entirely expended upon them; and hence I conclude, that if the Breakwater is brought to within 3 or 4 feet of the surface, the swell will be so effectually broken upon it, that there will be a very slight wave within the work, and only a light ripple on the beach; and as I have mentioned above, I am not sure that such a ripple in the beach will not be necessary, to prevent the too great accumulation of sand. I will not here enter into further examination of the effects of a greater or less height, as it will make this report too long; my conclusion from the above considerations is, that there is very little probability of a greater height being required, than that fixed by the Committee, but quite possible that less will be sufficient. This seems all that is wanted for the present, in order that some judgment may be formed of the expense of the work; it should not be attempted absolutely to determine at once upon the best method of finishing it, because much more will be known from the effects of the sea upon the work while under construction, than can possibly be discovered before hand.

On the subject of the form of the section, the Committee have calculated upon the stones spreading over a base of 75 feet, if the work is 25 feet high, and they are left to take a natural slope. This I believe will in fact

be found to be rather more than the truth, but it was better to reckon upon too large, rather than too small a base. The form of the section would then be this.



Supposing that the stones actually took this slope, (viz. a base of $1\frac{1}{2}$ to 1 of height), it is evident, that the thickness of the work at the level of high water would be 15 feet; I believe however that in fact the

natural slope would be not more than 30 feet of base for 25 of height, and if this was found to be the case, with the same area of section approved by the Committee, the breadth at top, the height, or the outer slope, might be increased as might be judged expedient, after observing the actual effect of the sea upon it. The area of the section is 104 square yards. I have mentioned above, that sand banks and reefs when they approach within 6 or 8 feet of the surface of the sea, break the main force of the swell; and hence I conclude, that by the time the Breakwater is raised 5 yards above the bottom of the sea, the surf within it will be almost destroyed; the area of the section, when it is that height, I reckon will be about 30 square yards, or less than $\frac{1}{3}$ of the whole area contemplated, and at this height or a little higher, I think it would be desirable to leave it during a Monsoon, in order to see the effect of the seas upon it. Should the work be undertaken now, it is probable that it would not be easy to accomplish more than this, this year. There will then be abundance of time, and much better data than we have at present, for determining whether a better form of section can be given to it, than has been determined upon.

Respecting the size of the stones to be used, it seems certain, that it cannot be an object of importance to have very large ones below the main action of the water; but in the part exposed to the seas, I see no reason why they should not be just as large as can be conveyed without a very great additional expense. As there is water carriage, there would be no advantage in having the stones less than from 1 to 2 tons, for any part of the work, and I should suppose that there will be no particular difficulty in carrying out stones of 5 tons, or more, for the upper part of the work; and if arrangements can be made for heavier ones they should be preferred. However, much may be done for increasing the stability of the work, besides using stones of a large size; the stones for the top of the outer slope should be blasted in such a manner as to be of as great a length as possible, and they should be laid with their ends to seaward, placing them carefully, as soon as the top of the work was within reach at low water. By this means every stone would be kept in its place by the mass above. At Plymouth the stones are mostly 3 or 4 tons, and they are laid in so long a slope, that each stone is only kept in its place by its own weight.

The Estimate for the carriage of the stone has been

formed on the supposition that they should be brought down the Adyar, passed over the Bar on trucks or by means of Cranes, and conveyed by sea, on Catamarams or Boats, from thence to the scite of the work. About a fortnight since, I went up the Adyar, in a boat drawing $1\frac{1}{2}$ feet of water, to the bed of rock on its south bank above Sir R. Comyn's house; this depth of water would probably answer very well, but if $\frac{1}{2}$ a foot more was required, it could easily be obtained at the expense of perhaps three or four hundred Rupees. The rock at that spot extends for 200 yards, or more, along, and close to the south side of the river, and from the appearance of it, I judged that it would answer perfectly. There seems therefore no obstacle to water carriage the whole way, but as the stones must pass the surf, it will probably be advisable, either to begin by throwing down a short line of stones not far from shore at the mouth of the Adyar, to facilitate the passage, or to convey the stones across at those times only when the surf is moderate. The Estimate for the carriage has been prepared by the Master Attendant, and so far as I am able to judge, there is no reason to doubt that the work can be done at the price allowed—viz. 1 Rupee per Cubic yard. The expense of quarrying is estimated at about $1\frac{1}{2}$ Rupee per C. yard, but I am inclined to think, that, under the management of an intelligent Officer, this might be much diminished. At these rates, however, the estimate will stand thus—

	Rupees.
Quarrying 20,400 C. yards at $1\frac{1}{2}$ Rupee..	35,700
Conveying 20,400 C. yards at 1 Rupee...	20,400
Sundries.....	5,000
	Total..61,100

But as the Government have liberally offered to furnish prisoners &c. to assist in the work, it is hoped that the whole of the expense of quarrying will be saved to the Subscribers, leaving only 25,400 Rupees to be provided; and as the subscriptions already amount to 40,000 Rupees, there remains a considerable sum to cover expenses which are not foreseen. Upon the above Estimate there would be sufficient to make the work 320 yards in length, without taking into consideration the probability of further subscriptions hereafter. In a work of this nature it should not be expected that a sufficient sum should at once be provided; the Plymouth work was more than 20 years in building, and they did not wait till the whole sum was ready, before they began. The present work may therefore be begun under more promising circumstances than is usual in such cases, having a sum of money at once provided, which exceeds the amount that is at present judged sufficient.

Only one fourth of each individual's subscription would be required at present, and probably not more than an additional fourth before the termination of the N. E. Monsoon. The remainder might be called for when wanted.

I have supposed, that the stones are brought by the Adyar and the Sea, but, could they be brought by a Canal along the bed of the long tank, and from thence in-

to the Cooum, and by that River to the north esplanade, it would be much cheaper, and they might then be shipped at the Custom house; by which means advantage would be taken of the Breakwater as it proceeded. I have examined this line, and find no obstacle to the plan. The Canal might be only $\frac{1}{2}$ a yard deep, and the water being near the surface, it would be easily supplied. In the bed of the Cooum the cutting must be deeper for the first two miles. It is also possible, that strong iron stone, or granite, may be found near the north end of the Nungumbacum tank, which would be a great assistance. I have seen indications of stone in that neighbourhood, and it should be carefully examined. It is a very material point to endeavour to obtain inland water carriage for the stone in preference to the sea, not only because the carriage of the stone to the north beach may then be carried on without interruption, but also on account of the great difference of expense. Thus, according to my estimate, if the stone is brought from near the Adyar, the expense of carriage by a Canal to the Cooum, and by that river to the north beach, and thence on stone, timber, or iron rails, to the Custom house, and on Catamarans from there to the scite of the work, would not exceed $\frac{1}{2}$ a Rupee per Cubic yard, instead of 1 Rupee; which would make a difference of 10,000 Rupees in the total expense of carriage. These points would be well worth the examination of the Officer who should have charge of the work.

As the Plymouth Breakwater has been frequently mentioned in the course of the discussions on this work, I beg to point out the vast difference between the nature of the two works.

1st. The Plymouth work is in 56 feet water; the proposed work would be in 20 feet, the seas that get up in the former depth could not exist in the latter.

2d. The gales to which the former is exposed last for several days, a Madras Hurricane never lasts more than a few hours, hence there is not time here for the sea to rise to any great height, nor for it to injure the Breakwater to that extent that it might be; for it is not by a single blow, but by a long succession of blows, that extensive injury is done to a Breakwater, the stones being removed one by one.

3rd. The former work is intended for use only in a gale, the latter only in moderate weather; if the former were very seriously injured in a gale, all the vessels anchored under it might be lost, and the whole object of the Breakwater lost too; but in the Madras work the utmost mischief that could be done would be the injury to the work itself, and, as the Hurricanes do not occur oftener than once in several years, it would, supposing the worst, require much repair only at such intervals, while yet it might fully answer its end.

It would make this report too long, were I to attempt to answer all the objections that have been raised by individuals; I have in the preceding paragraphs endeavoured to answer those that appear to have been most generally started.

In conclusion, I beg to notice the peculiar circumstan-

ces of this work, viz. that unlike all works on shore, it would consist of a mere loose heap of materials, and hence it is not absolutely necessary to fix the method of finishing it at once, but full advantage may be taken of all the experience that is gained in the progress of the work; before the work required to be finished, more might be known as to the best method of doing it, than could be discovered by several years investigation of the subject without that experience.

I remain,

Sir,

(Signed) A. COTTON,

20th June 1835.

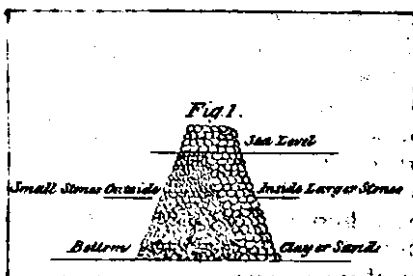
Letter from Col. DELLAVILAND.

GURNESEY, March 16th 1836.

My dear Cotton,

I have lately seen a long file of Madras Papers, full of the *Breakwater—Military Fund—Retiring Fund, &c.* all most interesting to me; but I shall in this letter limit myself to the first of these objects. In the first place, it gives me a pleasurable recollection of your visit to our little Island, when we had much conversation on this and other similar topics. I rejoice that the experiment is begun under your direction; and if persevered in, with spirit, care, and precaution, I have no doubt of its success. All that has been published, *against your plan, is futile*: I am still of opinion that a work *parallel* to the beach is the thing needful; and not one *perpendicular* to it, in the *first instance* at least. The dimensions, position, and materials, are the main points for consideration, supposing you have the funds requisite. As to the Position, I should have suggested the *experiment* to be made off the Fort; it would have been a data to estimate, and serve as a model for a more expensive work off the Custom house, with such improvement as experience might suggest. I feel no apprehension of mischief arising from your undertaking, even if it should be abandoned unfinished; provided only, the materials used are sufficiently *ponderous*; and in this you can scarcely fail, with the quarries you have at hand. A very small stone laid on the mud or sand, at a depth of seventy feet water, will remain unmoved for ages. I should say that one granite, *rough quarried*, of a *Cwt.* would abide there, in the Madras roads: As the work rises, it becomes more exposed to the action of the element; and instead of a flat yielding surface to stand and impress upon, it would have an inclined plane of hard substances like itself. But the weight of a stone increases in a *Triplicate* ratio, while its horizontal section does so only *duplicately*; the effect of the water may therefore be counteracted by increasing the size of the blocks. I again repeat what I have held, *officially* and *privately*, that the base of the work should be left to *nature*, and they will place themselves in their right situation; and above all, observe to use the smaller stones *first*, reserving the large blocks for the *last*. You may safely employ stones under a *Ton* weight, down to half, or even a *third* of a Ton, until your work is at man's

height from below the surface, or rather until you find that your *apex* is constantly thrown over, and blunted as it were:—then you should begin your heavier stones, but cast them on the *inner* side: It would be idle to place your large blocks on the outer side. The *inner* well secured, the sea will never move the *outer*, after it has acquired the proper *talus*. At this stage you will find the greatest difficulty, your work will often be disturbed; not so much by the striking of the surf, as by the *lifting* of the waves; the undulation of the water has that effect; the wave subsides with accelerating velocity, and rises with the velocity so accelerated, lifting, or tending to lift, the bodies it acts upon; hence it is, that a work in the course of execution, suffers more when it reaches the trough of the waves, than when it is just at the surface. The first storm that occurred after my return from India, did some damage to the Plymouth Breakwater. I went to see it—I reported to the Admiralty, and stated that it was left *too low*, and that without a superstructure it would greatly suffer. The following storm verified my predictions; I saw very large blocks actually *lifted out* of their position, where they could scarcely have been touched by the Breakers. Again I wrote to the Admiralty, for a superstructure, which I estimated at 50,000 £; but Rennie the Engineer had sent in his estimate for £ 170,000, to *face it* on both sides, with large blocks, carefully fitted into each other, and I believe clamped with iron. This mode has hitherto succeeded: but even if it were the best, which I do not allow, at so great a cost, he has an advantage *there* which you have not on your coast; a great *rise* and *fall* of water in spring tides, when the lower tiers could easily be ranged in their places. With you, I think a superstructure is indispensable, to rise 12 or 15 feet above the surface of the sea; for you must not flatter yourself that your work, terminated in an *apex*, some few feet above the surface, will hold. When brought to that state, it should remain till storms and swells have settled it, so as to form a surface sufficiently wide for a superstructure. This may not be for a year or two, or more; during which you will watch the operation of the waves upon it, and take your measures for its completion, and extension. What I mean for the figure of the work; and my distinction of large and small stones, is this.



There will be great saving of materials by this mode of erection, for I am certain the idea of the work assuming a wide base at a great depth of water is quite erroneous; and whatever more is given to it than the weight and shape of the stones would effect, is *waste*, to all intents and purposes. Your superstructure should be 12 or 15 feet thick; and probably nearly as high.

There is a great advantage in this way of proceeding, that however the work may suffer from time to time, it can only become more consistent and secure; it must, in the end, bring the work, if persevered in, to its intended use and effect. You should make some allowance for subsequent operations, when you determine on your distance from the shore; all that is *thrown over*, will fall *within* the work. I think 20 feet a good depth for the object now in view, measured from the *clayey* bottom; whatever there may be of sand above it, will move away when the work is completed. 200 yards in length is little enough—but the *horns* of your work will give it length. That dimension however is of the least importance, as it may subsequently be added to, when its operation has been observed; and thence you may best know at which end to make the addition. The angle at the shoulder of your horns, which will act as the *starlings* of a Bridge, should form an angle of about 150° with the line of the Breakwater; when the body of the work is raised, the lengthening of the horns will accelerate the current, and keep clear of sand the space in shore. I observe you expect an accumulation to form opposite the centre of the Breakwater, in a curved line against the bulwark: upon this point I differ from you; I think, on the contrary, that your horns will make the water deepest *there*, and accumulate the sand on the opposite side, against the Breakwater. When the work is completed, it will be convenient in every respect to erect a quay with cranes, on the line drawn on your plan, where you expect the accumulation; and ultimately a similar quay where I expect it to be formed; whereby the current will be greatly accelerated. The horns may, by degrees, be lengthened; if required, to clear the passage of sand: but it is probable that during the *change* of the monsoons, some little deposit may form at each end of the passage, till the *set-in* current again removes it. I perceive you propose taking the stones from the Adyar bank in catamarams over the bar. I have my doubts whether that be the best way; however I see you have tried it, with some success, and during the south west monsoons you may not find it so laborious. In the north east season, except you have a steamer, I fear you will not *progress* much. After the Breakwater is raised so as to *affect* the surf, you may perhaps do better, by bringing the stones from the Mount down to the Custom house; this would be for the *large stones* especially.

Should this undertaking answer your expectations, I should in your place keep in mind the construction of a Railway, from the south side of the Adyar. It has long been in my contemplation—nay, I believe in some of my reports I hinted at one, or a *Carrying Nullah* from the *Seven Pagodas* at Mahabalipooram, to bring the fine granite in that neighbourhood to Madras.

If your horns are extensive, the intermediate space *outside* will fill up to a certain degree with sand, during what I may call the *aquatic* season, or during a succession of mild monsoons; and in time a counter Breakwater may be made beyond this accumulation, so as to form

a solid body in this shape, to serve as a stepping stone to other works beyond it. One more observation, and I have done. In blasting the rocks, I used with great success fine *quartz sand*, instead of clay, to fill the *bores* above the powder; I believe only 5 per cent failed, and most of these bores served again. I thereby saved much time, and doubtless much mischief to the workmen. Those charges which failed were all *short bores*; and the reason is obvious. The expansion of the powder is so instantaneous, that there is not *time* to communicate the impulse to the whole length of the sand in the bore, if a long one; and the grains (of sand) at bottom, pressing into their interstices, offer a resistance equal to the rock itself. In *short bores*, the impulse being instantly communicated to the *outer extremity*, it gives way, and the whole charge blows out effectless.

You will give me great pleasure by occasionally favoring me with a few lines regarding your progress, and the ultimate realization of your expectations. I should also be glad to hear from you how the works hold out.

I am my dear Cotton

Very truly yours

(Signed) W. DEHAVILAND.

I have omitted to say, that I consider your estimate totally inadequate to the undertaking; but you may begin the work with it, and if it looks well, when your funds are exhausted, the Government as well as the community will continue their support.

Copy of Letter from GEORGE RENNIE Esq.,
To CAPT. R. A. GRINDLAY.

WHITEHALL PLACE, 31st Dec. 1835.

My dear Sir,

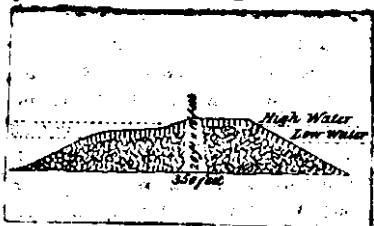
Herewith I return you the packet of Madras Newspapers you have sent me, respecting the Breakwater proposed to be made at that place. I have perused them with attention, and the result is, my conviction that the plan proposed will not answer. My reasons for this opinion are founded upon the experience acquired in the execution of the works of Plymouth, of Kingstown (near Dublin), of Holyhead, of Port Patrick, of Donaghadee, of Whitehaven, besides many public works of a similar nature, in this as well as in other countries. The construction of these Breakwaters has been practised at a very early period, the Ports of Alexandria, Tyre, and Carthage, were partly protected by Moles, or Breakwaters of loose stones, and in the time of the Greeks similar works were constructed at Ephesus, at the celebrated port of Pyraeus near Athens, at Egina, Mytelene, Semnos, Cyssus, Milo, Naxos, Eubœa &c.; and in the



time of the Romans, the most famous artificial Ports were, Portus Læmæ of Hercules (now Leghorn), of Brundisi, Tarentum, of Misena, Pazzoali, Nisela, Ravenna, Ancona, Ostia &c.; of which the latter presented the example of an insulated Breakwater in front of the harbour. In later times the celebrated insulated Breakwater of Civita Vecchia, of Trani, and Barletta, in Italy: and in more modern times the Moles of Genoa, Messina, Rhodes, Cette, Nice, Antibes, Toulon, Valentia, Barcelona, Carthage, Cadiz, Corunna, Ferrol, Rochefort, the Isle of Rhé, St. Jean de Leon, and lastly the famous insulated Breakwater of Cherbourg, Plymouth, and Delaware. Examples are not wanting therefore of moles acted upon by the waves, either in connected or insulated masses. The methods of construction adopted by the ancients, were either by throwing large stones into the sea until they had formed masses of sufficient magnitude to resist the action of the waves, or by sinking masses of stones and cement held together by frames, as described by Vitruvius, or by jetties of Piles driven into the sea as practised at Eubœa and elsewhere. The moderns have adopted the same methods, according to circumstances, and there seems no reason to deviate from the ancient practice, although several plans for the formation of Breakwaters have been proposed and practised by the moderns, as the masses of brick and cement sunk at Sheerness, by the late General Bentharn, and which entirely failed; and the more absurd propositions of floating chests of wood, and cast iron. The destruction of the Cones at Cherbourg, and subsequently of the barracks on that Breakwater, have taught the French several dearly bought lessons. The most approved method of forming Breakwaters has been to throw large stones, weighing from 5 to 10 Tons, in the line of direction of the proposed Breakwater, and allow them to assume their natural slope, which they will do below the action of the waves, and the waves will perform the rest. But in order that these slopes may be formed, it becomes necessary to give such a base as shall allow for the natural slopes both below and above water, and this experience has shewn to be the case, both in the Cherbourg and Plymouth Breakwater. The original form of the Cherbourg Breakwater was a prismatic figure, having 2 natural slopes of 45 degrees, and one sea slope of 8 degrees: experience has, however, proved the total inadequacy of the Cherbourg Breakwater, as originally constructed in 1781. After the failure of the Cones, inasmuch as, that its dimensions were too feeble to resist the impulse of the waves at Low Water, and that it afforded no protection to the Roadsteads between high and low water, the magnitude of the works has been tripled, and in some places quadrupled since that period; and when completed, it is expected to have its summit raised 10 feet above high water, to have a natural slope of about 45° on its interior side between high and low water marks, a sea slope of 6½ to one, and from low water mark to the bottom a natural slope of 45°.

The Plymouth Breakwater was originally proposed

to be constructed upon the Triangular System, with its interior slope inclined to an angle of 45° , and its exterior or sea slope at 18° or $3\frac{1}{2}$ to one. Subsequent consideration however led Mr. Rennie to adopt an entirely new form for its section. The average depth of the Breakwater at Plymouth below low water of an 18-foot tide is forty feet, but in some places the depth is 43 feet, and in others only 20 feet: now the breadth of the Breakwater in the part where it is 20 feet in depth at low water, (and which is the depth of the water at Madras), is 350 feet at the base, including the slopes, as it is now completed—the top of that part of the Breakwater having been swept or flattened down towards the landside by the great storm of 1829. The base was then only 250 feet, thus pointing out the necessity of a further augmentation of base and a change in the slopes. The actual section of the Breakwater as now completed is shewn by the annexed Diagram.



The above form has been found to answer most effectually, and to remain undisturbed during the greatest storms. A casing of cut granite has been put over a considerable part of the surface, and the previous filling the interstices between the large stones with quarry rubbish has tended to consolidate the whole into one great mass. With regard to the expense and other details of the Plymouth Breakwater, I regret that my time has been too much occupied to enter upon them at present. But with reference to the Breakwater at Madras, it is necessary to have more local information than the Newspapers afford, previously to deciding on the magnitude and form that such a work ought to have. I think I have adduced a sufficient example in the Plymouth Breakwater, to prove, that if that part of it shewn in the accompanying section requires a base of 350 feet in 20 feet low water, the Madras Breakwater requires much more than 75 feet for its base; moreover I can state, that when the late superintendent Mr. Whidbey attempted to diminish the slope of the Plymouth Breakwater in the ratio of 3 to 1, it did not succeed. The sea lowered it in the first gale of wind to 5 to 1.

I remain,
Yours very truly,
(Signed) GEORGE RENNIE.

Report by CAPT. COTTON.

To
The Secretary to the Breakwater Committee.
SIR,

According to the directions of the committee I have now the pleasure of forwarding the following report upon the Breakwater. I have so fully, at various times, had the honor of laying before the committee the re-

sults of my consideration of this question, that what I now write is little more than an abstract of my opinions before expressed, with the conclusions that I draw from the present state of the work executed, which has now been exposed to the waves and currents for 12 months, in the beginning of which time it had to bear the force of a regular severe hurricane.

I will first state, that nothing that I have seen in what has been done, has in the least altered the opinions, expressed in my first report, of the fundamental points in this question, viz. that a Breakwater consisting of rough stones, laid in a straight line, parallel with, and detached from the shore, will be a work easily constructed, of very moderate cost, and in all respects efficient, as a cover for the landing place, to destroy the surf opposite to it; and I believe that there are now few persons acquainted with Madras, who do not feel considerable confidence in the plan.

Many of the objections formerly entertained by different individuals were I think removed by the discussions which took place previous to commencing the work; some must indeed, as in other works of this nature, remain in the minds of most till the work itself removes them.

Such was the case with the Bulwark; so much doubt existed as to the success of any work for the protection of the beach, and so strongly was every proposition on the subject opposed, that probably nothing less than the immediate certain destruction of the Black Town, if nothing was done, would have proved a sufficiently powerful incentive to the execution of such a work, on any plan. It was however undertaken under those circumstances, and probably no work ever more perfectly and completely answered its end. I refer to this, merely for the purpose of supporting the observation, that no work can be undertaken of this kind, without great doubts of its effects being entertained by many, and some by all, till it is actually tried; and hence, if no such work is to be undertaken till the result is a matter of certainty, nothing of the sort can be executed. In the case of the bulwark, nothing could exceed the confidence with which certainly the majority of persons at Madras predicted that every stone would disappear in the sands, or be thrown into the middle of Black Town by the surf and the hurricanes; and I doubt whether there was one individual, even of those most in favour of the work, who did not think that there was really some doubt on these points.

So entirely however has the work answered in these respects, that I believe almost throughout its whole length it is now of precisely the same height as it was at first, not having sunk perceptibly; and so perfectly insignificant have been the effects of the hurricanes upon it, that not a stone of above two or three cwt. has been thrown upon the bank by them; on the morning of the last storm I inspected the work, and I do not think there was a stone thrown upon the beach road much above 1 cwt.

I will now refer to the principal objections that have at different times been made to the proposed Breakwater, and state what my opinions are upon them; they may, I think, be chiefly comprised under the following heads—

- 1st. It will be swallowed up in the sands.
- 2nd. It will be dispersed by the first hurricane.
- 3rd. It will not prevent the surf breaking, so as to allow of ships boats landing.
- 4th. It will cost an enormous sum of money.
- 5th. It will collect sands about it, and become connected with the shore, and the surf will form outside of it.

For the first objection, that it will be swallowed up in the sands, I think my best answer now, will be a simple reference to the present state of the work; so far as it goes it is entirely satisfactory on this point; by the soundings taken last month (October 1837), it does not appear that the least change has taken place in the height of the work since October 1836, previous to the hurricane. The soundings taken in the last mentioned month gave 7 feet at low water; this is as exactly the same, as the case admitted of the matter being ascertained. I do not mean to say that this is a full proof that the work will not sink at all, and especially when it rises above the level of the trough of the sea; but considering that there is a good weight of stone now on the spot, I certainly think it is very strongly in favour of the works not being swallowed up. The stones sunk to a certain extent while the work was going on, but it appears that after a time, when they had formed some foundation, the sinking ceased entirely; this was precisely the case with the bulwark; which has now been exposed to many storms, and has repeatedly been laid bare of sand, so that the sea broke fairly upon it. I cannot but think that to most persons who consider these facts, they will be almost conclusive as to the stability of the work, so far as it might be affected by the nature of the bottom. There is no doubt that the sands shift in the roads, as they are often said to do, but that expression is used in such different senses, that unless its meaning in this case is ascertained, it may greatly mislead. Though the bottom of the roads is not certainly, strictly speaking, liable to no changes, yet these changes appear to be confined within very narrow limits; where the vessels anchor there is always much the same depth of water, as is well known, and the bottom is extremely firm. But no coast whatever, except where it is composed wholly of rock, is perfectly without changes, and the question is, not whether the bottom never alters in any degree, but in what degree it does so.

The soundings lately taken seem to show, that at some distance within the line of stones the sea has deepened two or three feet, which has probably been caused by the work, but as the work has not been affected by it, it does not seem to signify; and on the other hand it argues against the supposition that a sand might form from the work to the shore. The current close in with

the shore must of course take the line of the coast when it continues nearly straight for a great distance, as in this case, and therefore it is difficult to conceive that it can be much disturbed by a work lying in the direction of it. The bulwark would seem much more liable to be affected by it than a work a little off shore, yet it has not been so.

Supposing, however, that the work should continue to sink in some degree for some years, to which certainly the evidence we have is wholly opposed, yet a remedy would remain, in throwing in more stones, and the more it sinks, the less likely it will be to sink further, as it must form for itself a more solid foundation. But, probably, it will be thought, that the experience we have had has been so satisfactory, as far as it goes, that it is not very useful to attempt to say more on the point.

The second objection which I have supposed, and which was most confidently asserted by some, viz: "that the stones will be completely dispersed by the first hurricane," has also received, in some degree, an answer, in the present state of the work. It is not at all clear that a single stone was displaced by the hurricane, though they were within about 8 feet of the surface; it is possible that one or two may have been thrown down, but so far as we can judge from the soundings, they are as nearly as possible in the state they were left, before the hurricane. On sounding immediately after that event, it appeared to me that the sand had been washed away at the foot of the inner slope, which had caused some of the stones to slip down, but if this was the case, it must have been to a very trifling extent. This is not a proof that the top stones would not be more or less displaced in a hurricane, but it seems conclusive that the injury would not be very extensive, and I cannot see how it can after this be doubted by any person, that the force of the sea in the Madras roads is very moderate, and not to be compared with that of the channel. Indeed, a very few moments consideration would convince most persons, that such a rise of the sea as takes place in the channel would sweep away the Black Town at once. The committee will remember that this was a point I insisted upon in my first report, as the result of my enquiries and examinations in England and at Madras, and I have now seen the effects of the sea in a hurricane at the latter place, and it appears to me that there cannot be any question at all on the subject. To persons acquainted with Madras, who have turned their attention to this point, it will not probably be necessary to insist further on it; those who have not seen a hurricane in Madras, will have heard their violence and that of the surf so often spoken of, that it will not perhaps be very easy to satisfy them about it. Yet, if it is considered that a hurricane only blows from seaward for a few hours with violence, perhaps 5 or 6, (which is not sufficient time for the sea to get up very considerably), that it is a straight open coast, without any thing to concentrate the swell, with a regular shelving bottom, having about 7 fathoms at 1 mile off shore, and gradually deepening from thence, if these circum-

stances are considered, it will not be expected that the sea will be very heavy, in comparison with that in the channel. However, as a further proof from facts, I should mention the little Breakwater thrown up last year, in the inner surf, before the mouth of the Tunnel at the North East angle of the Fort, which though composed of very moderately sized stones, neither sunk, nor was lowered by the waves in the hurricane; there are some piles, indeed, driven in between the stones, but they are very few, and not nearly enough to prevent the stones being moved, if their own weight had not kept them in their places. So deeply rooted are the notions that have taken possession of people's minds respecting the tremendous effects of the Madras hurricanes, and the violence of the surf, &c. that I am afraid it will not be easy for me by any thing I can say to produce much effect upon those who have never been at Madras; yet if they will only *consider the facts* stated, it seems difficult to suppose that they would not be in some degree convinced.

On the third objection, "that it will not prevent the surf breaking, so as to allow of ships' boats landing," I should first observe, that I take it for granted, that this objection can only refer to the length of the work; I need not suppose that any body would think a surf would form behind it, if it extended for a considerable distance along the coast, as in the case of the islands that have coral reefs running parallel to the shore at a moderate distance, which, although never rising much above the level of the sea, yet always keep the water perfectly smooth between them and the coast. Respecting the length of the Breakwater necessary to prevent the surfs passing round its ends meeting and forming a fresh line between the work and the shore, I certainly cannot give a very confident opinion, as I know of nothing that I have seen or heard of, that will directly assist me in judging on the point; I am inclined to think, that about 200 yards in length, at a distance of 350 yards, would in general secure a good landing for common boats, and that even in heavy seas the surf would at most only break once on the beach, and very moderately. The whole swell for the length of 200 yards must certainly expend its force on the Breakwater, and therefore it is only the swell that comes round the ends of the work, that can affect the space between it and the shore, and in spreading over that space, it appears to me clear, that its force must be at least nearly spent before it reaches the shore. This is not I conceive by any means a fundamental point in the question; the length of the work is a question of cost only, and I believe, that if a Breakwater of 200 yards in length did no more, than show clearly that one of half a mile long would be necessary, but effectual, there would be no difficulty in getting it constructed.

The effect of reefs of rock off a coast in destroying or diminishing the swell and surf is so well known, and so obvious, that I need not give many instances; but I cannot help referring to the often talked of project of removing the Port from Madras to Armegon, in order to shelter the vessels under the shoal that lies off that place;

there was I believe little doubt that vessels would be almost perfectly secure there; a vessel was anchored there, as is well known, in the Monsoon, for the purpose of ascertaining the effects of the shoal, and the communication with the shore was found to be very easy, as compared with Madras. But the distance of the place from Madras would be so great an objection, that the project seems now to be given up. Were there such a shoal off Madras, there would be already a good harbour, but it is very probable that it would still be considered worth while to raise it artificially, so as to bring it above the surface of the sea. But as there is no such natural shoal, it seems only necessary to make one, in order to give Madras all the advantages of Armegon; or rather much greater, for a regular Breakwater of moderate dimensions, would be far less objectionable than a wide spread shoal like that of Armegon. Indeed, an open straight line of coast, with a straight or slightly curved Breakwater, for vessels to anchor behind, would be a more convenient shelter for ships than almost any natural harbour; vessels could come in and go out in all winds, and there would not be a single danger in approaching it, which I believe is scarcely the case with any known harbour.

4th. Respecting the cost. The cost of stone at the beach, brought by the ordinary means, is very certain, on account of the vast quantities conveyed for the Bulwark, and the expense of the conveyance across the surf also has now been ascertained beyond a doubt; the cost, supposing the dimensions determined, is therefore now clearly known to be within certain limits; that is, that it would not cost more than a certain sum; for how much less it might be brought by improved means, must depend chiefly upon the extent of work to be done. In bringing the stone from Marmalong bridge to the mouth of the Adyar, and thence by sea to the site of the work, a considerable expense was incurred in the building and purchase of vessels both for the river and for the sea carriage, and very soon after the completion of the arrangements, the determination of Government to lay the Red-Hill Railroad, gave a prospect of so much cheaper a mode of conveyance than the line first chosen could ever afford, that it became evident that it was best to abandon that line, and wait for the completion of the Railroad. A considerable quantity of stone had been conveyed by the Adyar, in the course of which operation it was found, that the expense of sea carriage, chiefly owing to the current, was very considerable; a small steamer to tow the stone vessels, when the wind was not sufficiently fair or strong to enable them to stem the current, would indeed have altered the whole state of the case, but this advantage was not to be obtained. The expense of taking the stones across the surf, which by some it was supposed would be enormous, proved very moderate, between 3 and 4 Annas per ton; and it was greater than it would be at Madras, because there it would only be necessary to upset them from the Catamarams; whereas at the Adyar, they were hoisted into vessels, which took up much time. The blasting of the granite was found to be a very expensive operation;

the natives were not able to manage the pointing of the Jumpers well; the proper tempering of the steel requiring more skill than they possessed, there was a very great consumption of tools. The most objectionable part of that line of conveyance, however, was the sea carriage, and unless a steamer is employed, I would certainly recommend, that, if possible, the stone should be brought to the beach opposite to the work; and even if a steamer is used, when required to tow the vessels, the expense of loading and unloading the stone vessels in a heavy swell is a considerable objection to that mode of conveyance. The carriage of the stone by a Railroad or Canal to the beach is undoubtedly most desirable, and if the blasting of the granite can be avoided, it will greatly facilitate the work. The use of the Red-Hill road involves the important question of the suitability of the Iron stone found there for the Breakwater. That many doubt its durability, I believe to be owing to the great variety of stone which is known by that name. Persons have known instances of ironstone decaying rapidly, and therefore suppose that it is unfit for many works, but the fact is that it is found at the Red-Hills in all states of hardness, some of it is full of clay, and crumbles with the least force, and some is so hard as to form a most excellent and valuable stone fit for almost any work. As a proof of its durability out of water, I need not mention more than one fact, that near the Red-Hills there is one of the very ancient burial places generally found in India, and round the tombs there are large square slabs of this stone 6 or 8 feet in breadth, and about 1 foot thick, placed in an upright position; these must certainly have been there for very many centuries, as is well known; yet on examination I found that they were by no means of the hardest quality that is to be found in the neighbourhood. As for its durability in water, it is well known that the similar stone on the west coast forms reefs exposed to the sea, which are not worn away by the surf; and in Tanjore, where the stone is used for various Irrigation works exposed to running water, it is found to answer admirably, and it grows hardened by such exposure. I am therefore of opinion that this stone is well suited for the Breakwater, and I think it will hardly be doubted that it will answer, at least for the great mass of the work; though it may still be supposed that no stone less strong than granite will do for the upper part which is exposed to the blow of the sea. The use of the Ironstone will greatly facilitate the work, not only on account of the Railroad, but because it is easy to temper the Jumpers well enough to bore it, and it blasts very well. It is nearly the same specific gravity as granite, and can be obtained in blocks of any size that can be required. Stone is at present conveyed from the Red-Hills by the common roads to Madras, at the rate of 1 Rupee per ton, for road materials; the distance is rather greater to the beach; a large contract would probably be taken at $1\frac{1}{2}$ Rupee per ton; this, with conveyance across the surf would cost $1\frac{3}{4}$ per ton, or 2 Rupees per ton including blasting. The blasting has been tried to a considerable extent at the Red-Hills, and it was not accompanied by either difficulty or

great expense. If the stone is bored by Prisoners, and conveyed by the Railroad and Canal to the North East Angle of Black Town, the cost will be diminished at least one Rupee per ton. Had the granite been still brought by the Adyar, the actual results showed that it would have cost between 3 or 4 Rupees per ton, when deposited on the work, allowing that Prisoners were employed to bore the Rock, and to work the boats on the river. That is, this would have been the rate for some time, but it would have doubtless diminished as the people became more expert at the different operations. Such was found to be the case at Plymouth, where I believe the cost per ton diminished from 8 s. to 6 s. or less, though this was probably partly owing to the increasing value of money at that period. I should here mention, that the impression upon my mind from the operations at the Adyar, is, that in general it is better to arrange for the details of a work being done by the natives much in their own way, excepting in cases where the work is to continue a long time; in which case we may fairly expect that they would by degrees get into the way of doing things upon a plan to which they were not before accustomed; and that if the native method, as respects details, is not followed, it will be very difficult to estimate what the cost will be. In those works which have been executed more or less under my control, I have never had an Estimate of any consequence very greatly exceeded, where the details were managed by the natives in their own way; and in general the cost has agreed remarkably well with the Estimate; but in those which involved work that the natives were unaccustomed to, I have found that it was almost impossible to judge at what rate they would execute them, except by actual trial. However, whether the stone is in future conveyed by the common roads, or by the Railroad, there seems now little room left for doubt as to the actual cost per ton, and I conclude that the Committee will be able to determine that with certainty, if not by the data they now have, yet surely by having a few hundred tons taken down to the beach and thrown upon the work. The question of cost is then brought to depend solely upon the dimensions of the Breakwater.

What I have here said refers chiefly to the cost of a work of small extent, intended only for the securing of the landing, and not for covering the anchorage. If an extended work is undertaken, (and I trust the subject will never be dropped again, till Madras is as good a harbour as it is now a bad one), the method of calculating the cost will be different, inasmuch as it would then be worth while to execute any work that would facilitate the communication from the Quarry to the Breakwater, which when once completed, would render the cost of the stone very trifling. Thus, if the small Breakwater was completed, and a good landing secured by it, so that boats could be loaded with ease; if small steamers were used to tow out the stone boats, and the Railroad completed to the beach, the cost of the stone would probably not exceed three quarters of a rupee per Ton, supposing that the work continued for

some years, which must of course be the case. If the Breakwater contained about 800,000 Tons, which would be sufficient to make it a mile long, the cost of the stone would be about 6 lacs, and probably 2 lacs would be amply sufficient to make the necessary preparations for facilitating the conveyance of the stone, and for sundry expenses. In endeavouring to form a judgment in a general way of the cost of such a work as a Ship Breakwater, the bulwark will form a useful example. That work, or rather the part of it constructed in 1821, was about $1\frac{3}{4}$ miles long, 6 yards high, and I judge about 12 or 15 broad at the base, supported by a retaining wall of brick masonry also 6 yards high; this work cost about 8 lacs; the stones are granite, brought by the common roads from 7 to 12 miles, and mostly obtained without blasting. When it is considered that this work was constructed in the surf, that the beach had been eaten away to a distance of 100 yards and upwards (in some places) within the present line of the bulwark, that a wall of brick in chunam 6 yards high, (the top level with the surface of the beachroad) supports it throughout, and that the stone was brought by the common roads, at 10 or 12 times the rate for which they could be conveyed on a Railroad, I think it might fairly be concluded, that the cost of a Breakwater a mile in length in 40 feet water would not greatly exceed the sum I have mentioned. On the Red-Hill Railroad one bullock drew 9 common bandy loads of stone, or as much as 18 bullocks draw on the common roads. The above sum cannot be looked upon as a great expenditure for such an object.

Should it be considered advisable to construct the work of granite rather than iron stone, I am of opinion that the best quarry to bring it from would be that at Covelong; I mean for an extensive work. The advantages which it possesses over the other granite quarries in the neighbourhood, are, that the rock is almost entirely in blocks of all sizes, so that comparatively little blasting will be required, (which, as I have stated, appears to me a considerable point,) and that it lies at the very edge of the water, to a great extent along the shore of the Backwater, offering every facility for loading boats. The line between Covelong and the Adyar consists for the greater part of Backwater, and all the rest is low sandy soil, so that a Canal to that river similar to that leading N. from Madras could be completed at a very moderate expense; from the Adyar to the Beach, probably a Railroad would be the best kind of communication; to complete these works could scarcely cost $1\frac{1}{2}$ lacs of rupees, and they would form so valuable a work for general purposes, that they would probably abundantly answer, even were they not to be used for the Breakwater. The length of the Canal between the Adyar and the Covelong Backwater would be about 5 or 6 miles, and the Railroad to the beach about 7 miles in length.

I should hope, that with the data we now have, competent persons would not find it difficult to make a very tolerable estimate of the cost of the work, so as in some good measure to satisfy others that there is considerable

proof, that it will not exceed a certain sum; for I trust that if this is effected, and some confidence established respecting the plan, there will not be any difficulty in obtaining almost any sum that may be required for so considerable an object.

My supposed 5th objection will probably not be held by many; the only inference that can be drawn from the stones already thrown in, is, that the effect will be the opposite to this, and that the channel between it and the shore will be deeper than before; for the soundings lately taken show a slight increase of depth at a little distance within the line of the work. I am indeed of opinion myself, that there will be a deposit of sand opposite to the work on the line of the beach, in consequence of the weakness of the surf there; for the process which is constantly going on along the coast is this,—The surf keeps continually stirring up the sand, and while it is suspended in the water, the current, which of course sets directly along the coast, carries it either to the northward or southward; if the surf is interrupted by a Breakwater, whether the current is northerly or southerly, I suppose that the sand stirred by the surf in the neighbourhood will be deposited opposite to that work, and thus form a broad beach opposite to the Custom house; but this process would probably cease long before it extended to the Breakwater, in consequence of the increased current, as the channel was narrowed; this would also be accompanied with a deepening of the channel, but both these effects appear to me rather advantageous than otherwise, for by the extension of the beach, both space (which is much wanted) would be gained, and the point of the sand, being nearer to the Breakwater, would be more effectually sheltered; if the channel between the sand and the Breakwater deepens, it might not be necessary to construct another further out, but merely to lengthen the small one, for ordinary sized Merchant vessels to anchor behind it. This objection does not seem to require any further remarks.

In conclusion, I beg to protest against a conclusion to which many persons may be inclined to come, in case of the plan not being approved of for a Ship Breakwater, viz. that nothing at all should be done in the case. It is a great reproach to Madras that so much time should already have passed, without even an attempt to make it a safe anchorage; and if this proposal is acted upon or not, I cannot conceive any reason why another should not be adopted. Surely some person can be found who is competent to plan such a work, and whose opinion could be in some measure depended upon, though I have little doubt that some uncertainty about the results will remain till they are seen, as is the case with every work of this kind that is constructed. One thing certainly must be allowed, that vessels may run upon it and be lost, but this is inseparable from any plan, in the very nature of things.

As for the present work, I can only say, that I would press it on by every means, and get it completed as soon as possible, and at least make one attempt to stop the loss of life in the surf.

Since the agitation of this question began about two years ago, not less than 5 or 6 vessels have been lost, and many lives; and if the money required for a complete work is not willingly expended upon it, it will most undoubtedly be lost in the destruction of vessels, even should we not take into calculation the loss of life. I trust I need not presume to urge the Committee to make every possible endeavour to get the subject pressed forward. An effort must be made, the work must be done, in spite of doubts and contrary opinions, or never done at all; the way will never appear perfectly clear. If this is waited for, the only possible result will be the annual destruction of life and property; this indeed is a certain thing; that a Breakwater may be productive of evil, and be a mere waste of property is only possible, not, at all probable; but that it will on the contrary be a source of saving, far beyond its cost, almost as certainly as there will be a continual waste of property without it, is a point that I am well satisfied of. I do not mean to presume to urge its construction upon this plan, as if no better would be suggested; I should not indeed have proposed it at first, had I not felt confident

in it myself, after a good deal of consideration; nor should I now continue to recommend it, if I had not had my opinions further confirmed by longer consideration, and the observations I have made upon what has been done; and I certainly think, that a very great proportion of those who have turned their attention to the subject, have now some confidence in it; but whether this plan will answer or not, these things are certain, that there are men perfectly competent to plan and execute a work that will protect the anchorage at Madras, that the money, which, if nothing is done, will be lost by wrecks &c., in the next ten years, had much better be spent on such work; and that it will require to be taken up with some resolution, on account of the opposition and uncertainty which every scheme must be attended with.

I have the honor to be

UPPER ANNICUT }
11th Nov. 1837. }

Sir,

Your most obedient Servant,

(Signed) A. T. COTTON, Captain
Civil Engr. 3rd Division.

REFERENCE TO PLATE I.

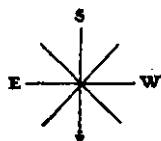
The plate of the Plymouth Breakwater which has been attached at the end of the volume is introduced on account of its intrinsic interest, and as forming a useful standard of reference connected with the study of such undertakings.

This drawing is taken from a copy of a small plan of the work given to Commander Buckle R. N. when Flag Lieutenant at the station in 1835, by the Clerk of the works. Some slight discrepancies may be discovered in the drawing, the section showing a single slope towards the rear, while the plan would indicate a double one, and the upper part of the same slope, it is presumed, should be shown in the section finished with masonry. The general form of the section is however accurate, and the dimensions have been very carefully laid down.

PLYMOUTH BREAKWATER:

commenced, Aug. 12th 1812.


The part tinted red is finished with masonry.
.....do.....do.....blue is to do.....
.....do.....do.....green is finished with rubble
.....do.....do.....not tinted on Eastern arm is about 10 feet
above low water, spring tides.



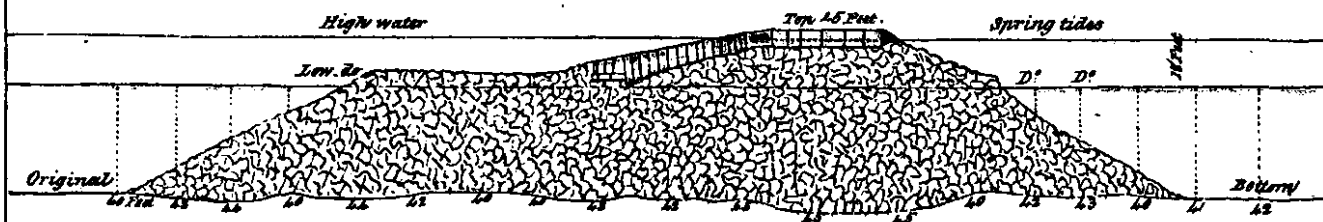
Plan.

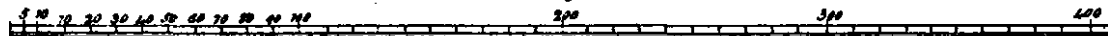



Lighthouse to be
erected on Western arm.

Scale of Feet for length.


Transverse Section.



Scale of Feet.


<i>Quantity of Stone deposited to April 3rd 1830.....</i>	<i>2003979</i>
<i>do.....do.....do..... Jan^y 22nd 1833.....</i>	<i>611423</i>
<i>do.....do.....do..... Dec^r 24, 1834.....</i>	<i>3660</i>
	<u><i>Total...3249062</i></u>

The Stone tinted blue is limestone, of which the work is chiefly composed. The yellow is Cornish granite

MADRAS LIGHTHOUSE.—REPORT BY CAPTAIN SMITH.

REPORT of progress in the execution of the new machinery and illuminating apparatus for the Madras Light.

To

The Acting Chief Engineer,

&c. &c. &c.

SIR,

In pursuance of a recommendation from the Madras Government, my services were in March 1835 directed to this undertaking, by a summons from the Honorable the Court of Directors E. I. C., who called for a detailed account of the project which had been submitted by me, and an explanation of the novelties introduced in it; and for whose further satisfaction and that of the Board of Control, models in illustration, and estimates of probable cost were prepared. In addition to this, the opinion of a committee of the Elder Brethren of the Honorable Trinity Corporation was taken; whose report being favorable, the scheme was finally sanctioned; though, from the delays inseparable from protracted correspondence, its execution was not ordered till January 1836.

The interval occasioned by this delay was not however lost, as I availed myself of the opportunity to make enquiries as to the best establishments for the execution of the apparatus, in comparing their styles of workmanship and prices, and in studying various minor details which admitted of modification or improvement, without affecting the general project.

These enquiries led to some of the alterations alluded to in the letter accompanying this report, the most important of which were—an improved construction of the Argand lamps—the substitution of plated for brass reflectors—an enlargement of their size, and reduction of their number—and a new disposition of the whole upon the frame; whereby a much superior compactness and strength was obtained, with an increased facility of access to its various parts. As these alterations will be more clearly understood from a comparison of the apparatus as it has now been completed, with the original project, I shall take the liberty of subjoining a brief description of it, as the readiest mode of bringing them to your notice.

But it is right to state, in the first place, that the final determination of the nature of the optical instruments to be employed, was not made till after a full examination and enquiry into the practicability of those further discoveries which have recently attracted attention; more particularly the French Lenticular, and Zonal, dioptric apparatus; the Oxy Hydrogen, or lime ball light proposed by Lieutenant Drummond, and the use of gas as a substitute for oil.

The principal objection to the French lenses, I found to consist in the great uncertainty and apprehension entertained regarding the security of the focal light, which is generated by a large and complicated lamp governed by clock-work, and which at the time I made my enquiries had never been tried in England, and was considered liable to serious objection. Nor did the advantage gained by the increased power of the French lens, (being derived from the contraction of the duration of the flash), appear to me to be of so much importance in a climate like that of India, as it might reasonably be supposed to be in situations where it is so frequently required to penetrate dense fogs; whence I was led to the conclusion, that if a sufficient intensity of light were obtained by the concentrating power of the apparatus used, a more useful effect would be produced by giving the greatest possible *duration* to the flash or interval of light, than by sacrificing this important desideratum to obtain a superfluous degree of brilliancy. The experience which has since been gained regarding the use of these instruments has justified the above conclusions, much complaint being made of the shortness and suddenness of the flash exhibited by them; for, although the ray of light cast by the Lens is three times more vivid than that of the apparatus designed for the present work, it is only visible during 5 seconds; while the latter will have a mean duration of not less than 24", which will occasionally extend to 48". I ought not to omit to add also, that the French lens apparatus would have been much more expensive, both in first cost, and in annual outlay. Mr. Fresnel's beautiful dioptric zonal arrangement was liable to the same objection as that above stated, arising from the great difficulty and risk attending the central lamp; and as it exhibits merely a *fixed* light, would be, I considered, unsuited to the exigencies of the present work, to which it seemed to be indispensable that some marked distinguishing character should be given.

Having, from the above causes, been compelled to lay aside all thoughts of the use of dioptric instruments, my attention was directed to the Oxy Hydrogen light, and to the substitution of gas for the Argand lamp. The former of these I found to be subject to difficulties, which, after repeated trials and many costly experiments, had been found to be insuperable by the parties expressly engaged to overcome them; and the latter, though less hazardous in application, had been found liable to serious risks, and to be complicated and troublesome in management; at the same time that its advantages were considered doubtful. Feeling, therefore, the great importance of avoiding the risk of future derangement, as far as possible, by a fastidious attention to the simplicity of the means made use of, I felt satisfied that the apparatus hereafter described would be approved of, and would most effectually secure the objects aimed at.

As the work consists of several distinct parts viz.—

The lantern—the reflector frame—reflectors—lamps—and the machinery—I shall proceed to describe them separately.

The new lantern is entirely composed of gun metal, and consists of a 12 sided polygon, of which nine of the faces or sides are transparent, and the remaining three blanked by the insertion of copper plates in lieu of the squares of plate glass. The interior diameter of the lantern is 9 feet, and its height $4\frac{1}{2}$ feet, exclusive of the roof, which is of the form of a pyramid, and is surmounted by a turn cap and cowl. An exterior balcony is necessary in order that the windows may be accessible from without, for the purpose of cleaning &c. Of this, for economy, the skeleton only has been prepared, (of iron) with a view to the completion of the rest with wood. The diameter of the lower curb of this skeleton frame, is 12 feet. Into the upper curb of the frame of the lantern is fitted a cross, consisting of a couple of iron bars intersecting one another at right angles in the centre of the lantern, on a level with the upper curb, and steadied by iron stays to 4 of the rafters. This cross carries a plate and friction rollers for the support of the spindle of the reflector frame. The floor of the lantern being the platform upon which it is erected, 8 large and 8 small ventilators have been provided, for the admission of the air below, and capable of being opened or closed from the inside.

The whole of the parts of the lantern are packed separately from the machinery, in order that it may be unnecessary to disturb the latter until after the lantern has been completed, and is ready to receive it.

The reflector frame consists of a strong wrought iron turned spindle, to which are affixed the supports for 15 reflectors, in two tiers, 8 above and 7 below; these reflectors are so disposed as to point in the direction of five faces of an octagon, three reflectors on each, which three reflectors are parallel to one another, and are therefore seen at the same time, constituting a “flash” when the revolution of the apparatus brings them in direct opposition to the eye. The light thrown by these three reflectors is emitted in the form of a conical beam, whose sides are inclined at an angle of 18° . Hence, as the different sets of reflectors, (being ranged on the faces of an octagon), cast their light in the direction of the perpendiculars to these sides, which are inclined to one another at an angle of 45° , it follows, that at any given time, there are 18° of the horizon, out of the 45° , which are covered by the spread of rays; and consequently, on the revolution of the machine, the duration of the flashes would bear to that of the eclipses, or dark periods, the proportion of 18 to 27 (equal to $45^\circ - 18^\circ$) or as 2 to 3. As the nature of the motion is however reciprocating, instead of rotatory, the above ratio merely expresses the average proportion of the light and dark intervals, which are themselves variable, according to the position of the spectator; and as the rapidity of movement is so adjusted, that the luminous beams cast by the reflectors sweep round the horizon at the rate of 90° in 2 minutes, it follows, that the duration of the flashes will vary from $0''$ to $48''$, and that of the eclipses from $0''$ to $72''$; the

sums of the durations of light and darkness, however, in every position bearing the constant ratio before stated viz, as 2 to 3. The reflectors being fixed, to the reflector frame as before described, become capable of rotation round the spindle as an axis; the upper neck of the spindle being engaged by the set of friction rollers before spoken of, and its lower end turning on a pivot fixed to the frame of the machinery, beneath the level of the floor of the lantern. By means of a spring clutch, this part of the apparatus may be disengaged from the wheel work which moves it, and made to revolve independently; for the convenience of cleaning the reflectors, trimming the lamps &c.

The reflectors are all similar, being paraboloids of 3 inches focus, and of the breadth of 21 inches over the lips, by a depth of 9 inches. They are manufactured, by hammering, from flat discs of rolled copper and silver, and afterwards highly polished. By the mode in which they are fixed to the frame, each reflector carries its own lamp, the burner of which is adjusted to the focus of the parabola, the chimney passing through an opening in the upper part of the reflector.

Of the effect or illuminating power of the beam cast by the combined operation of the three instruments whose united beams constitute one flash, as before explained, in comparison with that of the apparatus at present in use in the lighthouse, I am unable to give an exact estimate; having no precise knowledge of the comparative illuminating powers of the Argand lamp, and the common wick and tumbler lamp now employed; but from an experiment which I made previous to my leaving India, I have reason to believe, that the former is not less than $2\frac{1}{2}$ times as powerful as the latter; a proportion which is certainly not too great, if assumed in reference to the average illuminating power of the two lamps; the latter being subject to great diminution, while the former is nearly uniform.

Admitting $2\frac{1}{2}$ then, to be the ratio of the illuminating powers of the Argand, and common wick lamp, it may be demonstrated, that the additional effect gained by the action of the nine looking glass reflectors as at present applied to the 12 lamps, in the lighthouse, is equivalent merely to an augmentation of their power of not more than $\frac{1}{4}$; making the total effect of the 12 lamps as great as that of 14 would be, or equal to 6. 22 &c. Argand flames.

The effect of the parabolic reflector is to produce a beam of light which is feeble at first, and gradually increases in intensity till it reaches its maximum of illuminating power, which remains unaltered during a few seconds of brightest effulgence, and then gradually decreases in vividness. The illuminating power of the beam at the point of maximum effect is equal to that of 130. 43 unassisted Argand flames; thus, the comparative power of the brightest period of the flash cast by the combined operation of three reflectors, is to that of the present apparatus as 391. 3 to 6. 22, or as 62. 9 to 1; but although this estimate rather falls short of than exceeds the actual ratio of the augmentation which the illuminating power of the light will receive from the improved means to be applied to it, the effect upon the eye may be less

striking than this statement of it might lead one to anticipate; the vividness of a travelling beam of variable intensity appearing much less than that of a fixed light of equal power.

With regard to the construction of the lamps fitted to the reflectors, being sensible of the great importance of securing their durability, and guarding against derangement in every particular, I spared no pains, both in studying the greatest possible simplicity in their contrivance, and also in providing against the operation of the usual destructive agents. In the first respect, being dissatisfied with the action of the pattern first tried, a series of experiments was undertaken, in the course of which various experimental new burners were manufactured and submitted to trial, which finally led to the adoption of one which has fully satisfied my expectations. This contrivance, which from its simplicity will be readily understood on inspection, possesses the advantage of a motion for raising the wick quite distinct from the body of the lamp, so as in case of its derangement, to admit of its being thrown aside, and a spare one substituted. The burners also are secured against the usual corrosion at the point where the flame rises, by being tipped with platina; and, as a further security against a failure of the means for generating the light, a complete set of spare lamps, of a commoner kind, with iron tubes, has been provided; to be called into use, in event of the first requiring a general repair.

The machinery adapted to this apparatus is so designed as to communicate a *reciprocating* motion to the frame, causing it to pass and repass over an angular space of 90° . The different faces of illumination being as before stated, inclined to one another at the angle of 45° , there would have been an effectual provision for the supply of light to every point of the horizon embraced by the rays of the two extreme faces, had 45° been the limit of the arch traversed; but I was induced to prefer the wider sweep, through the quarter circle, by considering, that the action would be more certain, were each point in the azimuthal circumference exposed to the light of two sets of rays; while the further advantages would be gained, 1st, by the facility which such an arrangement would afford for varying the flashes by the use of crimson shades, should such a distinction ever become necessary hereafter; and 2ndly, by the greater regularity of the periods of light and darkness, of which the duration of every *alternate* series is thereby rendered *constant*.

The machine consists of a train of wheels of strong construction, which are kept in motion by a weight, and regulated by fans, capable of adjustment to the required velocity; and the reciprocating or *reverse* movement is effected by the alternate action of two vertical be-

villed wheels upon an horizontal one of double their diameter fixed upon the spindle of the reflector frame. The certainty of this movement at the periods of the successive engagement and disengagement of each vertical wheel in turn, (the vertical wheels turning on the same arbor, and taking into *opposite* sides of the horizontal wheel, half of each of their circumferences being without teeth), is ensured by a contrivance designed for the purpose, and consisting of a cycloidal *cam* or snail of a double curvature, which acts upon a radial pin projecting laterally from the side of the horizontal wheel above alluded to. This addition has the effect of obviating the possibility of the reversing (vertical) wheel failing to become engaged at the proper moment, and gives certainty to its action.

With the view of obviating unexpected difficulties, I made a point of causing the whole apparatus to be erected and kept in motion, (day and night), for about two months previous to its despatch; during which time it was inspected by various scientific gentlemen, including the Deputy Master and several of the Elder Brethren of the Trinity Corporation; who have evinced their approval of the scheme, by the erection of a Harbour light upon the same principle, at South Stack.

As the work may now be so soon submitted to your inspection, I shall refrain from troubling you with any further details; as the above description will I hope suffice to convey a general idea of the mode in which the project has been carried into execution, and I hope also to satisfy you, that every security for the continued regularity and permanent efficiency of the machine, which its nature allowed, has been provided; I shall therefore merely add, that although in compliance with the original Plan and the intentions of Government, the work has been so constructed, as to be suited to erection upon the site of the present light, (with the modifications noticed in my first Report upon it,) yet that it may be also fitted to any new building; and, as the former plan would confine its range to limits far within the bounds of its capability, it would be a great pity, were the present opportunity of adding to its height, and thereby increasing its usefulness, allowed to pass unimproved. Hoping therefore, that in consonance with this opinion, you may be led, on the final execution of the undertaking, to give your recommendation to a measure so essential to its complete success.

I have the honor to be

Sir,

Your most obedient Servant,

(Signed) J. T. SMITH, Captain,

Corps of Engineers.

ESSAY ON THE METHOD OF ILLUMINATING LIGHTHOUSES

WITH A DESCRIPTION OF A RECIPROCATING LIGHT, BY CAPTAIN J. T. SMITH, F. R. S.

BEING THE SUBSTANCE OF A PAPER READ BY HIM BEFORE THE INSTITUTION OF CIVIL ENGINEERS—
WITH SOME ADDITIONS.

The subject of improvement in the construction of Lighthouses having recently occupied a considerable share of the public attention, and its close connection with the maritime welfare of this commercial nation rendering every step towards its accomplishment a work of utility, even should it fail to deserve notice for its scientific interest, I am induced to lay before the Institution the following brief description of an apparatus of a novel kind, which has recently been constructed under my superintendance for the Madras Government, with a view to its being sent out to that Presidency, and erected in Fort St. George.

The advantages which were contemplated by the alterations which I have succeeded in bringing to perfection, in the apparatus above alluded to, have no reference to any modification of the means employed for the original production of the light; but more particularly to an economy introduced by a more effectual distribution of it, by whatever means it may have been generated. This saving is effected by a contrivance so simple in its operation, and at the same time so obvious when explained, that I should not have ventured a description of it, were I not in hopes that it might be beneficial to others that the practical success of the experiment should be made known, and desirous also to introduce it, as a new principle of illumination, to a place beside the two established systems from both of which it differs, and which are now so well known as the *fixed* and *revolving* Lights.

The new apparatus to which I allude, and which it is the object of this paper to describe, I have named a *Reciprocating* Light, the motion which is impressed upon it being of that description; but as my account of the contrivance itself would be incomplete, were I not also to explain the motives which led me to propose it, and wherein consists its difference from, and advantages over the existing systems for which it is proposed as a substitute in some cases, I shall, before entering upon a more detailed explanation of it, venture to premise a few remarks as to the general principles of illumination, which will I hope have the effect of rendering my meaning more clearly intelligible.

In *fixed* lights, as is already well known, the distribu-

tion of light is effected, according to the system hitherto adopted in England, by means of Argand Lamps, and a number of parabolic reflectors placed round the circumference of a circle, facing outwards, and so disposed with respect to each other, that each reflector is pointed towards a different part of the horizon, a very small portion of which is illuminated by it; the tendency of the reflector, from its peculiar shape and catoptric properties, being, to collect the light of the Lamp placed in its focus, and propel it in a dense beam along its axis, or in the direction of the point immediately in front of it; to a very small space on each side of which its effects are confined. This space or breadth of the luminous beam is usually calculated at $7\frac{1}{2}$ degrees on each side of the axis or 15 degrees in all;* consequently the number of reflectors required to fill the whole circumference of the horizon with light, ought not to be less than 360° by 15° , or 24. If a part of the horizon only require illumination, a smaller number, in proportion, is sufficient.

A *revolving* light may be explained, by first supposing the above system of reflectors to be mounted in a frame which is connected with machinery suited to give it a revolving motion. It is plain, that if the entire system proper for a fixed light were thus made to rotate, a spectator would still see an uninterrupted beam of light,† since the diverging rays from the 24 reflectors filling up the entire circumference of the horizon, as before explained, the effect of each, as seen during the revolution by a spectator from a distance, would not cease till that of the succeeding one had commenced.

If we now suppose, that instead of the complete system above referred to, every alternate reflector be removed, the disposition of the remaining ones being unaltered, it will be obvious that the appearance produced would undergo a very marked change; for now, on the light of any one reflector ceasing to be visible, the illumination would not be kept up, as before, by the action of a succeeding one, but an interval of darkness would ensue, corresponding to the blank left by the removal of its adjoining reflector; and the effect of the system after this alteration, as viewed during rotation, would be that of a

* This is not the entire space filled by the light of the reflector, which, in fact, spreads through about 18 degrees; but the illuminating power on each edge of its beam being very feeble, it is usual in arranging the disposition of a fixed light, to allow one reflector for every 15° only, so that the beams cast by them overlap, as it were, at their junction; and, by uniting their effects, partly compensate for their want of intensity.

† In the case here referred to, the beam would be uninterrupted, for the reasons given; but it would not be uniform in intensity. For the tendency of each reflector being to collect the greatest quantity of light close to its axis, and proportionally less and less as we recede from it, its effects become weaker towards the edges of the space filled by its beam, so that the light is much more feebly seen by a spectator situated on the line opposite the junction of two reflectors, than when immediately in front of either of the mirrors themselves; and hence, the effect of the revolution of such a system would be to produce an undulating appearance, unless great rapidity of motion were imparted to it.

series of bright and dark periods, which constitute the “flashes” and “eclipses” peculiar to the revolving light.

This principle is striking and effective, as well as economical, when compared with the fixed lights; for it will be readily understood from what has been above explained, that if the eclipses and flashes be of equal duration, only half the number of reflectors and lamps required by a fixed light become necessary for the illumination of a complete circumference of the horizon; and it will be further obvious, that if, as is usually the case, the dark periods or eclipses be made of a *longer* comparative duration, the number requisite would be still further diminished: for instance, if the eclipses were proposed to be of double the duration of the flashes, then instead of removing every alternate reflector, as in the case above alluded to, the plan adopted would be to remove two and leave the third, thus reducing the number from the 24 indispensable to the fixed principle, to 8 only.

There is however one circumstance attendant upon this contrivance which in many situations detracts greatly from the superiority it would otherwise possess over the fixed light, and this it is the object of the improvement which I have introduced to obviate. This defect consists in the useless expenditure of effect which is occasioned by a revolving light sweeping the *entire* circumference of the horizon, when placed in a situation where only *half* of it requires illumination. When a Lighthouse is situated upon a line of coast, as most are, it is plain that no real benefit can result from illuminating the land side; and, consequently, in such a situation that portion of the lantern which looks inland, in lieu of being cased with glass, is always “blanked” by inserting copper plates, to avoid expense, risk of breakage &c.

Now when a light upon the *fixed* principle is established in such a situation, the effect produced is precisely proportioned to the means employed, and none of the light is lost;* since none of the reflectors are pointed inland: but in a revolving light on the other hand, this adaptation of the means to the end to be gained, cannot be applied; for while the revolution continues complete, the reflector which at one time points to seaward *must* a few minutes afterwards be directed towards the land, or rather against the *blank wall* which closes the lantern on that side; so that while one half of this system is fulfilling the purpose for which it intended, the effects of the other half are absolutely thrown away.

This is of more importance, when, instead of each flash being produced by a single reflector, as in the above supposition, a number are combined (pointing in each direction) to augment the vividness of the beam. In this case the total number employed being greater, the absolute loss is thereby enhanced. In the new apparatus recently constructed for Madras it was determined to group three reflectors together to produce each flash; and it was also decided that intervals of darkness of dou-

ble the durations of the periods of light should be allowed to intervene, to form the eclipses. These conditions would have required (by the present system of revolving lights) agreeably to the explanation above given, that 8 sets of 3 reflectors each should be used, or 24 in all; but being struck while preparing the design for this apparatus with the manifestly unprofitable result of such an arrangement, and being very desirous from other attendant circumstances to diminish the number of reflectors and lamps as far as possible, without decreasing the predetermined results, I was naturally led to enquire into the possibility of obviating the evil; and after some consideration it occurred to me that this might be very easily and simply effected, by merely stopping the revolution of the apparatus after it had traversed a certain portion of the circumference, and then *reversing* the motion, so as to cause it to reciprocate backwards and forwards, and thereby confine the action of the reflectors disposed towards the sea to that side only; thus obviating the necessity of placing any mirrors or lamps whatever on the side facing the land. I have been enabled, by this means, to fulfil the conditions proposed at $\frac{1}{4}$ ths of the expense which would have attended an adherence to the revolving principle; and the saving might have been further increased to nearly one half, had I not been anxious to avoid the possibility of any defect in the distribution of the light near the coasts, by extending the limits of the illuminated arc to four points of the compass inland, on each side.

The contemplation of the efficiency of this scheme as a means of illumination, apart from the contrivance by which it is carried into effect, is based upon considerations of so obvious and plain a kind, as to need no explanation; nevertheless it would not be right for me to quit this part of the subject, without pointing out a peculiarity in its effects, which though far from decreasing the value of the system when judiciously applied, is not the less worthy of notice, as it shews the necessity of exercising a proper discrimination in its adoption; and, it cannot be denied, tends to circumscribe the sphere of its usefulness, by excluding it from those situations, where, from the multitude of beacons thickly studding a dangerous coast, and the difficulty of impressing a distinguishing character upon each, it becomes necessary to have recourse to an observation of the length of the eclipses, or the time elapsing between the periodical recurrence of the flashes, as a means of enabling the mariner to determine the particular light which he is approaching, and without which the protection derived from it would be comparatively of no value.

From the variety of modes of distinction at present in use in the British Lighthouses, it has hitherto, I believe, been unnecessary to rest entire dependence upon the differences in the periods of revolution; and it is no doubt wise to delay doing so as long as possible, that mode of discrimination being the least secure, and open

* This regards the azimuthal distribution only, as it would be tedious and out of place here to take into consideration the vertical divergence of the rays. Since, as this divergence is the same in both cases, the argument is in no respect affected by its operation.

to various objections. Should it however at any future time become indispensable, it will introduce an obstacle to the reciprocating system, to which that auxiliary characteristic cannot be applied; for although the total quantities of light and darkness seen by a spectator in every position are *constant*; yet, from the peculiar nature of the motion, the durations of the flashes and eclipses vary with every new position of the observer; a circumstance which, if not understood, might lead to mistake and fatal consequences.

These remarks, however, it ought to be added, apply only to those cases, where, from the existing number of similar works it becomes important to avoid the danger of confusion; and ceases to be applicable to this plan when it is proposed to adopt it in situations sufficiently remote to be secure from the liability of incurring that evil. In the present case for instance, the reciprocating light to be erected at Madras will be the only moving light on the whole coast of India, and hence cannot possibly be mistaken, for any other at present in existence; but I consider it would be equally safe to introduce the system wherever the determination of the precise periods does not enter as an indispensable condition; and in such situations it will be strongly recommended by its economy, as the annual saving effected by it will be found to be well worthy of consideration; in addition to its being attended by other advantages, such as reduction of weight and bulk, superior cheapness in *first* cost, and diminution of the labour requisite to keep the apparatus in order, &c.

Description of the Reciprocating Machine.

Having thus given an outline of the nature and peculiarities of the system above described, it only remains for me to add a few remarks regarding the arrangement of the machinery by which the movement is effected.

The mechanical problem of resolving a continued circular motion in one plane into a reciprocating circular motion in another, is one attended with so little difficulty, and the solution of it must be so readily familiar to many of the Members of the Institution, that I should be wrong to detain them a moment upon the subject, were it not for the purpose of briefly noticing one of those little difficulties which frequently step in between the design and successful accomplishment of a new undertaking, however simple in its original plan; and to take the opportunity to describe the mode by which that difficulty has been very satisfactorily overcome, as an assistance to others who may engage in a similar undertaking.

After much thought upon the subject, and an attentive consideration of several plans, which I either met with in mechanical publications, or which suggested themselves to me, and some of which were tried on a small scale by models, I selected one which appeared by far the most promising, from the simplicity of its action, as well as from its requiring only workmanship of a kind

well understood. This contrivance will be most easily explained by first adverting to the means by which a continued revolving motion may be communicated to a reflector frame.

To effect this the whole of the reflectors are fixed in their proper positions in the frame; the parts of which are connected with a central spindle placed vertically, and to which motion is communicated from a machine of common construction, (moved by a weight and regulated by fans)* by means of a couple of bevelled wheels, one of which is fixed on the vertical spindle just mentioned, and hence revolves in a horizontal plane, the other turns in a plane at right angles to the above, its arbor or axis being also at right angles with the spindle; (vide Figure 1. Plate 2.) and this latter wheel being also connected with the train of machinery communicates to the reflector frame a continuous rotatory motion.

Now if instead of this *single* vertical wheel, acting continually on one side of the horizontal one above mentioned, we conceived *another one* similarly situated on its opposite side, and engaged in the teeth on its margin; and if we moreover imagine that these two wheels are mounted on the same arbor, and consequently turn in the same direction; it will be evident that they would, if successively engaged, produce *opposite* motions in the spindle and the apparatus; but that if both were engaged at the same time, no motion at all could be effected, since by their opposite tendencies they would act against each other.

This successive action is therefore effected by fixing both of the wheels upon the arbor in the same manner as if they were singly employed, and then cutting away the teeth of the alternate semi-circumferences of either, so that while those of one are engaged and produce motion in one direction, the blank circumference of the other is presented, and the moment the former ceases to act, the teeth of the latter come into play, producing an opposite movement. (vide Fig. 2. Plate 2.)

This apparatus upon execution and trial was found to produce the intended effect very steadily; but I soon observed, upon studying its action carefully, with the express object of searching for any latent cause of future derangement, that however satisfactorily it might act when well set up, it would be incapable of withstanding the effect of those disturbances, which long friction, and wear of the parts, or accidents and ill treatment might subject it to; and without a perfect security against which, I should have felt it unsafe to dispatch it to so distant a settlement. The reason of this will be seen by a reference to the fig. No. 3 Plate 2 which represents *ABC* the horizontal bevelled wheel and *EDF* one of the vertical wheels above alluded to, at the very moment when the last tooth of the latter is escaping from its engagement with the former, and when the change in the movement is about to take place. Now the conditions of the light demand that

* The machinery attached to the apparatus belonging to the Madras Light House is upon the common principle, though differing entirely from the pattern usually adopted in England; various alterations having been introduced, in order to accommodate it to the position and circumstances under which it was to be applied.

Fig 1.

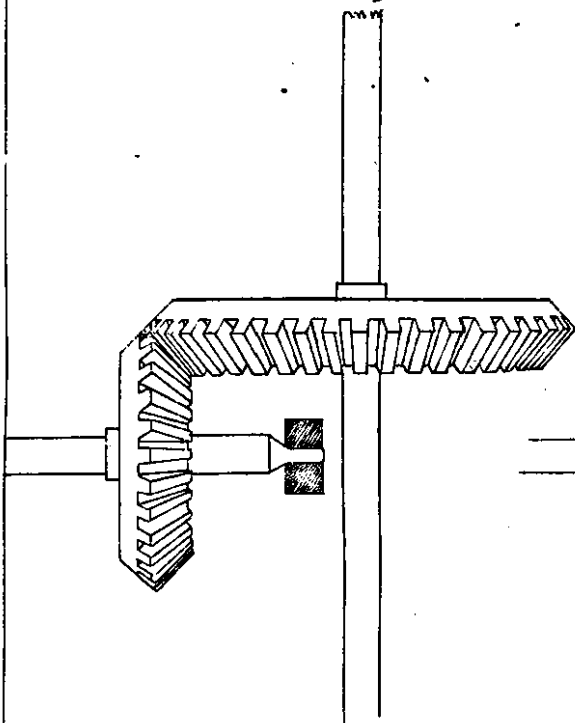


Fig 2.

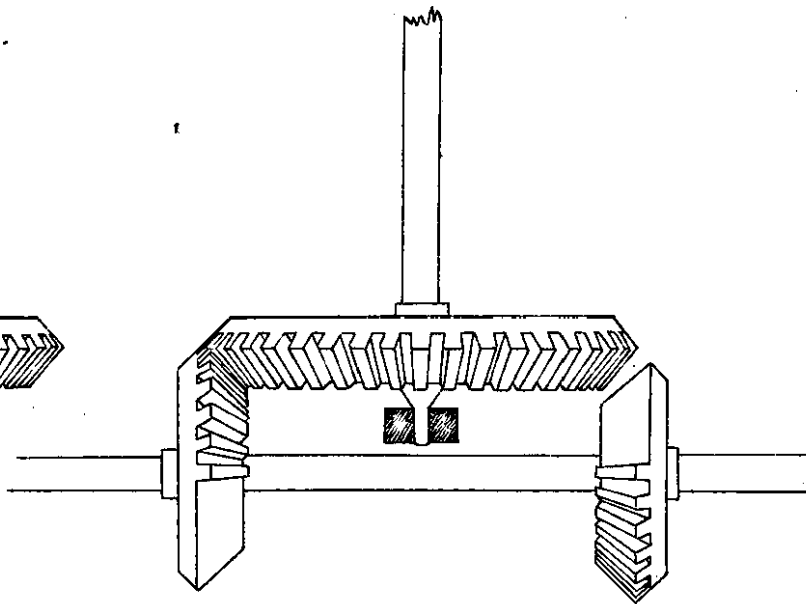
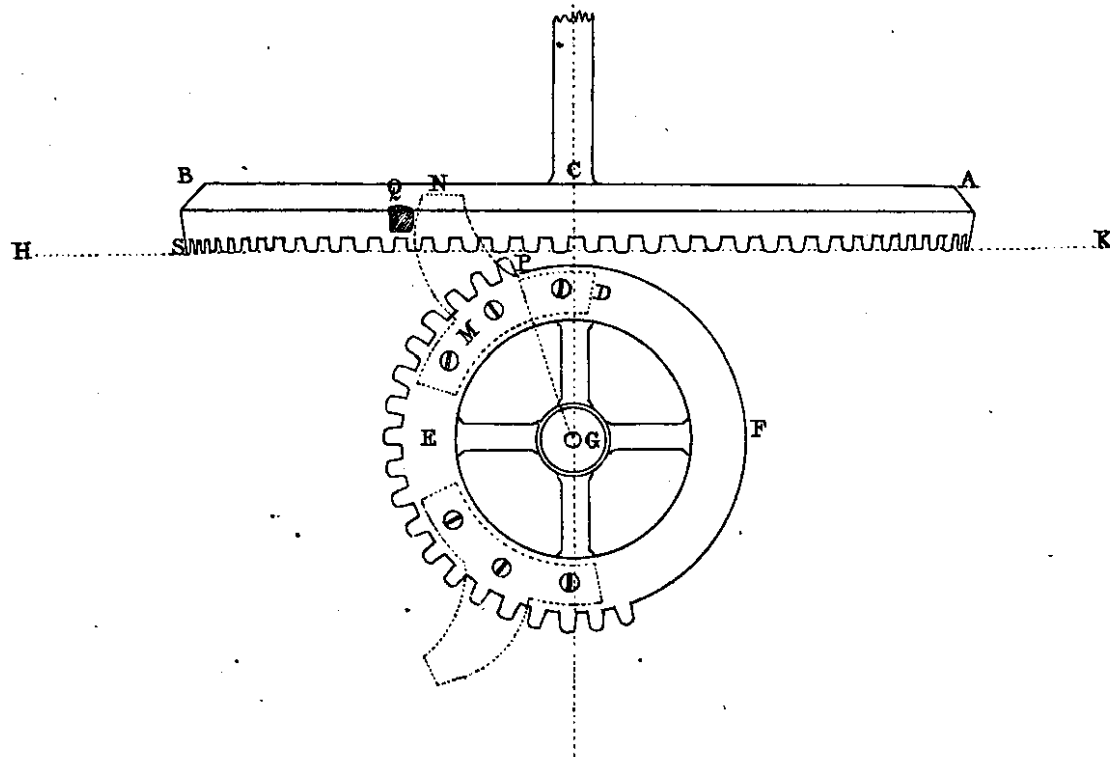


Fig. 3.



there should be no material loss of time in reversing the motions, that is, that the movement from *Q* to *A* in the upper wheel should commence in not more than a second or two after that in the direction of *Q* to *B*, caused by the action of the wheel *EDF* has ceased. Moreover it will be plainly seen, that as the change of motion which ensues after the tooth *P* has quitted its hold causes the whole range of teeth from *P* to *S* immediately to return in the direction of *K*, passing over the head of *P*, there would be some risk (more particularly if by any derangement, the wheel *BCA* should have become swayed out of its proper position and its edge fall below the line *HK*,) of these teeth striking the top of *P* on their return; or what would be as bad, of their failing to disengage it at the proper time; which could not be prevented, unless before this return movement commenced, the top of *P* had dipped sufficiently below the line of their path *HK* to be out of the reach of such an accident. But it unfortunately happens, that at the point where the tooth *P* is situated, the dip below the horizontal line occasioned by the curvature of its path amounts to little or nothing, (being represented by the versed sine of the angle formed by the radius drawn to it, with the vertical *CG*,) and is hardly perceptible until it has reached a considerable distance from the vertical position, so that before it would have amounted to $\frac{1}{8}$ of an inch, which I satisfied myself would be sufficient to place the security of the movement beyond the reach of probable accident, the delay or loss of time would have amounted to not less than 7 or 8 seconds. It occurred to me, however, that if I could make the final connection between the wheels by means of a tooth situated on part of the wheel *FDE* endowed with a more *oblique* motion, that it would then be in my power even to increase the clearing space above mentioned, if necessary, without the sacrifice of any material delay. Such a tooth I accordingly set about to design, and after a few trials succeeded in cutting out the model of one which completely effected my object. It is represented in Fig. 3. by dotted lines, and ought more properly to be termed a *cam*, or *snail*, as it acts upon a short straight pin *Q* projecting from the side of the horizontal wheel, and communicates to it precisely the same motion as it would receive from the teeth, which now become unnecessary, and might be entirely removed. In order to ensure the exact equivalence of the motion to that for which it is substituted, and to cause the cam to follow close to the circumference of the upper wheel, its edge has a double curvature, that of *MN* which is seen in the figure, and a similar one in the plane at right angles to this, whereby the upper part of the snail is bent more and more away from the eye of a spectator viewing it as represented in the figure. Its face is also twisted in a spiral direction, in order to accommodate it to the varying inclination of the radial pin it acts on. The adoption of this simple contrivance has completely obviated the difficulty which seemed to stand in the way of perfect success; and since it has been applied, although the interval elapsing between the motions is only 2 seconds, I have found the apparatus to work so completely free from the risk I was apprehensive of, that I have

as yet found it quite unnecessary to do more than merely file the tops of the last two teeth; sufficient space having been gained by that means. It may perhaps be advisable to remove a little more previous to transferring the machine to the unskilful management of the natives to whose care it will hereafter be entrusted.

I should not however have been satisfied with the security of this movement, unless, in addition to its freedom from the chance of derangement by the ordinary effects of wear and long continued use, it had also been rendered exempt from the probability of disturbance by accidental mismanagement.

In order to understand clearly that precaution is requisite in this respect, it is necessary to return to fig. 1 plate 2, and consider in what manner the apparatus for a continued rotatory motion differs from that required to produce a reciprocating or reverse one.

In considering the operation of the two wheels represented in fig. 1, it will be obvious, that, as the effect to be obtained is *continuous*, the parts which are engaged together to produce it are never freed from their action upon one another; whereas in the apparatus represented in the second figure, it will be equally plain, that the horizontal wheel upon which the motion is impressed must be entirely set free from connection with its driver on the one side, before it can yield to the impulse of that on the other. At the instant of time, therefore, after the action on one side has ceased, and *before* the teeth on the opposite margin have become locked together, it will be seen that the upper wheel is entirely free from connection with either of its two drivers; and, were it not for the snail about to come into operation, would be capable of a complete revolution round its axis, *independently* of the drivers; which though thus prevented in one direction, can still take place in the other, namely towards the point to which the snail would impel it.

In figure 4 plate 3 the light and shaded parts represent the two opposite margins of the horizontal wheel, and parts of the two drivers acting upon them; that which is shaded being the one nearest the eye, the plain one that which acts on the farther side of the spindle; and on this the snail and the pin it acts upon are represented by dotted lines, as if they were seen *through* the rim of the wheel *ABC*. This diagram is supposed to represent the machine at the moment when the snail *MN* has ceased to act upon the pin *Q*, and when it has dipped a small space below the level of its under surface; but before the snail *TV*, which acts in the direction of the arrow behind the spindle *WC* comes into operation. At this moment, therefore, the apparatus being freed from its connection with the snail *MN*, is prepared to take the motion which would be communicated by the snail *TV*, and were it to be accidentally touched, might be made to turn in the direction of the arrow, till the pin *X* was stopped by the *back* of the snail *TV*. Such a derangement is very unlikely to happen, it is true, since in order for it to take effect, it must be caused by a pressure applied in the right direction, and at the critical instant of the passage from one motion to its reverse.

Nevertheless, as such an event, if it did happen, would throw the machine out of gear, and cause it to stop, I thought it would be well worth while to adopt any expedient which would prevent the possibility of such an accident, and after some trials contrived the following plan, which is very simple, and answers the purpose most effectually.

The operation of the snail MN does not cease until the opposite one $T'V$ has nearly reached the pin X ; when MN has ceased to act, therefore, the apparatus, though free, can only move in one direction, that shown by the arrow; and this is the direction in which it must move when the snail $T'V$ comes into play. What is

wanted, therefore, is merely such a stop as shall prevent its moving away from the snail. This is effected by elongating the first tooth brought into action by the snail, and which is shown on the figure by Z , and causing it during the previous motion, or whilst the snail MN is in action, to pass over a flat spring PZ which lies along the upper margin of the driving wheel, and is released at the instant that MN is disengaged. This flying up, opposes an obstacle in front of the tooth Z which makes it totally incapable of motion without carrying its driver with it; and thus prevents their relative situations being changed.

APPENDIX.

Description of the Method of cutting the Cams.

The determination of the curves for the different parts of the cam described in page 19, having been a problem requiring some thought, and the practical method then adopted being of a general character, capable of application to other circumstances, and therefore likely to be generally useful, I shall here endeavour to describe as concisely as lies in my power the method by which it was effected; though the subject is necessarily difficult of explanation, from the various motions to which it is necessary to refer, and to their taking place in different planes.

To facilitate the exhibition of this part of the subject, it may be advisable first to consider what is required; with a view to the separate examination of each of the desiderata, and a synthetic mode of determining the compound form to be obtained. In order to this, I have represented, in figure 5 plate 3, the paths both of the horizontal and the vertical, or reciprocating wheels, as they would be seen in their respective planes; having ventured, by what must be substituted for perspective, to delineate their exact geometrical proportions in each plane, though both are exhibited in one view. Were the subject not a mere diagram, it would be an incorrect representation of an oblique view of both the planes in which the wheels move; but as it is, being intended to shew the relative changes brought about by the motion of each wheel in regard to the straight line which defines the intersection of their two planes; which line is, for both, correctly represented by KL , I am enabled by this arrangement to bring them into juxta position, and thus to place their connection clearly before the eye.

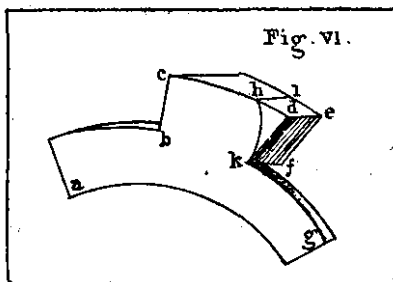
It may here be proper to state, that the line KL in figure 5, indicates the intersection of a horizontal plane touching the lower surface of the pin Q , of figures 3 and 4, with a vertical plane corresponding with the outer surface of the reciprocating wheel, and touching the root of the pin as well as the margin of the wheel into which it is fixed.

This plane also coincides with the inner surface of the cam, at its origin from the margin of the wheel EDF ; for the margin of the horizontal wheel is flush with the outer surface of the vertical wheel EDF or, in other words, touches the plane in which that surface is contained; and the projection of the pin beyond this margin determines the breadth of the cam, which is merely affixed by screws to the face of EDF .

In figure 5, therefore, let BDC represent the margin of the horizontal wheel, of which A is the centre, D the place of the pin Dd — EDF the vertical wheel. Now the object to be attained is, to fix on the point D of EDF a piece of such a shape, that it shall act on and impel the pin D , so as to produce a motion in the wheel BDC precisely the same as if the two bevelled margins rolled over one another. Referring to the lower half of this figure, and carefully recollecting that it represents the vertical plane, in which view the path of the pin Dd is defined by the straight line KL , it will be seen, that while the motion of the radius of which the pin Dd is a part is along the line DL , the point D of EDF travels along the curved path $D123456F$. Hence, while the former has continued within the horizontal plane, the latter has dipped below it. The cam must therefore rise above the circumference EDF , and that in such a manner as continually to cut the horizontal plane at the very point the radius Ad would have reached; which points for the successive positions of the radius $A1A2A3, 4$ &c. are shewn by the letters $x1, x2, x3$ and so on. To fulfil this condition, the edge of the cam must be shaped in the curve represented by $F-0123456f$, the method of describing which will be presently explained; it being merely necessary to add in this place, that the zero point is in contact with KL , and with the radius, when in the position AD , the point l when it has shifted to the position $A1$, the point f with the position Af &c. It is thus shewn, that with reference to the vertical plane, the anterior face of the cam must necessarily possess the rake or curvature Ff ; and in regard to the horizontal plane

also, it may easily be deduced by a similar reasoning, that a lateral bend is equally required, in order to compensate for the increasing deviation, as regards this plane, of the path of the wheel *BDC* from that of *EDF* (which latter is now represented by the line *KL*). The same opportunity may also be taken, whilst referring to this plane, to shew in what manner the anterior face of the cam requires a spiral twist in addition to the two curvatures above described, for if *Dd* represent the position of the pin when at the point *D* of the wheel *BDC*, it will be evident on considering the position of the vertical wheel and its projecting cam, that at this point that part of the cam in contact with *Dd* (viz. its root *Fo*) must coincide with *Dd*, or be square to the circumference of the wheel to which it is attached. When the radius, and with it the pin, have however moved onwards a little, for instance to *x6*, it is seen that its position is now oblique to the circumference of *EDF*, which is here represented by *KL*; that part of the cam, therefore, which is in contact with the radius at this point must be shaped with a corresponding obliquity, in order that it may fairly coincide with the pin; and this obliquity continually and regularly increases, from the bottom upwards, like the spiral face of the thread of a screw.

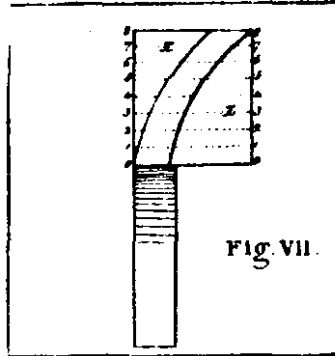
In order now to obtain this complicated form practically, the first step was to prepare and fit on to *EDF* a piece of wood of sufficient bulk to include the whole piece afterwards to be cut from it; and this was merely of the shape of a circular segment, to the central part of which was superadded a die of a concentric figure, but much enlarged in width, the whole being of the form shown in the annexed drawing (fig. 6). Having previously determined the angle *DAgf* fig. 5 through which the cam was to act, the height *bc* (fig. 6) of this additional piece was found by measuring the height *Ff* (fig. 5) of the corresponding curve; the breadth *de* by the corresponding *fg*. These dimensions being obtained, *fk*, *ed* and their opposite sides were cut at right angles to the plane of *abc*, and in fact all the corners were square. The segmental part *abkg* was suited to be fixed to the face of the vertical wheel by screws. The next step was to obtain the curve *kh*, and the mode of doing so will be easily understood after what has already been explained, by referring to fig. 5. Having laid down a diagram representing the wheels *BDC*, *EDF* of their full dimensions, and drawn the line *KL*, a number of equal and very small parts was set off from *D* to *g* on the circumference of *BDC*, and a similar and equal series on the circumference of *EDF*. These were numbered on each 0 1 2 3 4 &c. from the point *D* both towards *g* & *F*; also radii were drawn from the centre *A* to the different divisions on the line *Dg*, and their intersections with the line *KL* marked with the corresponding numbers *x1*



x2 x3 and so on. A piece of transparent paper being now cut a little larger than the circle *EDF*, was secured to it by a pin passing through the centre *M*, round which the paper could turn. Then, having drawn a line *MD*, and fixed the point *D* on it as the place of the origin of the cam, this line was turned gradually round in the direction of *F*, until the point *D* was successively brought to the divisions on the circumference of *DF*, numbered as above mentioned 1 2 3 &c. At each of these divisions the line *MD* was prolonged in the direction of the corresponding division *x*. Thus when *D* arrived at No. 1 division of *DF* it was lengthened by the addition of a little line joining it to *x1*; when it arrived at No. 2, the lengthened *MD* was further extended by being joined to *x2*, and so on. The curve *Ff* thus obtained was easily transferred to the model (fig. 6), and the superfluous wood *khief* cut away; *hi* being made parallel to *de*, or square to the face of the wheel. The next step was to delineate and cut out the spiral twist of the face whose edge was just found. In order to do this it was necessary to mark off on the model the different divisions 1 2 3 4 &c. of the curve *Ff* obtained during the last process, and by carrying parallel lines across the newly formed face of the model, to obtain the corresponding points on the opposite or *inside* of the block. Having then laid down on the plan (fig. 5) the whole breadth of the cam by the line *OP* parallel to *KL*, the distance *Og*, representing the twist at the point *f*, was first measured and marked off from the top of the curve on the inner face of the cam, in the direction of a line which would be cut on it by the horizontal plane when the point *f* is lowered so as to be on a level with it. The reason of this will be more clearly comprehended, by remembering that the curved face of the cam had been cut square all the way down, and that the line *OG* (of fig. 5) represents the substance necessary to be removed from a square cut face to make it coincide with the radius. The same process was applied also to each of the other divisions marked down the inner curved edge of the face, by dropping perpendiculars from each, as that shewn at *x3* and setting off the difference *YZ* thus found. When all these were completed, the points thereby fixed were united by a curved line, which showed the proper inner boundary of the face; and the only point necessary to be attended to in reducing it to form, was, that the corresponding points in the inner and outer curves should be joined by straight lines.

There now only remained to determine and shape the lateral bend, and this with the assistance derived from the previous operations was easily contrived. If *Pg fD* fig. 5 represent the plan of the top of the cam after the face has been properly formed, and we have a pin of the length of *Dd* or *gw* only, it is plain that the part *wf* is superfluous, and that by laying off either of the distances *gw* or *fw* on the anterior face, from the proper edge, we should have the position of *w* for that point of the face. The same was repeated at the different points from top to bottom, with this variation only, that in every one except the uppermost, both the inner and

outer distances have to be laid off. When this operation had been completed it was found that the edges corresponding to the circumference of *BDC* fig. 5 and of a point a quarter inch beyond it, which was the length of the pin, were traced down the face by the two curves shewn in fig. 7. The superfluous matter *x x* having been cut away, the model was completed. From this, castings were made in gun metal, which being finished and fitted to the wheels, were



found to answer perfectly. Each of them when correctly placed exactly followed and remained in contact with the pin, whilst the wheels turned one another by their teeth; shewing, that the effects are the same, and that the two may be either made to move together, or be substituted one for the other.

The investigation of the theory of excentric cams or wipers of this kind cannot be too strongly recommended as an exercise to the mechanical student. When we recollect, that by the aid of such an instrument alone, a machine may be constructed *without any other parts whatever*, capable of mechanically signing one's name, we cannot fail to be struck with the variety of applications to which its services may be rendered available.

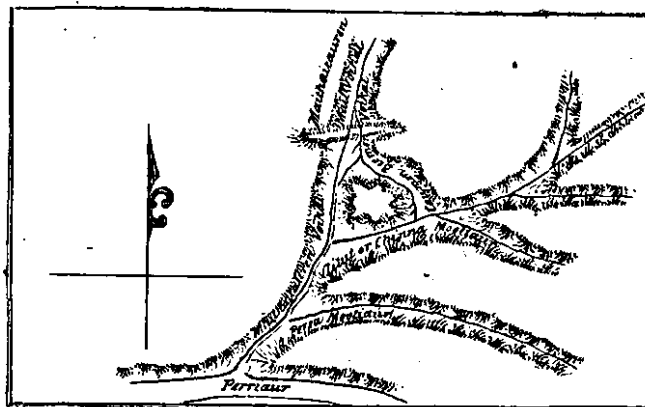
REPORT UPON A PROJECT,

BROUGHT FORWARD BY THE CULTIVATORS IN THE PERREACOLUM VALLEY, FOR TURNING THE WATERS OF THE CHINNA MOOLIAUR, INTO THE MAITACAREN-MAIT-VOIKAL, TO BE DISCHARGED INTO THE VYRAVENAUR, NEAR THE HEAD OF THE SAME VALLEY.

Various schemes have been set on foot for increasing the supply of the numerous streams which water this fine valley; but there are few undertakings regarding which an uneducated person is so likely to entertain mistaken views, as in the feasibility and advantage of giving mountain streams a different direction, from that, in which, in obedience to the configuration of ground, they are already flowing. The difficulty of overcoming intervening eminences is not sufficiently appreciated, whilst want of consideration of the extent of surface drained by each stream, leads to an over estimate of the value of the waters sought to be obtained. When attempts, moreover, have been made, they have often failed from want of knowledge as to the manner and sequence in which the various portions of the project should have been undertaken. It is not long since investigations were made regarding the possibility of turning the waters of the Rajacolumaur (which flows along the ridge of the Yellamullay hills, and is discharged into the Perriaur,) into the Shoorlyaur near Cumbum; but the old annicut constructed previously to the British management, was found to be 105 feet below the ground, over, or through which, the stream was to be conducted. It appears too in this case, that a muselman tahsildar, about 60 years ago, at once raised the dam 8 yards, so as to give it a total height of 15 yards; but no previous attention seems to have been paid to the rapid conduct of the vast body of water so retained; and the disastrous consequences were of course inevitable. In the topographical account of the hills separating Dindigul from Travancore, drawn up by Captain Ward of the Surveying department, a notice is contained of a project to turn the waters of the Chinna Mooliaur, (also a feeder of the Perriaur,) into the Shoorly; and I had at first supposed this alluded to the one now under examination; but though similar in design and contiguous in position, the former plan varies a good deal from that entertained at present.

The Chinna Mooliaur takes its rise in the western ridge of the two lines of mountains, which separate Travancore from the north part of Tinnevely. Its course from east to west diverges slightly to the south, until the Maitacaren-voikal, (rising in the small transverse chain of hills bounding the Perreacolum valley in the southward, and forming the apex of that valley,) running from north to south falls into the Chinna Mooliaur, when the united waters pursuing the direction of the smaller stream, are discharged into the Mooliaur, or Perri Mooliaur in contradistinction to the Chinna Mooliaur; and these again compose one of the many large tributaries received by the Perriaur. From the source of the Chinna Mooliaur to its junction with the Maitacaren-voikal

is a distance of little more than 4 miles, during which distance (its course being it is to be remembered nearly from east to west), it has received two tolerably large rills on its south, and two on its north bank. The most western of the latter, or that nearest the junction with the Maitacaren-voikal, bears the name of the Caumen Beeman-voikal, and it was through this opening that the former attempt mentioned by Captain Ward was made, to turn the Chinna Mooliaur into the Maitacaren-mait-voikal. The annicut is still to be seen, in testimony of the enterprize shewn by the individual whose name is perpetuated in that of the voikal; but here, again, the main attempt appears to have been to construct a dam, and not to previously prepare, by suitable excavations, a conducting channel, so as to ensure the delivery of the water turned off by the artificial obstruction. This too has been a failure, and the Caumen Beeman-voikal, which is traceable from the Chinna Mooliaur to the Maitacaren mait voikal, has its banks breached in various places by the tendency of the water to its parent stream. The subjoined diagram may facilitate the description of these localities.



The plan now proposed, is to construct a dam across the Chinna Mooliaur, a little distance above the junction of the Maitacaren-voikal, which here with a slope of little more than 40 feet, has had a length of only 1400 yards, from the crest indicating the inclination towards the Perreacolum valley. The waters being thus thrown into this stream, and retained in it by a strong embankment, it only remains to extinguish this fall towards the Chinna Mooliaur by means of excavation, so as to produce a reverse slope to that now existing; and the discharge to the northward into Goodalore, of what is now to the southward into the Perriaur, will be accomplished. The dam may be placed at a sufficient distance above the junction, to make the total height or depth of excavation, inclusive of the depth of channel

required for the new supply of water, not more than 43 feet, and that but for a very short distance. The crest marking the double inclination, on the one side to the north, and on the other to the south, is an extremely narrow ridge; standing on which, the Maitacaren-voikal, for the same name with the affix of "mait" or "upper," to the N. channel prevails on each side of the apex,) may be seen running in different directions, its fall towards the southward being much less rapid than to the northward, whence the length of the excavation to produce a reverse slope from the proposed dam will not be of any great length. The total base line, as it may be called, of the cutting, will, I find, be only 2750 yards; in order to obtain during this distance a fall from the annicut of 12 feet; and owing to the impetuous character of the discharge of the various streams descending from a considerable height with vast velocity, I do not think that, with the view of reducing the expenditure and labour, and difficulty of cutting, it would be safe to reduce this seemingly great declivity. It is moreover on the rapidity with which the new channel will deliver its waters into Goodalore, that the stability of the annicut will depend.

It may now be proper to enter into some examination of the circumstances of the Perreacolum valley in respect to its position, irrigation, and means of supply. The valley from its head to the abrupt angle made by the river Vigay in its progress to the east, is about 40 miles in length, and its greatest breadth is nearly 18 miles, its course deviating but slightly to the eastward of a meridional line. It is enclosed on its west, south, and east sides by high ridges of hills; and has two important irrigating streams running in a longitudinal direction, the Shoorly, and the Vigay. The latter of these is by far the more valuable in point of supply, and its chief sources are not more than a few miles to the east of those of the Shoorly; but it pursues a course of almost 20 miles amidst the numerous ramifications of the hills separating Dindigul from Tinnevely, before it emerges into the plains, and becomes subservient to the wants of the cultivator; whilst the Shoorly finds its way into the low ground within a few miles from its head, and by its means land is cultivated at least 20 miles to the south of the Vigay irrigation, although the sources are almost in the same parallel. From the head of the valley to the junction of the Vigay and Shoorly, following the meanderings of the stream, is a distance of fully 40 miles, and it is to the wants of this portion of the valley that attention is primarily to be directed.

There are supplies of running water, however, to the south even of the Shoorly, and an extensive sheet of cultivation is to be found before that stream reaches any rice lands. The delineation of this matter is both obscure and incorrect in all the maps which I have seen, and it is necessary to attend to the actual position of the streams, to obtain a precise knowledge of the exact appropriation which it is contemplated to make of the Chinna Mooliaur.

The most southern stream is called the Vyravenaur, and

rises in the Yellamullay hills, it is then joined by the Shorngunaur, rising a few miles to the northward in the same range, when it is crossed by the Vyravenaur annicut, supplying the Goodalore Tamaracolum; and pursuing its course, it receives in its south bank the tribute of the Maitacaren-mait-voikal, which will be remembered as the intended conductor of the expected increase. At this place the Vyravenaur has attained a respectable size, and sinks its proper name into that of "chinna voikal", in order, it is said, to distinguish it from the Shoorly, which undergoes a similar change of title to be called at first, the "perrea voikal"; but it is important to remember that there is no direct tribute paid by the Vyravenaur into the Shoorly. Correctly speaking, the Vyravenaur is immediately turned to the purposes of cultivation, and is absorbed in effecting this purpose. The only communications between the Vyravenaur and the Shoorly, are, first by a surplus calingula built across an old breach and called the "Keechan Oodapoo," and, secondly, by the drainings from that sheet of cultivation in which the Vyravenaur has been described as exhausting itself.

All supplies then, from the Mooliaur will be thrown into the Vyravenaur, which is only secondarily a feeder of the Shoorly; and that there never was a direct intercommunication seems plain from the Keechan calingula, built in fusly 1230, being invariably known by the name of the "Wodapoo." It is said that the Vyravenaur attains a sufficient height twice or thrice a year, to send a stream over the surplus calingula into the Shoorly; but, judging from the relative heights between the surface and crest of the calingula, when a small fresh was running down the Vyravenaur, I should think this a very doubtful point.

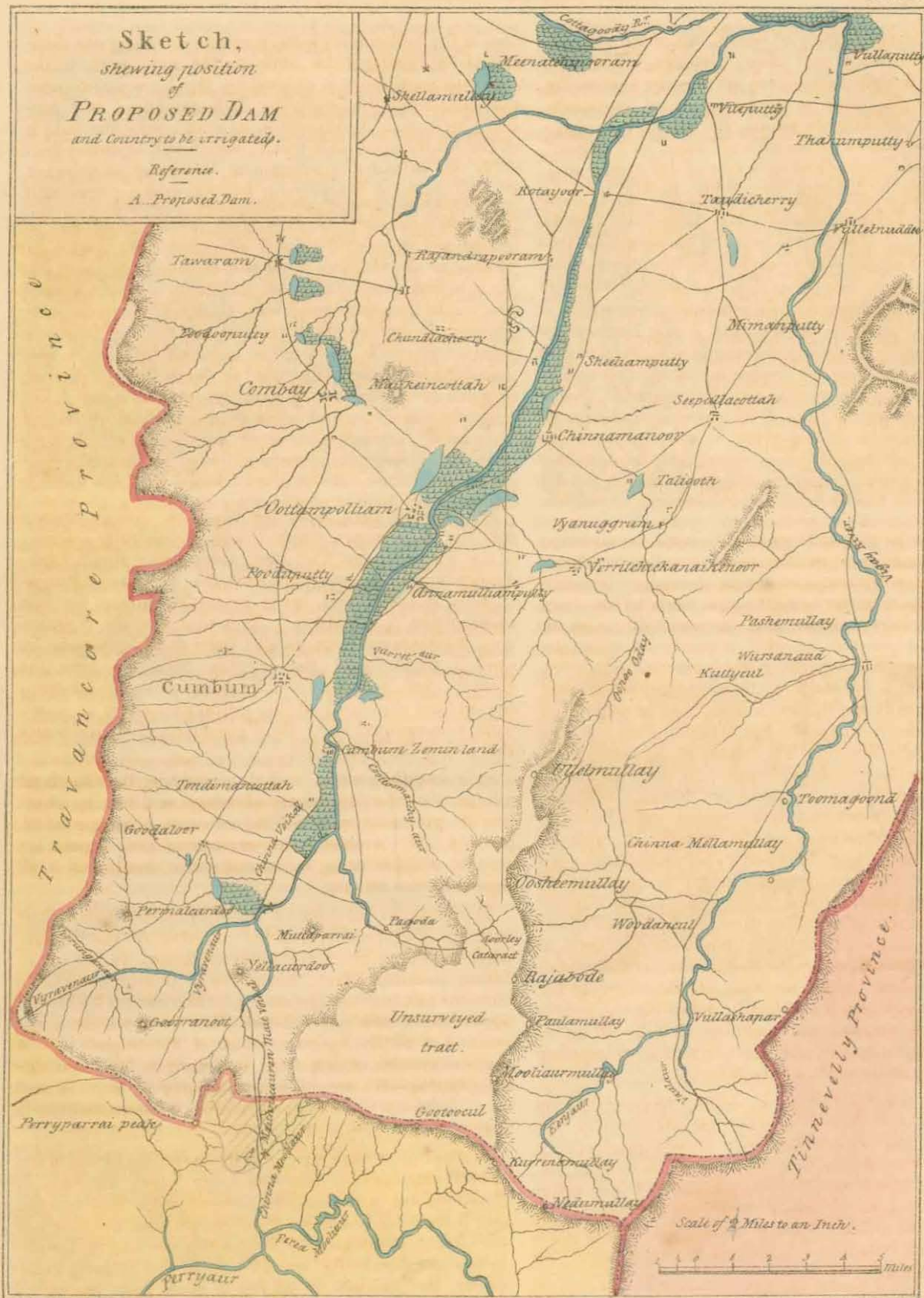
It is into the chinna voikal, supplying the Cumbum village, that the large body of waters will first be poured; its present ayacut of 686½ cawnies, or rupees 6412, in fusly 1246, yielded a net revenue of 860 rupees, an amount of 2448 being for uncultivated land, and 3103 rupees for remissions.

Between the junction of the Maitacaren-mait-voikal with the Vyravenaur, and the junction of the Shoorly with the Vigay, there are twelve annicuts; two of which belong to Zamieendars; but of the 10 paying revenue to Government, the total ayacut is 6109 cawnies 15, or rupees 39,256, which in the same fusly 1246 yielded a net revenue of 13995 rupees; whilst 11208 rupees 13-4 was the amount of remission, and cawnies 2410 (or rupees 14,052-6.) were left uncultivated for want of water. A tabular statement containing these particulars is annexed.

Without, therefore, examining into the likelihood of the general expectation, that the large Vigay annicuts in Maudacolum, and that the channels into Shevagunga and Raunad shall receive great benefit from the waters of the Chinna Mooliaur, it is abundantly obvious that, within the comparatively small limits of the Shoorly cultivation, the position of affairs is such as to warrant a large outlay for the obtainment of a more bountiful sup-

Sketch,
shewing position
of
PROPOSED DAM
and Country to be irrigated.

Reference.
A. Proposed Dam.



The span drained does not appear to be more than 6 square
instead of 21-

ply of water, and reference should be made to this particular tract only, in estimating the advantages of the project under consideration.

From the nearest approximations I could make the Chinna Mooliaur drains a superficial extent of about 15 miles, and the Maitacaren-voikal a surface of about 6 miles. The whole of this space of 21 square miles is exposed to the force of both monsoons, and from the best information I could obtain, supported by examinations made in the early part of April, and May, in the present year, before the commencement of the South west monsoon, the stream of the Chinna Mooliaur is fully entitled to the character of being *perennial*, and it is on this uniformity of supply that a material part of its value depends. On the 15th April the section of running water was 36 x 1 feet, and on the 9th of May 36 x 2; the velocity was not taken in either case, but it is probable that it was not much less than on my visit, when the water was remarkably limpid and free from all disturbance, running in a gentle and transparent stream, whose conditions were, a section of 81 square feet, with an hydraulic mean depth of 2 feet 1 inch, moving with a superficial velocity (determined by three careful experiments made under very favorable circumstances,) of 25 inches per second at the surface. Taking 20 1/2 inches as the mean velocity, (which it is,) we have—81 superficial feet x 1 ft., 8 1/2 in velocity=138 3/4 per second for the cub. feet of discharge per second, and 138 3/4 x 86400" (the number of seconds in a day of 24 hours)=Cubic feet 11,955,600, discharge per diem. Applying this quantity to the state of the Shoorly cultivation for fusly 1246, we have the supply required as follows.

Required for 2410 Cawnies of tursee,	
at 100 cubic yards per cawney per day.	241000
Ditto for the value of land on which	
remission was granted.....	182400
Allowance for evaporation from annicut to junction with Vigay, say sixty miles long, or two days time, at 1/2 inch per diem.....	35200
	Total 458600 C.yards.
	27
	12382200 C. feet.

12 x 30 miles x 36 = 129600
 10600 x 36 = 381600
 12382200 = 12382200

that is to say, the quantity obtainable from the Chinna Mooliaur is nearly sufficient for the whole cultivable land, which in the worst season perhaps ever known, either claimed remission or remained tursee: this alone appears to me sufficient to demonstrate the expediency of the undertaking.

But the calculation above given in detail, because deducible from a state of things coming under my own personal observation, offers a most inadequate representation of the value of the stream sought to be obtained. In the first place, it is proposed to build the dam 7 feet high, which during both monsoons would convert the section of 81 square feet, into 252 square feet, with a superficial velocity of 33 inches per second, at least. Taking the mean velocity at 29 inches, we shall have, as a not

21 x 30 miles x 36 = 2268000

improbable delivery per day, 252 section x 2 ft 5 in velocity = 609 cubic feet per second; and 609 x (as above) 86400" = 52617600 cubic feet per day, or enough to supply 19488 cawnies. Nor are such freshes likely to be of rare occurrence, whence I deduce, that though it may (in the figured statements submitted to Government for the purpose of shewing an immediate value to be realized, great enough to warrant their patronage of the undertaking,) be advisable to confine the attention to the Shoorly cultivation, yet it is only reasonable to conclude, that the benefits will often extend to a much greater distance, and materially improve the channels in Maudacolum and Ramnad.

In the next place it is to be remarked, that, as there will assuredly be a large conversion of one crop into two crop land in the Cumbum valley, the May and June freshes will not fail to induce the ryots to cultivate a first crop of the large inferior red rice well suited for the purposes of home consumption, and so enable them to send a larger proportion of better growth to market for the liquidation of their kists; and although the Revenue settlement of the Perreacolum talook, is such as to prevent any direct pecuniary advantage from a double harvest, yet the participation of Government in the prosperity of its cultivators is so immediate, that this, and the unfailing supply of water and forage to the large herds for which these localities are famous, may well be enumerated amongst the claims which this project possesses upon the favour and support of Government.

The site selected for the dam is a short distance above the confluence of the Chinna Mooliaur and the Maitacaren-voikal, and it is advantageously chosen. The works which I have thought necessary, are on a more liberal scale, than were proposed on the first examination of the ground; but the encouragement I have derived from considering the localities, is so great, and I have become impressed with so very favorable an opinion of the undertaking, that I am unwilling to compromise any of the good which it seems reasonable to anticipate, by a desire to exhibit the smallest class of dimensions, or to render those advantages but of a few years duration, when previous consideration and well placed liberality might easily render them permanent.

The proposed dam is to consist of a strong front and rear retaining wall of good masonry, with a body composed of rough stone in chunam; this with wing walls and buttresses appears all that is necessary. It is intended to place this diversoir in some measure obliquely to the stream, so as to give the water a direction towards the channel. The cut from the dam has to be carried across the tongue of land included between the two streams, and little excavation is wanted; very strong embankments however are essentially necessary, and the point on which apprehension seems most reasonable, is the likelihood of breaches taking place in the first flexure of the channel, before the reverse impulse has been communicated to the water. I have on this account estimated for a very substantial masonry revetment to the whole portion of embankment against which there will be any considerable impact, and it has proved to be one of the

most expensive provisions in the estimate. The cuttings which I have proposed are also prolonged, so that the difference in level between the head of the channel and the tail of the excavation shall be 12 feet, which I think advisable, to ensure as immediate and rapid a discharge of the waters as possible, from the dam into the plains below.

It now only remains to offer a few observations on the mode of carrying the work into execution, and in submitting this I shall endeavour to be as brief as possible. The whole of the project is so extremely popular, and has excited so great an interest throughout the whole collectorate, that all possible assistance from the Meerassidars, in exerting themselves and in sending their pullers may securely be relied upon. It will be necessary to make extensive previous arrangements, for obtaining supplies of all sorts for the large bodies of workmen which I should recommend being employed; there are convenient places, (thavalums), for the establishment of bazars, both above and below the Vennata parrai hills. An abundant provision of tools, equal to the wants of the greatest number of workmen likely to be collected, should be made before any assemblage of the people takes place. At certain seasons, fever of a dangerous character is somewhat prevalent, but there are many periods when the work may be carried on in perfect security; and the inhabitants who seem to consider themselves acquainted with the times in which, from the absence of wind and long previous drought, fever is to be apprehended, may perhaps be best consulted as to the months in which operations ought to be discontinued; especially as their own anxieties are sufficient safeguards against the interposition of any unnecessary delay; It appears to be thought also, that strangers are less liable to suffer, than those who from long residence in the neighbourhood may perhaps have had their constitutions already enfeebled by the attacks of previous years. For the rest, when the people are collected and adequately supplied with tools, the circumstances cannot be considered otherwise than favorable for a rapid execution of work; for the shades of the forest will shield the people from all heat, and they will have a ready supply of wood and water for all purposes.

As to the mode in which the undertaking ought to be put in hand, it appears to me of first importance that no attempts be made to establish the dam, until the path for carrying away the water is fully opened, to the required depth, and of the requisite slope; it is, as I have before stated, to the neglect of this precaution that we see in India so many instances of imperfect execution of

a design originally good. The difficulty appears, by general opinion to be vested in throwing a work of masonry across a running stream, instead of preparing previously by excavation a suitable conduct for the water obtained by the contrivance of the Projector. I think therefore that the last thing to be done is the erection of the dam.

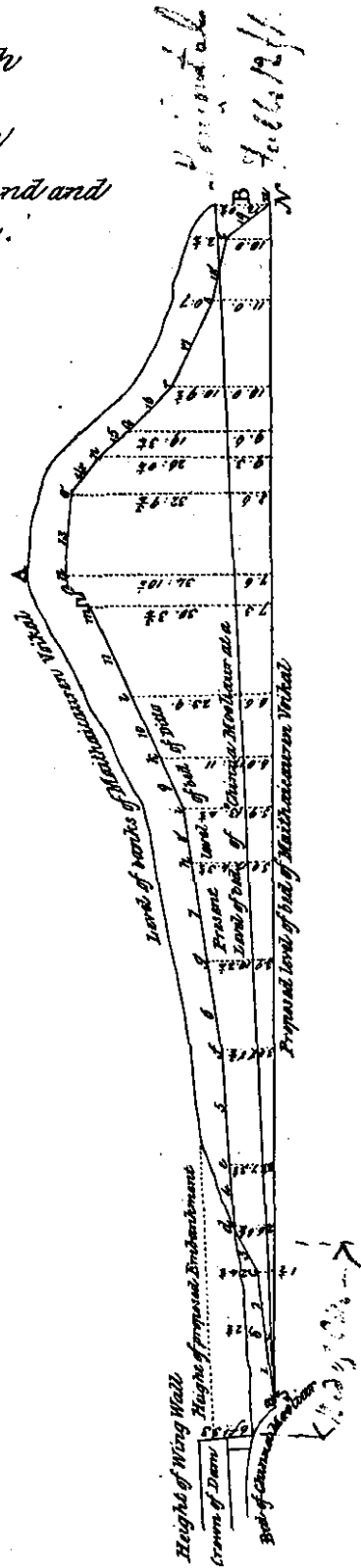
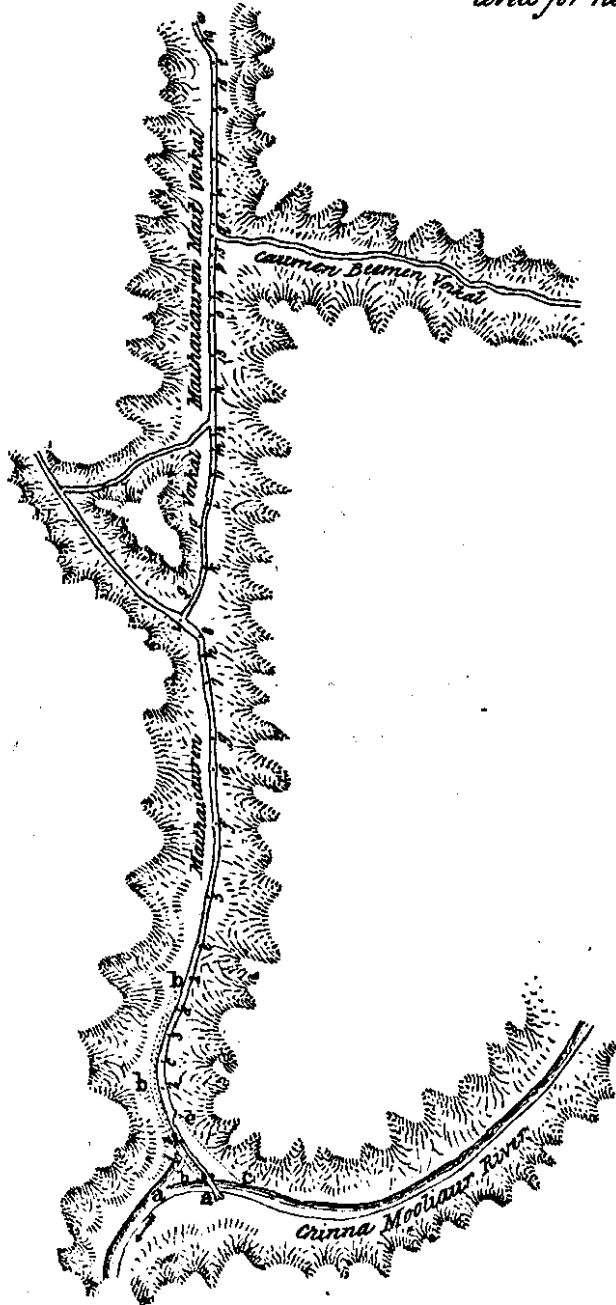
There are 180712 cubic yards of excavation, which may be called employment for 500 men for 40 days. This number should be divided into two parties, and one placed at the crest which marks the separation of the Maitacaren-voikal and Maitacaren-mait-voikal, and the other placed at the last term of the series of levels, or at the Northern point, or tail, of the proposed excavations; the former party would be employed in carrying down the cutting to the full depth, so as to procure a reverse slope (from that now existing) at each portion of their work; whilst the other, guided by the estimate, would work towards the crest, preserving the slope indicated by the section shewn in the working plan that will be furnished. Each set of men will work towards the proposed dam, and will complete the embankment, and retentment of the head of the channel before opening the West bank of the Chinna Mooliaur; meanwhile materials, which are to be got in the neighbourhood, will have been collected, for the construction of the dam; the chunam will perhaps have to be brought from the low country, masons, must be engaged in as large numbers as there is extent of work enough to give full employment to; the bank will then be opened, the new channel will be found to act as a drain immediately, the work will be kept tolerably dry, and the dam may be completed within a few weeks from its commencement.

These remarks will be sufficient, I trust, to shew the routine which it would be advisable to pursue; and in a general report like the present, it may not be advisable to enter into more minute detail; but when the sanction of Government has been obtained, the fullest communication will be established with the Principal Collector, and every possible assistance will readily be afforded by the Civil Engineers Department.

(Signed) C. E. FABER, Captain
Civil Engineer 4th Division.

TINNEVELLY DIST.)
Nelluembaloom)
Talook)
Coolavaneegapooram,)
22d September 1837.)

*Detailed Sketch
of
Proposed Dam
with Sections of ground and
levels for new Cut.*



- References.*
 a. Proposed Dam
 bbb... do... Embankment
 cc... do... Head of Channel



STATEMENT SHEWING THE EXTENT OF CULTIVATION &c. UNDER THE IRRIGATION OF VYRAVENAUR AND SHOORLYAUR RIVERS, TENCURRAY TALOOK: MADURA DISTRICT, FOR FUSLY 1246.

Rivers.	Names of Annicut.	Names of Villages.	Extent of Ayacut Land.		Extent of land under Cultivation.		Extent of Tursee Land.		Amount of remission granted by the Circar.	Net Amount collected by the Circar.
			Land.	Amount of Revenue thereof.	Land.	Amount of Revenue thereof.	Land.	Amount of Revenue thereof.		
Vyravenaur.	Keechan Annicut....	Cumbum.....	686 4	6,412 10 8	499 8	3,964 0 0	186 8 1/2	2,448 10 8	3,103 15 8	860 0 4
	Woottamattoo Annicut..	Cumbum.....	289 6	2,521 12 3	289 6	2,521 12 0	0 0	0 0 0	0 0 0	2,521 12 0
		Poodooputty.....	149 12 1/2	1,427 8 0	140 14 1/2	1,377 2 3	8 14 1/2	50 5 9	387 14 5	989 3 10
		Hunoomundaputty.....	391 2 1/2	3,282 0 9	338 4 1/2	2,982 0 9	52 14	300 0 0	2,401 11 10	680 4 11
		Woottamapolliam.....	686 15	5,084 1 0	584 6 1/2	4,177 10 6	102 8 1/2	906 6 6	2,367 7 7	1,610 2 11
		Total..	1,517 3 1/2	12,315 6 0	1,352 14 1/2	11,058 9 6	164 4 1/2	1,256 12 3	5,157 1 10	5,901 7 8
	Pauliampooroovo Annicut.....	Woottamapolliam.....	403 9	2,091 10 9	292 10	1,241 9 0	110 15	840 1 9	1,034 0 0	207 9 0
		Googoolapooram.....	360 5	1,129 14 8	266 8 1/2	886 0 6	93 12 1/2	243 14 2	731 8 3	154 8 3
		Karkuttaan Colum.....	515 12 1/2	2,390 12 11	90 15 1/2	418 10 10	424 13 1/2	1,875 2 1	271 7 0	144 3 10
		Total..	1,279 10 1/2	5,512 6 4	650 1 1/2	2,543 4 4	629 9	2,959 2 0	2,036 15 3	506 5 1
Chinnamanore Do.....	Chinnamanore.....	817 7	5,309 9 1	397 1	2,678 4 10	420 6	2,631 4 3	110 11 0	2,567 9 10	
	Poolanundapooram.....	215 13 1/2	1,371 5 3	124 8 1/2	884 5 8	91 4 1/2	486 15 7	266 6 6	617 15 2	
		Total..	1,033 4 1/2	6,680 14 4	521 9 1/2	3,562 10 6	511 10 1/2	3,118 3 10	377 1 6	3,185 9 0
Shoorlyaur.	Makien Cottah Do..	Makien Cottah.....	294 15	1,572 1 6	182 5 1/2	1,119 11 7	112 9 1/2	452 5 11	0 0 0	1,119 11 7
	Seelienputty Do..	Seelienputty.....	309 1	1,735 0 1	110 11 1/2	833 6 9	198 5 1/2	901 9 4	163 0 0	670 6 9
	Cottore Do..	Cottore.....	390 1/2	2,138 9 11	167 6 1/2	954 5 4	225 10	1,184 4 7	216 2 8	738 2 8
	Goolianore Do..	Goolianore.....	106 12 1/2	448 9 3	31 4 1/2	120 10 0	75 6	327 15 3	21 7 9	99 2 3
	Woopaurputty Do..	Woopaurputty.....	197 15	1,049 2 11	104 13 1/2	558 0 9	93 1 1/2	491 2 2	75 0 5	482 0 4
	Veerapaundy and Chuttraputty Do..	Veerapaundy.....	215 4 1/2	1,149 3 6	78 9 1/2	489 13 5	136 11 1/2	660 6 1	57 0 3	432 13 2
			76 12 1/2	242 14 7	0 0	0 0 0	76 12 1/2	242 14 7	0 0 0	0 0 0
	Total..	292 1 1/2	1,392 2 1	78 9 1/2	489 13 5	213 8 1/2	903 4 8	57 0 3	432 13 2	
	Grand Total..	6,108 15	39,256 15 1	3,699 4 1/2	25,204 8 5	2,410 10 1/2	14,052 6 8	11,208 13 4	13,995 11 1	

(27)

(Signed) CHARLES EDWARD FABER, Captain
Civil Engineer 4th Division.

MAGNESIA CEMENT—REPORT BY CAPTAIN COTTON.

To
The Secretary to the Board of Revenue,
Department of the Public Works,
Fort St. George.

SIR,

I have the honor to acknowledge the receipt of your Memorandum of the 14th August, and despatched 9th September, accompanying copies of papers on the subject of Magnesia.

With respect to its use on public works in this division, I beg to state, that it has only yet been applied in one instance to any extent, viz. in constructing the apron of the upper Annicut—in that case it entirely failed; I am now however fully satisfied that it was owing to our not being experienced in the use of the material.

The main cause of its not having been more extensively used, hitherto, has been the expense of it;—when I took charge of this division in 1833, I was not aware that it was to be obtained nearer than Salem, which is on an average 130 miles distant from the works of this division, and this made the cost very great. Since that, I have heard of its being found at various points much nearer to the river, but it was only two days ago that it was discovered by the Collector in a hill close to the bank of the Cauvery, about 20 miles above Trichinopoly. This is a most favourable site, as it gives us water carriage to every part of the Delta, and will make its cost so moderate, that it may be very extensively used. I had several times sent people to search for it, and offered rewards, yet no information respecting this site had reached me, though I conclude from Dr. Macleod's letter, that it must have been known to that gentleman.

The cost of it will now be as follows:—

Quarrying 1 Candy of 500 lb of stone, -	0, 4, 0
Charcoal and burning ditto. - - -	0, 3, 0
Pounding &c. - - - - -	0, 1, 0
Weight when burnt of 250 lb or $\frac{1}{2}$ Candy,	0, 8, 0
Cost of 1 Ton on the spot, - - - -	4, 8, 0
Ditto. of 1 Parra or 3 C. feet, -	0, 4, 0
Conveyance for 50 miles by water, the average distance of the Irrigation works of the Delta, $2\frac{1}{2}$ Annas per Parra - -	} 0, 2 $\frac{1}{2}$, 0
Packing in casks, the casks being returned, - - - - -	0, 5, 0
Total per Parra...	0, 11 $\frac{1}{2}$, 0

At this rate it will not add much to the cost of works, and it will no doubt be constantly used in future.

Its cost at the coast and at Madras will be. Price
of 1 Ton burnt and pounded as above stated at the
Quarry, - - - - - 6, 8, 0
Packing in casks, including cost of casks, 12, 0, 0
Conveyance to the coast by water distance
110 miles, - - - - - 4, 0, 0

Total per Ton burnt at the coast...	22, 8, 0
Conveyance to Madras by sea, - - -	4, 0, 0
Sundries, - - - - -	0, 8, 0

27, 0, 0

On deducting part of the value of the casks, 7, 0, 0

Cost at Madras per Ton burnt, - - - 20, 0, 0

Or per Parra, - - - - - 1, 2, 0

The cost of the raw stone will be

Quarrying 1 Ton, - - - - -	1, 2, 0
Conveyance to the coast, - - - - -	3, 4, 0
Do. to Madras, - - - - -	3, 8, 0
Sundries, - - - - -	1, 0, 0

Cost of 1 Ton raw, at Madras, - - - 8, 14, 0

Which when burnt will weigh $\frac{1}{2}$ Ton. I am of opinion that upon the whole it will be best to convey it to Madras unburnt, and to burn it there; it will certainly be safer, and I judge cheaper too; I could not recommend its being transported by water except in casks. With respect to its use as a material for masonry cement, notwithstanding the failure above mentioned, I consider it of the greatest value. I tried it first about 3 years ago, by making what are here called cubes of brick work, and found it set very rapidly, and in a few months it became so hard, that it was impossible to separate it from the bricks; however small the cube was broken up, the bricks were always broken, without the cement being separated from them. I have lately made a great variety of experiments with it; using stone from various quarries, and with different proportions of sand and other materials. Almost every one of them has formed an excellent cement, setting generally in one or two hours, sufficiently to be secure from the effects of water passing over it. I have however been greatly puzzled in one respect in my late experiments, viz. that in almost all of them I found, that a ball of cement, if plunged immediately in water, before it had begun to set, would not set at all. As I had certainly found the case otherwise when I tried it some years ago, I was at a loss to account for this circumstance, nor have I yet been able to satisfy myself about it entirely, though I think that I have now found the real cause. The stone taken from the surface of the ground is all extremely hard, while in general that found below the surface is

much softer though apparently equally pure, and it hardens by exposure to the air; there is therefore some difference between the surface stone and that found below, and though I have failed in making the cement from the latter set in water, I have lately tried some surface stone with success, and it is probable that the early trials were made with surface stones. I must however make further trials, as, till this is ascertained, it cannot be considered a perfect water cement. I have tried stone from many different quarries, have taken the greatest care in burning it, and mixing it immediately, with reference to this point, so that I think it is impossible but that it must be owing to the nature of the particular stone used, that it has failed in this respect, and to imperfect burning &c. It is to this circumstance, viz. that it was not known that it was liable not to set if immediately covered with water, that I now attribute its failure in the instance above mentioned. Notwithstanding this however, it is undoubtedly a most important addition to the means we have hitherto had for managing the Irrigation of the Delta, both by enabling us to form a masonry of much greater strength than could be formed with lime, and also on account of its being quite secure from injury by water, within an hour or two after it is used. As the rivers never continue full for many days together, slight repairs can always be performed during the season of the freshes, which before could not be effected from the want of such a material as this. Its extreme hardness also will enable us in many cases to use it as plaster, where otherwise granite must have been employed, which is so very expensive a material in the Delta.

I have the honor to forward, herewith, some balls of cement of different proportions and materials. The hardest is formed of Magnesia and the magnetic iron ore found in this neighbourhood.

On the specimens now sent I have to remark—

- 1st. That every one forms a strong cement.
- 2d. That the strongest appear to be—
 - 1st. A mixture of Ore and Magnesia in equal parts, both finely pounded and sifted.
 - 2d. Magnesia alone.
 - 3rd. Magnesia one part, and sand 1 or $1\frac{1}{2}$ part.
 - 4th. Magnesia and sand, in the proportion of one of the former to 2 or 3 of the latter.
- 3rd. That the mixture of lime and iron stone with the magnesia also forms a very hard cement; I tried this chiefly with reference to its use at Madras, as it would make a much cheaper cement there than magnesia and sand alone would be. It must however be observed, that all these specimens have been made within a few weeks, and the proportional degree of hardness may alter after some months. The iron ore is extremely pure, containing I am informed 75 per cent of iron. I regret that I had not the reports of Dr. Macleod when I made

these experiments, as they would probably have given me more information than I could gain by my own enquiries; I have the honor to request that the Board will be pleased to obtain copies of those reports, for the use of the department in this division.

I beg to send also herewith a memorandum of the method I have used in preparing the magnesia cement.

TALLAMALLY }
14th October 1837. }

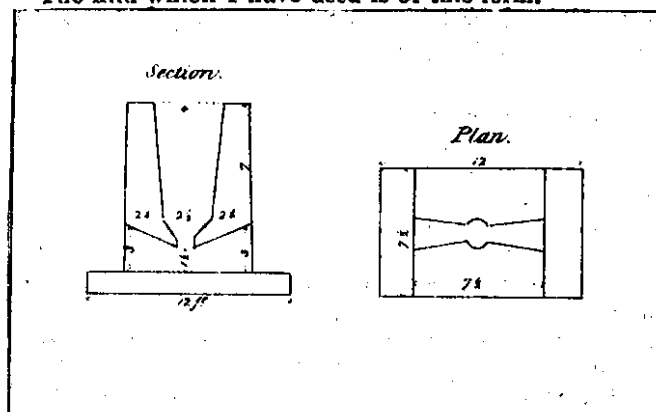
I have the honor to be
Sir

Your most obedient Servant
(Signed) A. T. COTTON Captain,
Civil Engr. 3rd Division.

Memorandum on burning and preparing Magnesia.

The stone should first be broken so small, that no pieces are more than $2\frac{1}{2}$ or 3 inches thick; if it is in thicker lumps, they will not burn through in a small kiln; if the kiln is very large, so that they will remain in it for 48 hours, they may be much larger.

The kiln which I have used is of this form.



These dimensions are for a very small kiln; it will hold about 25 parahs of charcoal and stone mixed—11 of charcoal, and 14 of magnesia, which is about a good proportion.*

Some air holes should be left through the sides of the kiln, low down, to assist the draft if it will not burn up well; but when the kiln is once thoroughly lighted, it will probably be necessary to shut them up, to prevent the heat becoming too great, in which case the outside of the magnesia will melt, while the inside remains half burnt; it does not require a very great heat to melt the stone, which spoils it; I think as great a heat (short of melting it) as possible, is adviseable, though not probably absolutely necessary; but the most essential thing appears to me to be, that it should remain exposed to that heat for a considerable time—24 hours for small pieces of 3 inches thick; and more time, if not broken so small. It must be continually drawn out from the bottom of the kiln, but not quicker than to allow of the kiln being discharged once in 24 hours, and if in taking

* I am however inclined to think that with a large kiln, kept always full, and the draft well regulated, a smaller proportion of fuel may be found sufficient.

out this quantity, (*viz.* 14 parabs in 24 hours) it is found that the charcoal comes out unburnt, it should be drawn more slowly, and if there is no appearance of the stone being vitrified, more air may be allowed to enter by the draft holes. The stones should be drawn carefully, and picked out from the ashes.

The stone, if well burnt, will break easily with the hands, and show quite through its very peculiar internal structure, very much resembling starch when broken into small pieces.* It will pound very easily indeed into a fine powder. It will be very light, about $\frac{1}{2}$ of its original weight. If it does not crumble freely in the hands it is not burnt enough.

In lighting the kiln, a great quantity of charcoal should be put in first, otherwise the first stone will not be burnt; if it should be found not to be burnt enough, it may be put in again at the top. The kiln should on no account be allowed to sink low; it should be kept constantly full; late at night it should be piled up, and if no person attends it at night, very little air should be admitted, that it may not burn fast till the morning, so that all the stone may not be less than 24 hours exposed to the heat. If there are not some symptoms of vitrification in some of the stones, it is probable that the heat is not sufficient; in which case more air must be admitted, and if with that it burns out too rapidly, a greater proportion of charcoal must be used.

The burnt stone may be easily pounded in a mortar, and it should be passed through a hair-sieve, or a muslin, and mixed with $1\frac{1}{2}$ or 2 parts of sand, which had better be sifted too.†

It must be beaten well, and I think a much heavier beater than is used for chunam should be employed. It should be mixed with sand thoroughly, while dry. It will set in some degree in two or three hours, and

become hard in a few days, after which it will continue still to harden, though slowly, for many months or probably years. Some plastering tried at the annicut became in a fortnight harder than any stone, except granite, marble, and stones of the first degree of hardness.

It will make an excellent cement, if mixed with more sand, though not so hard as with the proportion mentioned. I find that a mixture of lime makes it less liable to crack, when used as plaster, but it will not be so hard; I should however recommend its being tried for a terrace in the proportions of lime 1, magnesia 4, and sand 10. It has not yet been much tried for plastering, it cracks a little if mixed with only an equal quantity of sand, but probably with a larger quantity it might not. If it is used for terraces, some trials should be made, as it has never yet been so applied here.

When the magnesia is mixed with an equal bulk of pounded and sifted magnetic iron ore, it makes a cement of extreme hardness; and probably the Hematite ore from Rosanoor, 20 miles North west of Sooloorpet in Nellore, would answer equally well.

The magnesia of course absorbs carbonic acid from the atmosphere after it is burnt, but I think very gradually. If pounded and put into chatties or casks, I have no doubt it would keep for years; the chatties should be washed over with lime, to make them airtight.

It would not however be much injured, I think, by being kept in a heap in a dry godown for four or five months; of course the sooner it is used the better. If it is wished to make a trial of the Rosanoor ore, there is some at the Red hills which might be used.

TALAYMALLY } (Signed) A. T. COTTON Capt.
October 13th 1837. } Civil Engr. 3d Division.

* Some few specimens that I have burnt, do not however exhibit this peculiarity.

† If the magnesia is finely pounded and sifted, a greater proportion of sand may be used, than otherwise.

REPORT BY LIEUTENANT LUDLOW.

To
*The Secretary to the Board of Revenue,
 in the Department of Public Works.*

SIR,

I have the honor to forward, herewith, some specimens of Cement formed with Magnesia, Iron stone, and sand, and request you will have the goodness to lay them before the Board of Revenue.

The Magnesia used was obtained from the superintending Engineer at the Presidency, and has been in store at Madras upwards of two years since it was calcined. I had it recalcined, and used it 3 or 4 days after.

The Iron stone was of the best description, used, not calcined, but reduced to a fine powder. The sand was common yellow sand of an inferior description, produced near this place.

It has been supposed by some, that compounds of magnesia, although setting firmly when formed into balls, have not the property of adhering to surfaces. The result of these experiments proves the fallacy of this idea, for these compounds both adhere to the surface of bricks, and join them so effectually, that it is with the greatest difficulty they can be separated.

I do not think, however, that forming the Cement into balls is a fair way of trying it, and in the Table it will be observed that several of those compounds "set dry" which when plaistered on a brick turned out unfavorably, when rolled up into a ball gave an entirely different result; which I attribute to their retaining a larger portion of water in setting, than they could do if spread out on a larger surface.

The specimens which are put down as setting in water, were not immersed immediately, but were first allowed to dry for about 20 or 30 minutes. They were then put into water about 2 or 3 in the afternoon, and before the following morning had become as hard as they now are. If placed in water immediately, they are apt to fall to pieces.

The fact of these compounds requiring 20 or 30 minutes to dry before being put into water, is not likely to be of the smallest practicable importance, for no ma-

sonry work is ever submerged in a less time than that. I feel convinced, however, that upon further trial it will be found, that a compound may be produced which will set when immersed immediately after made. Of the experiments Nos. 4, 6, 8, and 12, the results were favorable whether set in or out of water, 3 out of these 4 are compounds of the three ingredients—Magnesia, Iron stone, and sand; and in 3 out of these 4 there is a larger proportion of the Magnesia.

In experiments 5, 7, 9, 10, 11 and 13 the result was favorable when the compound was allowed to set in water, but the reverse when set dry, with the exception of the balls which I have alluded to. In the dry set trials the worst results were produced when the sand bore a large proportion to the other ingredients.

The general result appears to me to be very satisfactory, and from the circumstance of almost of all the compounds setting well in water, I have little doubt but that an excellent water cement will be eventually produced from these materials. The laterite is I am of opinion a very valuable ingredient in a water cement, from the quantity of oxide of iron which it contains.

There is doubtless at present much uncertainty attending the use of magnesia, and very contradictory results are frequently produced; the most effectual method of clearing up these doubts, and ascertaining the causes, either of failure or success, would be an extensive and carefully conducted series of experiments, both here, and in those parts of the country where the mineral abounds. A few tons of magnesia would suffice to make a set of experiments here, which must I conceive throw much light on the subject. I beg therefore to request, that should the Board consider it advisable, they will obtain the sanction of Government to the supply of the quantity required.

RED HILLS, }
 2d. Decr. 1827. }

I have the honor to be
 Sir,
 Your most obedient Servant,
 (Signed) S. O. LUDLOW,
 2d Lt. of Engineers in charge
 Red Hill Rail Road.

TABLE OF THE RESULT OF SOME EXPERIMENTS MADE TO FORM A CEMENT WITH IRON STONE, MAGNESIA, AND SAND, IN DIFFERENT PROPORTIONS.

No. of Experiments.	Magnesia.	Iron Stone.	Sand.	How set.	Result.
1	1	1	0	Dry	Plastered on Brick :.....good. In a Ball.....Do.
2	1	2	0	Dry	Indifferent when plastered on a Brick. Two Bricks cemented together with it : good. In a Ball indifferent.....
3	1	3	0	In water Dry	In a Ball indifferent..... Same as No. 2.....
4	1	1	1	In water Dry	Do. Do..... Plastered on Brick :.....good. Brick cemented with it :.....good.
5	1	1	2	In water Dry	In a Ball :.....fair. Plastered on Brick :.....very good. In a Ball :.....good. Plastered on Brick :.....very good. In a Ball :.....very good. Plastered on Brick :.....bad.
6	2	1	1	In water Dry	In a Ball :.....Do. Plastered :.....very good. In a Ball :.....fair.
7	1	1	2	In water Dry	Plastered.....very good. In a Ball :.....Do. Plastered :.....bad. In a Ball :.....Indifferent.
8	2	1	2	In water Dry	Plastered :.....very good. In a Ball :.....Do. Plastered :.....fair.
9	2	1	3	In water Dry	In a Ball :.....Do. Plastered :.....very good. In a Ball :.....Do. Plastered :.....very bad.
10	1	2	3	In water Dry	In a Ball :.....good. Plastered :.....very good. In a Ball :.....Do. Plastered :.....very bad.
11	1	0	1	In water Dry	In a Ball :.....fair. Plastered :.....very good. In a Ball :.....Do. Plastered :.....very bad.
12	2	0	1	In water Dry	In a Ball :.....very good. Plastered :.....very good. Ball :.....Do. Plastered :.....Indifferent.
13	1	0	2	In water Dry	In a Ball :.....good. Plastered :.....very good. In a Ball :.....Do. Plastered :.....very bad. In a Ball :.....bad.

RED HILLS, }
2nd December 1837. }

(Signed) S. O. E. LUDLOW,
2nd Lieut. of Engineers.

REPORT OF COMMITTEE.

Proceedings of a Committee of Engineer and Medical Officers, which assembled at the Medical Stores on the 25th and 29th September 1835, agreeably to Garrison Orders dated the 24th of the same month, to examine a supply of Calcined Magnesia received from Salem, and report on its fitness for building purposes, as a Cement.

Present.

Lieut. Col. W. GARRARD, *Chief Engineer—President.*

Lieut. Col. W. MONTEITH, *K. L. S. Supp. Engr.*

Surgeon J. WHITE, *Medical Storekeeper.*

Assistant Surgeon J. G. MALCOLMSON,

” ” P. M. BENZA, *M.D. Body Guard.*

} Members.

1. The Committee having met, proceed to examine samples of calcined magnesia received from Salem, together with various specimens of cements prepared from them, submitted for their inspection by the Superintending Engineer.

2. The composition of the native carbonate of magnesia of Salem having been stated to be as follows ;

Carbonic acid	51. 5
Magnesia48
Water0. 3
Silica 0. 2

100

with only slight variations in the proportion of silica in different specimens; the committee directed their enquiries to ascertain whether the samples of the calcined mineral recently received were thoroughly calcined, and that they were not adulterated with any ingredient likely to affect their qualities as a cement.

3. The two samples last received from Salem, appear to have been very perfectly calcined, and contain little or no carbonic acid. They are also free from admixture of lime; and the very small quantity of silica they contain, can in no way affect the quality of the magnesia for any purposes of the arts.

4. The samples submitted to the committee, and the bags in which they were contained, had no appearance of having been wetted in the course of transport to Madras; but, from the known facility with which thoroughly calcined magnesia absorbs moisture from the air, it was not

improbable that any inferiority in the samples recently received might depend on this cause.

5. It was accordingly found, that the several specimens lost a very considerable part of their weight by recalcination, amounting in one specimen to upwards of 30 parts in the hundred; but, as $5\frac{1}{2}$ parts of the moisture thus driven off were again absorbed from the air in the course of 15 hours, when exposed on a table in a close room, the committee are of opinion, that any deterioration which may be found to arise from this cause, could not have been obviated by the parties supplying the material.

6. The committee carefully examined portions of the Magnesia cement on the walls of the Superintending Engineer's Office, and on the sea face of the Fort, (in one of which, prepared from 3 parts by measure of sand and 2 of the last supply of magnesia, salt water was employed without injury); and find that they had acquired a great degree of hardness, although not fully equal to some specimens prepared from a former supply, which had been longer exposed to the air, and which had attained an extreme degree of hardness. It would appear, also, that a proportion of sand amounting to about $1\frac{1}{2}$ parts by measure to one of magnesia, increases the usefulness of the cement for general purposes, but that this proportion may be increased or diminished, according to the view with which it is employed. When applied as an hydraulic cement, it should not be subjected to water for upwards of 12 hours from the time of its application.

7. In conclusion, the committee are of opinion that the calcined magnesia received from Salem forms an excellent cement, suited for any building purposes to which it may be applied. Adverting, however, to the fact, that the action of calcined magnesia as a cement depends on its quickly uniting with a certain proportion of water, and that when thoroughly calcined it rapidly absorbs water from the air, the committee beg leave to recommend, that the native carbonate of magnesia should be calcined as near as possible to the works in which it is to be employed; and, that if kept for any time, it should be secured in air tight casks. As the stone loses rather more than half its weight by calcination, its bulk remaining the same, it will be desirable that the expence of carriage should be lessened as much as possible, by obtaining it from those situations from which it can be conveyed to Madras by water.

WULLOORPOLLUM SLUICE.

Report by the Civil Engineer, *Second* Division, on the capabilities of that portion of the Masulipatam and Rajahmundry Districts lying towards the coast, between the rivers Kistna and Godavery; with reference to the irrigation which it may derive from those rivers.

1. The information obtained in the course of the investigations lately pursued into the connection of the Colair lake with the rivers Kistna and Godavery, aided by the operations conducted under former Civil Engineers, appears to me to be sufficient for laying down in a plain definite manner, the basis of any future system of works which the Government may be disposed to execute, in furtherance of the prosperity of this division of its territory.

2. The data on which such propositions must rest are, first the relative levels of the Kistna and Godavery in regard to the intervening country,—and secondly, the nature of that country; its soil, its adaptation for wet cultivation, in point of evenness of surface, or the obstacles it may present in regard to hills, stony ground, sandy or leaky tracts, intersections by rivers, hollows, &c.; taking also into consideration the nature of the existing cultivation, the uncertain supply of the present tanks, the disposition of the natives to extend the culture of rice, and the facilities for disposing of this produce; including likewise some enquiry into the past and present circumstances of this tract of land.

3. My own personal observation upon these points has obviously been limited, but Captain Caldwell's diaries from 1798 to 1803 inclusive, aided by other documents which have been placed within my reach, embolden me to prepare a brief report on the subject, which may at least lead to enquiry, and awaken interest on what is certainly of much importance. The strong impressions made on me by my late attentive examination of the part of the country under review, in connection with the valuable series of levels that have now been completed, have induced me to offer the remarks which follow.—The levelling operations alluded to, are—

First, Mr. Topping's, carried from Baizwarah up to Muctada, along the north bank of the Kistna.

Second, The same continued from Baizwarah across the country to Masulipatam.

Third, Captain Caldwell's levels, from Baizwarah on the Kistna, to Tallapooty on the Godavery, viâ Ellore.

Fourth, My own levels along the Weyairoo to the Colair, connected also with the Godavery,—and,

Fifth, The same continued from the Colair to the Chinnapore Canal, near Masulipatam.

4. Thus the elevation of the district between the heads of those important streams the Boodemair and the Weyairoo is first ascertained, and finally, the elevation of the land on which their waters are principally distributed.

5. The declivity of the bank and bed of the Kistna has been determined, but the same information regarding the Godavery is not within my reach.

The secretary of the Board of Revenue however, addressing the Right Honorable the Governor in Council on the 14th November 1796, enumerates among the papers he had examined, No. 6 K—as “a series of levels down the Godavery from Taundapooty to Coringa, (original by Captain Caldwell)” which also had been laid before Government by Mr. Topping himself: such a document would be highly useful could it now be procured.

6. For the present I shall postpone all detailed consideration of the Godavery, though towards the end of this report, will be found a few remarks drawing attention, in general terms, to the facilities it affords for watering a considerable portion of the Rajahmundry district.

7. Adverting then to the Kistna, and to the opinion of scientific men regarding it, I find that Mr. Topping in his report of 14th February 1794, para 12, inclines to question the feasibility of making use of so slight a fall as that river possesses in its course through the Masulipatam district. Major Beatson, in his communication to Government of the first December 1792, contemplated the necessity even of establishing an unicut at Baizwarah, whereby to raise and force the waters over the adjoining plains—and Captain Caldwell appears never to have taken up the subject formally, being fully engaged, seemingly, in the more immediately practical objects of his office, and in conducting his executive duties. While, however, investigating Major Beatson's project for a first class reservoir at Baizwarah, Captain Caldwell made the important discovery of the hollow there, which includes the bed of the Boodemair, being 20 feet below the top of the Kistna bank near Ibrahimpatam, and on this occasion he makes the following remark “from this result no doubt is to be entertained, but that great advantages may be drawn from the river.” (para 16 of letter to the board of Revenue, under date 24th December 1800.)

8. The above statements present no matured opinions, nor any definite suggestions in regard to the means to be adopted in deriving advantage from the Kistna;—From them, the last conclusion, perhaps, which would be surmised, is that of the real difficulty, consisting in dealing with a large occasional surplus, or in devising a method of so regulating the degree of supply, as to prevent the admission of a superabundant body of water. Nor would a perusal of these reports ever have suggested the

establishment of a well arranged system of river channels, arising from the assumed inference in them of the fall of the river being too gentle, and the banks too high, to admit of a measure of the kind.

9. The concluding part of the last paragraph shews in what light I regard this question of irrigation from the Kistna, and it remains now to demonstrate the grounds on which this opinion is based, and to exhibit an outline of a plan for carrying it into effect, together with some estimate of the cost to be incurred, and the advantages to be derived from its execution.

10. First, as to the foundation of the assertion, that in deriving irrigation from the Kistna a difficulty will be encountered in getting rid of any water not actually consumed by the tanks and fields, it is to be observed, that this arises from there being no drainage in the 30 miles above Masulipatam; for between that place and the Samaldivi river, not a Nullah falls into the sea.

11. It is owing to the face of the country being thus flat, that the people are still enabled to raise so much grain when the Monsoon is favorable, for as the rain water cannot run off, the ground is *then* flooded as effectually, as if under the range of reservoirs; the great evil of this description of cultivation, is its uncertainty. The fluctuations of the seasons will ever induce speculation, which cannot but be ruinous to so impoverished a class as the tillers of land in this part of the Circars. Again, it is the same evenness of surface—which so peculiarly recommends this tract for channel cultivation; thus advantageously circumstanced it might be watered like a garden; irrigating streams might be led over the face of it in all directions. And if water could by any means be drawn from the Kistna, and turned on these plains, as through a pipe capable of being opened or closed at pleasure, there seems no reason to question the beneficial results that would follow.

12. The effect of introducing a large irrigating channel on a flat country of this description, is a link in the report that ought not to be omitted.—Supposing then such a channel to consist of a main canal and a variety of branches, and that these and their dependent tanks are all supplied, and the cultivation saturated, and that still the stream continues to flow, the result will obviously be an inundation of the plain, on which the water will rise till some opening is found for its escape. Of course it would not be necessary to discharge the whole of the surplus through one duct, but preferable in many cases to allow it to pass along the various branches, by which means the latter would be preserved clear.

13. This principle is exhibited by nature on a very large scale in various parts of the world, as for instance in the Rhone, and the lake of Geneva,—and it was in consequence of this circumstance not having sufficiently entered into the calculations of the Mahomedan projectors of the Delhi canal, two centuries back, that the disastrous submersion of a valley took place, accompanied by the destruction of a town.

14. To apply these observations, then, to the subject of this Report, and first, as regards the Godavery, and

drawing an unfailing supply from that river, for the annual replenishment of the Colair lake;—I may assert, that in any plan which I have yet proposed for this purpose, there can be no danger whatever; for the fact is, that no hollow exists which could be flooded in a destructive manner; the whole country is so flat, having also a gentle inclination towards the sea, that no ridges, or chains of eminences are met with, whereby the water could be pent up: indeed were this possible, it would long since have been placed beyond the reach of doubt, by the frequent overflow of the river. Nor can there be any apprehension of the channels from that river becoming dangerously enlarged; the stiff soil skirting the Godavery sufficiently guards against this contingency, while the fall at the head of such channels might always be so modified, as to retard the flow in that part.

15. Hence it may be concluded, that water to any extent required for purposes of irrigation, may be drawn from the Godavery with the utmost safety; and that opposition to this measure, grounded on alarm lest it should produce mischief by inundation, is only the result of an uninformed prejudice, which is very natural on the subject.

16. The only water drawn from the south side of the Godavery, near the fork of that river towards Rajahmundry, has been for the supply of the Colair lake; but the ancient canal from the Kistna which fell into the Boodemair, had the somewhat different object of supplying a variety of tanks on the border of the Colair, rather than the lake itself; for the latter seems to have been regarded merely as a receptacle for surplus.

17. Of the ruined state of this series of tanks, formerly under the Kistna, another report of mine (that of February 1836) treats, while Captain Caldwell's diaries of the end of the last century prove their condition at that period to have been precisely similar to what it is at present; and this no doubt is the state in which, with immaterial change, they have remained ever since the loss of the permanent communication with the Kistna, and in which they must continue until that canal be restored, an operation only to be performed by Government, since its site is in the hands of a different interest from that of the cultivation which would derive all the benefit from it.

18. The feasibility of such a work is readily explained. The bed of the Boodemair at Baizwarah is 20 feet below the borders of the Kistna at Ibrahampatam. Now although the river occasionally rises above its bank, yet it does not usually possess a continued flow within 10 feet of that height; nor would it be expedient to establish the head of a permanent channel on a level more elevated than 15 feet below the top of the bank, as it would be necessary to provide for the irrigation of the country in those years when the Kistna might fail considerably of its usual flood level. The difference of 4 feet between the head of the channel and the bed of the Boodemair at Baizwarah, will be abundantly sufficient for the ten miles which intervene between the points, since, as may be inferred from para 14 of this report, I should construct

the first mile of channel without any fall whatever, and from that point to the end, the declivity would be gradually increased. At one thousand yards from the mouth, I should establish a dam across the channel, with capacious ~~and~~ sluices, so that, when necessary, it might be altogether closed—the channel would then in its operations closely resemble a duct, such as I have indicated at the close of para 11, and in para 12.

19. It does not seem necessary to dwell farther on the executive part of this question;—and the expediency of carrying this project into execution may be rested on the single consideration of the value of the tanks dependent on it. I have not succeeded in acquiring figured statements of what this value may be, for which I must refer the Board to the Collector. The inspections I have made assure me of the capacity of these old reservoirs, and of the very extensive cultivation which was once presented under them; a restoration, however, of the Boodemair tanks and dependencies, is by no means to be regarded as the limit of what might be derived under a permanent river channel of this description; since by it the whole of that rich flat extending towards Masulipatam, might at 15 miles from Baizwarah be irrigated.

20. This report I shall draw to a close, by adverting to the Nullah called the Pulleiroo, which was once a regular river channel from the Kistna, and conveyed the means of fertilization over a vast extent of country; of the ruin that has followed its shutting up, I have had occasion to remark, in my inspections during the month of February 1836; and as this is a matter which cannot fail to excite the attention of the authorities whose province it is to watch over the general interests of the Government territories, it is not necessary farther to dilate upon it. I have already shewn, that the admission of water may in such situations very well be regulated, and it is exceedingly easy to embank the sides of the channels, wherever such a proceeding may be required. In India, the adoption of this expedient is common enough, not only with channels, but with large rivers, as for instance the Godavery; in like manner, in North America, the lower part of the Mississippi is skirted by bunds which guide it to the sea, although its stream is much above the level of the adjoining country, and the earthen rampart on each edge is only 2 and 3 yards thick at top, and thrice that width at bottom, the river at the same time running with a velocity of 4 miles an hour, and with a depth of 100 feet—the surface of the stream, indeed, is sometimes 10 feet above the city of New Orleans itself. It is worth while noting these circumstances, as exaggerated notions frequently prevail, of the peril incurred by dealing with large bodies of water, instead of these apprehensions being limited to enterprises undertaken without previous scientific enquiry, or an acquaintance with resources on the occurrence of difficulties. I consider, therefore, the loss of the Pulleiroo to have been an injury gratuitously inflicted on the country.

21. Another great mischief which the closing of the Pulleiroo has occasioned, lies in the consequent deterioration sustained by the Port of Masulipatam. At present the depth of water on the bar there, at low tide, does not exceed 2 feet; in 1807 there was 3 feet of water; in 1796, 5 feet; and it is asserted that twenty years prior to the last mentioned period, there was never less than 10 feet of water on the bar. No doubt, when the Pulleiroo was maintained in efficiency, the Masulipatam inlet received such a quantity of drainage from it, as tended materially to clear its passage of silt, and thus to deepen the back-water, one consequence of which would be, the reception and discharge at every tide, of a much larger body of water, the action of which in passing and repassing over the bar, would tend to lower its crest, and prevent accumulation there.

22. Finally, and after a laborious investigation of the subject, I may assert, that there is every reason for concluding, that the greater part of the rich plain between the Kistna and the Colair, might be rendered as fertile as Tanjore itself, since it is perfectly under the command of the Kistna river; nor in effecting so desirable an object, as converting this dry land into a plain of wet cultivation, would it be necessary to do more than renew, improve, and extend, the very works which must have been in operation when the country was in its highest state of prosperity. For the additional produce thus raised, Masulipatam itself evidently offers a market, as grain in large quantities continues to be imported there.

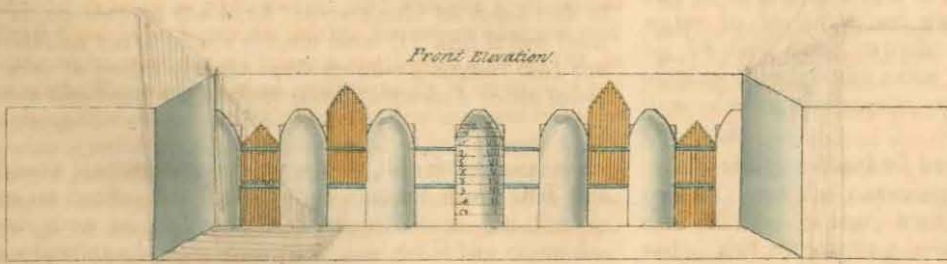
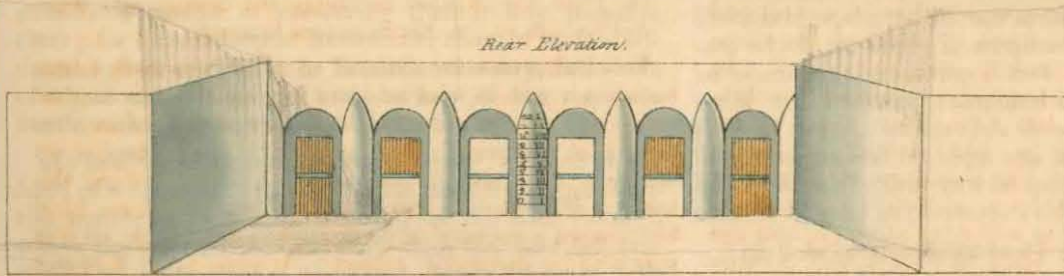
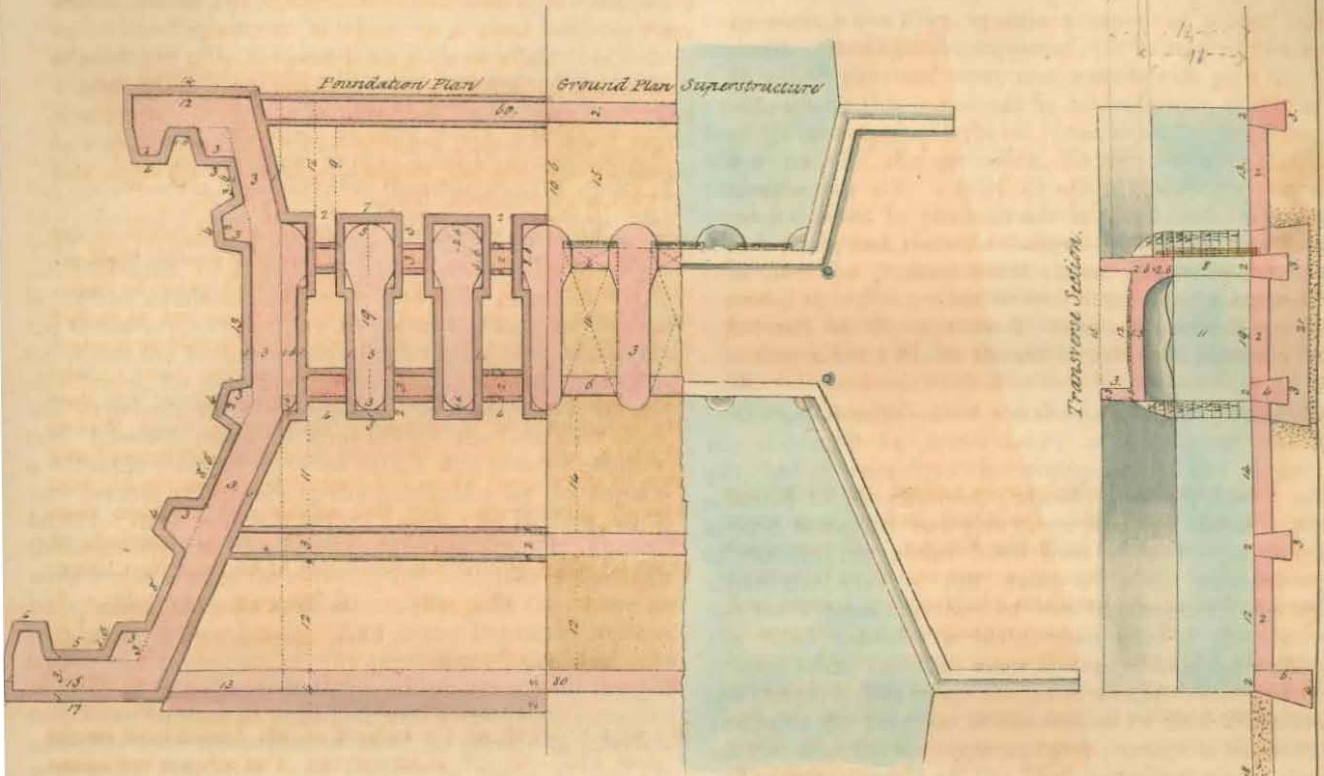
(Signed) E. BUCKLE Lieutenant,
Civil Engineer 2nd Division.

5th April 1836.

MEMORANDUM, on the subject of the Sluice built in the year 1837, at the head of the Pulleiroo river channel from the Kistna, adjoining the village of Wulloorpollum, in the Masulipatam district.

The Pulleiroo river channel, to which the work under notice is attached, was formerly of considerable magnitude and importance, and is supposed to have drawn its supply, at one period, from a source 15 miles higher up the river than the present one, not very far from the town of Baizwarah; this head, though, must have been abandoned a century ago, though with a little care it may still be distinctly traced. At some later date the connection between the channel and the river was maintained by a shallow cut, or, possibly, a natural indentation slightly improved by art, which, during high freshes, threw in a flood from a point on the river close above the village of Wulloorpollum, indeed two heads of such a channel are pointed out, one lying in the village itself—the other a little to the north of it. After a careful examination of the whole course of the Pulleiroo, accompanied by levels taken along the same, and an inspection of the tract of country formerly watered by it, the conclusion arrived at was, that with a source at Wulloorpollum, nearly the whole of the ancient field under the Pulleiroo might be irrigated by its restoration, on this li-

PLAN OF THE RIVER SLUICE
 built at the head of the Pulleiroo Channel
from the
Kistna adjoining Wulloorpollem
in the
 MASULIPATAM DISTRICT.



Wing Wall & Buttress.



Scale 0 10 20 30 40 50 feet

mitted scale, while those portions which by their greater elevation would be excluded from its range, might yet receive branches from another large channel which takes its rise about 25 miles higher up the river, bearing the name of the Boodemair, the renewal of which, also a valuable undertaking, is in course of execution. It is not necessary in this place to enter on details connected with the excavation of the Pulleiroo, but only to state simply, why a sluice should be attached at all. The proposal of such a work, indeed, struck the people of this part of the country with much amazement, no structure of the kind, it seems, had ever been heard of, nor does any exist, that I am aware of, along either the Kistna, or the Godavery, or the river Toombuddra, or Pennar, nor as far as my experience extends, at any place either in the northern Circars, Nellore, or the Ceded Districts, while at the same time it is remarkable that the want of works of this character has long been sensibly manifest, and both the progress of irrigation checked, and its difficulties increased, by the absence of any provision for regulating the admission of water into river channels. On the Godavery, one cut, the Apparow Culwab, having for its object the better supply of the Colair lake, was actually closed, for no other apparent reason, than the inability experienced of exercising any control over its waters. Lower down on the same stream, the Gostah Nullah, a valuable channel restored within the present century, now creates annoyance to the cultivators by the superabundant flood which it brings down. In Bellary, while the channels from the Toombuddra are actually supplied with under sluices for carrying off sediment from their beds, which they do most effectually, still they have no regulators at their heads. And on the Pennar in Nellore, owing to the absence of any provision of the kind, the mouths of the channels there, which are all cut in light soil, have become so enlarged, and consequently receive annually such quantities of sand, as greatly to interfere with their efficiency, and leading to much annual expense and trouble in preserving them in any measure clear; for a considerable distance the channel is often widened to twice or thrice the breadth necessary, the whole of which superfluous bed must be kept of the requisite depth, either by the ryots or by the State.

An additional reason for establishing a sluice at the head of a channel from the Kistna, are certain peculiarities connected with the declivity of the land through which the river flows; not only does the land fall gradually as it approaches the coast, but it likewise falls away from the river towards the north, so that by making an opening in the bank, there would be some risk of inundation to the plains remote from it; and it has been in order to guard against such inconveniences, that the Kistna has been embanked from Baizwarah to its lower branches.

Above Baizwarah, it may be said, the river never overflows its banks, nor does it often happen now, that this occurs even so high up as Wulloorpollum, but farther down the inundation is annual, and on it the crops depend; however, as the inundation leaves a rich deposit,

the land is of course soon raised above its original level, when it consequently demands for its irrigation artificial channels, while at the same time the Kistna, by the deposits of its flood, gradually encroaches upon the sea, and the limits of its periodical inundation have therefore a progressive sea-ward tendency; these operations of nature are not understood by the common people, and their misconception on the subject, leads them into many practical errors, as well as entailing on them heavy losses and disappointments, owing to their engaging in wet cultivation when there is little prospect of a crop being realized. It might be supposed, perhaps, that the ease with which the river undermines its banks, and the degree to which this is constantly taking place, would also tend to reduce the level of inundation, by preparing a wider bed for the periodical floods; however it seems probable that this is fully compensated for, by the accession derived by the islands and sand banks along the river's path, and thus the dangers in this respect do not influence the general inundation. Under any circumstances, it is clear, that River channels on a large scale constitute by far the most certain sources of revenue, and that a head Sluice should be attached to such channels.

On any details relating to the excavation of the Pulleiroo it would be unnecessary to dwell, in this paper, but in regard to the dimensions of the sluice, as adapted to the channel, I should observe, that it is intended to supply two very large feeders, and is capable of discharging about 3000 tons of water per minute when the river is full, though in its present state not more than one-third of this is admitted; but when the flood subsides a little, then more of the sluice is thrown open, and four vents instead of two vents supply the channel, but when the latter shall in course of time and with the progress of cultivation be doubled in magnitude, then the six vents will give passage to the stream.

The construction of the Wulloorpollum sluice resembles a bridge, on tall narrow arches, of these there are six, into which the water is admitted by as many rectangular openings, measuring 8 feet by 4 feet, and to these vents are shutters, composed of a number of balks or slips of wood, which slide down through cross stones into grooves, and by them any breadth of water way can be given, while they can be quite closed, half raised, or entirely opened at pleasure. (vide plate VI.)

The floor of the sluice is 11 feet below the adjoining bank of the Kistna, and the river being occasionally known to rise to 2 or 3 feet above the bank, the head of water to be sustained above the sluice will sometimes be 14 feet deep, which would exert a great force in passing through the same; ordinarily the river does not flow, during the season, within 1 or 2 feet of the top of the bank.

The sluice is flanked by oblique wing walls well buttressed, and the pavement extends out 15 feet in front, and 30 feet in rear, with retaining walls at each extremity, and intervening cross walls for strengthening and supporting it.

Over the sluice a roadway is carried, there being an extensive communication kept up along the bank of the river. A precaution has been taken in the construction of the sluice, against the danger of any pressure from below on the crown of the arches in times of flood, having a tendency to tear them up; this has been effected by making the apertures towards the stream only 8 feet, while the soffit of the arch is 11 feet above the pavement, and thus the work is screened against too free an admission of water, should the shutters be neglected. During the season of 1837 the greatest head of water above the sluice was 11½ feet, and this with only the two centre vents open, (or under two apertures, each 8 feet by 4 feet), kept the channel below at 10 feet deep, that is, the fall was 1½ feet through the sluice under these circumstances, and there was of course a leakage through the closed doors.

The fall of water round the head of the Pier was, with the depth of 6 feet above the sluice, about 6 inches, and with only 2 feet of water running down, it was observed to be 2 inches.

With a head of water of 8 feet, great difficulty was experienced in closing the last few sliders, so as entirely to shut up the sluice; the force of water may indeed be in some measure estimated from an accident that occurred in attempting to shut up the last vent, by tying rough planks to the cross stones, time not having admitted of preparing regular sliders, but the violence of the under stream fractured both the cross stones, the middle one of which was a slab of lime stone 2½ inches thick, such as is used in lithography, and the upper one was granite: of the latter the piece torn out measured 4 feet by 5 inches by 3, it was snapped off flush with the brickwork, and carried 30 feet by the stream, being afterwards found buried in mud near the extremity of the apron. On the centre pier head, both towards the stream and on the opposite side, a graduated scale was inscribed and figured, in Native, as well as in English characters, by which a person standing at the side of the sluice is enabled to read off the quantity of water both above and below it, likewise the fall round the pier head; and by keeping a register of this, together with the breadth of sluice way opened, a means was afforded for determining, with some accuracy, the quantity of water received in the course of the season. The sluice worked well during the freshes, nor, beyond what has been stated, did it fail in any particular, except, that all the grooved lime stone slabs became more or less fractured, which has induced me to prepare iron frames in lieu of them.

Above the sluice, in the 200 yards intervening between it and the river, a heavy deposit of sand lodged along the bed of the channel, and the same also reposed on the floor of the sluice, on the subsiding of the freshes. In addition to this, a large quantity of alluvial deposit was accumulated in the form of mud banks against the oblique wing walls, and in the end sluices which had been kept closed, as well as wherever any still water rested. In the channel below the sluice, the violence

of the stream must have carried off the sand held in suspension by it.

The foundations of the sluice are laid in sand, and are 18 feet below the surface of the ground; a rich black soil prevails along the bank of the river in this part, to a depth of about 12 feet, and this stratum appears to overlay a bed of sand throughout the whole of the Masulipatam plains, but with a varying thickness. The height of the sluice from the top of its parapet walls to the bottom of its foundations is 21½ feet. Great pains was taken with the masonry throughout, the attention paid to breaking bond and securing all the angles of the work was particularly minute; much of the chunam employed, however, had been prepared ten or twelve years before by the Pioneers; it was nevertheless found quite good, and was accordingly used, in the proportion of two parts of sand to one of chunam. In the pavement and in the Pier occasional layers of brick of a very large size were introduced, these bricks were purchased from the Zemindar of Wulloorpollum, and were of a very superior order. A solution of the nut (the mirabolans) used by native dyers as a mordant, was also mixed with the cement for the pavement, being supposed to improve its adhesion very materially, when exposed to the action of water. The sluice was principally built during the months of April and May, and plastered in June; it was thrown open to the earliest freshes in July, on the very morning of the last cross stone being inserted. The very first arrangement for undertaking the channel and sluice were only entered on in December 1836, and the sluice was completed and the channel ready for a supply in July 1837. Taken in themselves the operations are nothing; but where such improvements have long been unknown, they were looked upon as of imposing magnitude.

It was not without the greatest apprehension that the natives had watched the progress of the undertaking; from the local Zemindar down to the poorest ryot, all regarded it as a rash proceeding; many persons also from distant parts of the country visited the work; while, from the prevailing prejudice against it, great difficulty was experienced in carrying it through; nor was any party prepared to see both channel and sluice rendered efficient in one season, consequently, the admission of the river in July took the cultivators quite by surprise. When however the people became familiar with the working of the sluice, I found some trouble in repressing their desire to admit more water than was expedient, and in a short time all apprehension and prejudice in regard to the scheme was dissipated.

The sluice was estimated at Rupees 4500, within which amount its cost falls; and on the restoration of the Pulleeroo about 9000 Rupees have been expended; but this operation cannot be yet considered as complete, for the banks of the channel, where exceeding 2 yards in height, ought to be cut into a double slope, and the section should be of a very capacious form, in order that full advantage might always be taken of the sudden rise of the river.

It is not easy to determine at present what may be considered an average season, as relates to the river flood. For four or five months in the year, that is, from July to October inclusive, there is a considerable body of water in the river, though where it sweeps by Wulloorpollum it runs perhaps during this period from 10 to 15 feet below the bank. The deep bed of the Kistna is about 24 feet below the bank, having however its general sandy bed at from 12 to 18 feet below the bank only, and from the ridges of this character much sand is introduced into the channel. The river during the season of its freshes is subject to sudden swells, rising and falling 6 feet at a time, or continuing for three or four days, sometimes seven or even ten days together, flowing down nearly full. The fresh of 1837 was considered by the natives as more copious than ordinary, and a course of experiments was carried on during this flow, to ascertain the discharge at different heights and velocities; but as there was no demand for any large supply of water, its admission was restricted, and altogether but 34,000,000 cubic yards, or about twenty five and a half million tons of water were drawn off from the river; but in an average year it is supposed that 50,000,000 cubic yards would be yielded, even in the present condition of the channel, and this might be increased half as much more. The financial results of such a project may be sketched out as follows. In this part of India it is computed that every square yard of land requires a cubic yard of water for its irrigation, this large allowance being understood to cover wastage of every sort, and to be sufficient for light soils; but in the rich alluvial plains adjacent to the Kistna, much less water is required, and the rains alone on so

flat a tract, with so little drainage, would be almost sufficient, could they be depended on. If however an additional half yard of water be allowed to a yard of land, it will be an abundant provision, and the 50 million cubic yards would yield a crop on 20,661 acres, which at 8 Rupees the acre would give the annual return of 165,288 Rupees; by a different method of estimating results, the amount comes to about a lac and a half, and this on an original outlay, of at present only 13,000 Rupees, or if the work be carried out as is suggested, the total outlay will not exceed 20,000 Rupees; to this should be added an annual charge of 1000 Rupees for cleaning the channel and maintaining it perfectly efficient, which is highly requisite, otherwise the very rich sediment of the Kistna water will speedily obliterate half the excavation that has been made. A further disbursement ought also to be prosecuted in favour of the long neglected tanks which once flourished under this channel. Were 2000 Rupees to be annually applied to their improvement, and the whole be accompanied by a careful revenue supervision, instead of the present wretched Zemindary management, a marked improvement might soon be expected to appear in the face of the country; the once populous villages would again rise from their ruins, cultivation be restored to those fertile plains now left barren, and famines cease periodically to visit those districts which have the greatest natural advantages; while, at the same time, the revenue fluctuations would be brought within some reasonable limits. Such extensive benefits, however, can only be realized by corresponding and unremitting exertions.

ACCOUNT OF THE DISCHARGE OF WATER BY THE WULLOORPOLLUM SLUICE, FROM THE RIVER KISTNA IN 1837, THE YEAR OF ITS ERECTION.

1st Fresh.	Admitted on the 15th July 10 A. M., it had subsided on the 21st July at 6 P. M. 5 days only are taken into account.	
15th to 21st July.	The Sluice had 4 vents open, the depth was usually from 2 feet to 3 feet, but of this 6 inches was mud. Taking however the flow of the channel below the Sluice, we shall have 5 days, at 175 cubic yards per minute.	1,260,000
2nd Fresh.	Commenced flowing 31st July, lasted till 8th August; but the last day is omitted from the account, being of little amount in such a calculation.	
31st July to 1st August.	Depth 5 feet to 6 feet, 2 centre vents open, 2 next half open, discharge 1,000 cubic yards per minute.	1,440,000
2d and 3rd.	Depth 6 feet 9 inches, vents as before, discharge 1,100 C. yards per minute.	3,168,000
4th.	Depth 6 feet, 2 vents open, discharge 900 cubic yards per minute.	1,296,000
5th and 6th.	Depth 5 feet and 4 feet. Sometimes 2, sometimes 4 vents open, average 800 cubic yards per minute.	2,304,000
7th.	Depth 4 feet to 2 feet 6 inches, 4 vents open, discharge 400 cubic yards per minute.	576,000
	Total 2d Fresh....	8,784,000
	Carried over, Total both Freshes—Cubic yards....	10,044,000

Wulloorpollum Sluice.

	Brought forward.....	10,044,000
<i>3rd Fresh...</i> Commenced on the 27th August, terminated on the 8th September; but the first and last days not taken into account, being inconsiderable.		
27th to 28th Aug...	Omitted.—Depth from 2 feet to 4½ feet.	
29th & 30th Aug...	Depth on the floor above the vents from 6 feet to 7½ feet, 2 vents open, 2 half open, the remainder closed. Flow per minute 1,100 C. yards.	3,168,000
31st Aug. & 1st September.	Depth 7½ feet and 8 feet, 2 vents open, the remainder closed. Flow at the rate of 1,200 per minute.	3,456,000
2d do.	Depth 8½ vents as before. Rate 1,450	2,088,000
3d, 4th & 5th.	Depth from 10 feet 6 inches to 11 feet, 2 vents open, 5 sliders out of each of the adjoining ones, and 3 out of the end vents, total width of orifice 13 feet, rate 1,800.	7,776,000
6th September.	Depth 8 feet, vents as before, rate 1,300.	1,872,000
7th do.	Depth 7½ feet to 5½ feet, 4 vents open, rate 1,100.	1,684,000
8th do.	Fell to 2 feet, not taken into account.	
	Total 3d Fresh....	19,944,000
	Or for the three freshes....	29,988,000
<i>4th Fresh...</i> Commenced 4th October terminated 7th October.		
4th October.....	Depth from 1 to 3 feet, 4 vents open. Average discharge 200 cubic yards per minute.	288,000
5th do.....	Depth 4½ to 5 feet. 4 vents open. Average discharge 650 cubic yards per minute.	936,000
6th do.....	Depth 3½ feet. 4 vents open. Average discharge 400 cubic yards per minute.	576,000
7th do.....	Depth 2 feet—not taken into account.	
	Total Fourth Fresh....	1,800,100
	Total for the four Freshes....	31,788,000
<i>5th Fresh...</i> Commenced 14th November, ended 16th November.		
15th November.	One day, from 3 to 3½ feet water.	576,000
<i>6th Fresh...</i> Commenced 17th November, ended 21st November.		
17th, 18th, 19th, 20th.	From 4 to 5 feet water. 4 vents open. Average discharge 600 cubic yards per minute.	2,592,000
20th.	Fell to 2 feet, not taken into account.	
	Total of the six Freshes....	34,956,000 C. yards.

The discharge was measured by taking the velocity of the water in passing down 100 yards of known section, at about half a mile below the Sluice, in which part the bed of the channel was perfectly flat. From the force of the water, the section underwent some change during the Freshes, but this was also taken into account. The following were the velocities at the assigned depths of water passing through the Sluice.

At 3 feet depth, 100 yards in 2 minutes 24 Sec.

— 6 feet — do. — 2 — 0 —
— 9 feet — do. — 1 — 43 —

These are the average velocities, the mid-stream velocity on the surface would be

— 3 feet — 100 yards— 2' — "
— 6 feet — do. — 1' — 40"
— 9 feet — do. — 1' — 28"

ON A NEW SYSTEM OF FIXED LIGHTS.

BY CAPTAIN J. T. SMITH.

The preparation of this volume, affords a favorable opportunity of giving some account of the successful trials which have been lately made under my superintendence, of a new system of Light house illumination, which, although possessing but little claim to scientific notice, may not be the less acceptable to the practical Engineer, to whom, more especially to those who may be engaged on such subjects in this country, it will I feel confident, render extensive and valuable assistance.

The new arrangement which is here referred to, was first suggested in studying the best means of constructing a small light to be hoisted on a flag staff, to answer the purpose of a light house; in considering how to produce a maximum effect in which, I was led to the trial of a new kind of reflector, whereby an imitation was attempted in catoptrics of the very beautiful dioptric arrangement, designed by the illustrious Fresnel, and now well known as a fixed, light of the first order on the coasts of France.

The results of a trial of this instrument being as favorable as I had expected, the advantageous consequences of the use of many in combination next occurred to me, and an opportunity presenting itself, in a call which was made for a temporary improvement of the Madras light, a cheap apparatus was constructed upon the plan indicated by the theory of this contrivance, and has been fully successful in its results; other combinations have therefore been since recommended and executed, so that the suitability of the plan to various opposite circumstances, has been fully and satisfactorily ascertained.

The motives which induce me to recommend the system now to be described to the notice of my brother Officers in this country, will however be best understood and appreciated, if I give a sketch of the difficulties which it has been designed to contend against. I may therefore before entering upon a description of the contrivance itself, point out what these are, and notice the great difference which exists between the circumstances attending the illumination of our coasts in India, and the corresponding provision in Europe, and the many obstacles which present themselves to our availing ourselves here of the improved means already adopted for that purpose in those countries, where beacons have been so long established.

The first of these arises from the much inferior place in the scale of importance, which this subject occupies in this part of the world, and in consequence, the much smaller degree of attention to which it is considered entitled. The rugged and inaccessible nature of the

coasts of Britain, and the great value and magnitude of the property constantly at hazard in the busy trade along her shores, naturally induce a vigilant watchfulness over the efficiency of the Light house department; and supply abundant means for its maintenance, which is accordingly supported by a Corporation possessing a princely fund, in the disposal of which they are ever ready to meet the claims of the maritime community upon whom they depend, with a liberality worthy of the objects desired.

In this country, although the gradual increase of our commerce, and the growing importance of the coasting trade, have latterly awakened the attention of Government to the subject of coast illumination, and led to the consideration of means for its improvement; and although we have been taught by the frequent losses of property, and the disastrous accidents which have accompanied them, that the strongest interests, as well as the loudest claims of humanity, are linked together in supporting the appeals for its establishment upon a liberal scale, the position we occupy is very different to that which I have just adverted to. The great length of our shores in comparison with the present value of the maritime traffic along them, imposes too heavy a burden upon the resources of that rising interest, to permit of the application of more than a very partial and imperfect remedy for the deficiencies which are continually presenting themselves; and the claims which are constantly made on this behalf, not being balanced against the profits of the tax raised in its support, as is the case when the department is placed under a separate management, each new claim is entertained as a fresh burden upon the resources of the state, which it is thought necessary to treat upon terms of the strictest economy. While therefore, in England, the accordance of a grant as large even as £ 150,000 for a single Light house is obtained when the occasion demands it, without any very extraordinary difficulty; and the expenditure of 15 to £ 20,000 upon objects of less importance may be heard of as of frequent occurrence, we have in this country to confine our wants within, not only the tithe, but even the hundredth part of such a proposal, or for ever sacrifice the chance of any improvement at all, and the Engineer Officer in preparing his design for a work of this character, is bounded as to his estimates within limits, which in Europe would be scouted as altogether impracticable.

The influence of this limited economy upon the resources of the Engineer is two fold, first by confining the amount of his expenditure towards the improvement of his Apparatus, and secondly by contracting the space

also in which he has to dispose of it, in consequence of the small size of the building which he can afford to erect for its exhibition. The last, is the most serious difficulty of the two, because an accommodation to circumstances by a sacrifice of the cost is in the one way possible without so great a diminution of effect, by discarding the expensive material used in England for instruments of this kind, and turning to account the cheapness of labour in India; but the loss of space brings with it evils which it seems almost impossible to get rid of upon any system of illumination hitherto known; and this I shall presently explain, as it was this obstacle to the adoption of the usual modes, that compelled me to devise a new principle, such as that which it is the object of this paper to describe. The difference in character and objects, which essentially recommend the plan I have adopted, will be practically exemplified by the circumstance, that whereas the instruments employed at home are usually provided, for a complete circle of the horizon, at a cost of from 10 to 20,000 Rupees, independently of the cost of the tower, and require for their disposal the space afforded by a circular lantern of from 6 to 13 feet diameter, those which I have to describe, have been constructed at charges varying according to power from 100 to 1000 Rupees, and may be contained within limits ranging from a diameter of 6 feet down to the size of a cylinder of 1½ feet diameter and two and a half feet high.

I hope I shall not be misconstrued to state by the above, that when confined within the very limited dimensions I speak of, the apparatus would be equal in effect to the splendid and expensive instruments elaborately fitted up in the light houses on the coasts of England, or to recommend the use of them as substitutes, when the more expensive and efficient means are attainable; I merely wish to express in this place, that an efficient light (such for instance as to be clearly visible in the most unfavourable of the above suppositions, at a distance of 15 or 20 miles) may be constructed within the dimensions stated; a convenience not attainable by any other system that I am aware of; and that an Engineer may thus be enabled to erect an efficient beacon under circumstances, which before would have been entirely impracticable. I shall hereafter proceed to shew, that the proper application and extension of the same principle, when required on a larger scale, will be accompanied by effects much superior to those produced by the finest catoptric English lights, and that in a particular which has hitherto been little regarded, and is deserving of the first attention.

I have had occasion in the earlier part of this Volume* to describe the nature of the apparatus which has hitherto been universal in the English fixed lights, which I have there spoken of as comprising a series of parabolic reflectors placed circularly, facing outwards, and so disposed with respect to each other, that each

illuminates a certain angular portion of the horizon, within which its effects are wholly confined.

The essential character of this system, therefore is, that the whole circle of the horizon is divided into a number of separate sections or angular spaces, each of which is lighted exclusively by its own distinct reflector, and receives no light whatever from the other instruments in the apparatus; when therefore, any given portion of the horizon has to be illuminated, it is indispensable to apply as many reflectors as may be indicated by the number of degrees comprehended by the space, divided by the number of degrees filled by each reflector, the omission of any one of which would be inevitably accompanied by the production of a dark space, within which, the Light house would be altogether invisible.†

In designing an apparatus on the above plan, therefore, if the lantern is unavoidably limited to very small dimensions, we are compelled, owing to the necessity of using many reflectors, either to reduce their size so much as almost to take away their whole efficiency; or another expedient may be resorted to, that of diminishing the focal distance of the mirrors, and thereby increasing the lateral space through which they act, so as to cause a smaller number to suffice—or both these expedients may be adopted in combination.

The former of these plans is attended with considerable loss of efficiency, which affects the useful results in a high ratio, the illuminating power of reflectors varying according to the square of their linear dimensions. The latter involves great difficulty in the manufacture of the instruments, besides a great sacrifice of the rays of light, which by the wide divergency given to them, both in the vertical as well as the lateral direction, are made to expand in the form of a pointed conical beam, and thus cause as much loss by the dispersion of the rays into the upper regions of the air, as they effect gain by increasing their separation in a lateral direction.

Nor are even the above accommodations sufficient to meet the necessities of the case, when the limits are as small as some of those before referred to. When the size of the lantern is contracted to a less diameter than 4 feet, the adoption of reflectors even at any sacrifice becomes very difficult; the great heat thrown out by a number of lamps, and the crowding of the space by them, their reflectors, and reservoirs for oil, opposing almost insurmountable obstacles to success.

Moreover, the gradual reduction of the size of the mirrors, and the consequent diminution of the aid of reflection, necessary in the accommodation of the above system to narrow dimensions, signifies the abandonment of those advantages upon which the efficiency of the light so highly depends; and the final term in this progress of degeneration ends in the catoptric power being reduced to nothing, and the lamps being left to

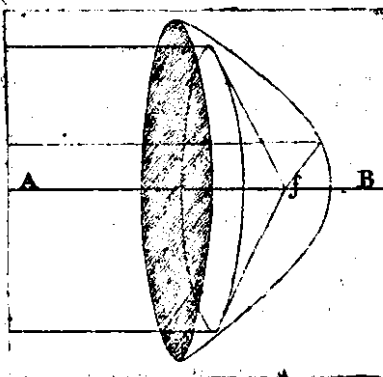
* Page 16.

† It is unnecessary here to notice the direct unassisted light of the lamps, as this is so feeble in comparison with that by reflection.

their own unassisted powers, of which the augmentation by scientific means becomes impracticable.

These difficulties were presented in an aggravated form in the proposition which was ordered to be carried into effect, for converting the flag staffs at the various ports into beacons for the guidance of vessels into their harbours, by hoisting a lantern to a sufficient height to give it the necessary command. This had already been attempted before my attention was directed to the subject; by means of a lantern containing merely a single lamp in which the Argand principle had been aimed at, though unsuccessfully, owing to the want of chimnies, which are not procurable at out stations. On the occasion of a light of this description being lately called for, I was requested to study the subject, with a view to render the project more effectual, by improving the power of these small instruments, and the following considerations led me to the scheme I have since adopted.

In the reflectors now employed on the coasts of great Britain, and in fact in all those in common use, the principle of construction is that of giving to them the property of collecting the rays which emanate from a central point, and propelling them all in parallel lines in the direction of the axis of the mirror, which is a line perpendicular to the middle point of its surface. This property which is usually aimed at in all mirrors, however faulty their real figure may be, is correctly attained by shaping them in the form of a paraboloid, that is, a



solid generated by the revolution of a parabola round its axis. The mathematician who is already familiar with this property of the parabola, will be aware that it is due to the nature of the curve, and to the circumstance, that in solids of rotation, all the sections through the axis are similar to one another,

and similarly situated with respect to the axis of rotation; and hence, that as the property of each curved section, is to return the rays in directions parallel to its own proper axis, which axis is in this case common to all, being also the axis of rotation, the result is that all the rays radiating from the focus are propelled in a direction parallel to this common axis and to one another.

The necessary consequence therefore of the use of reflectors of the above form, if the light emanated from a focal point would be, that the emergent rays being strictly parallel, would merely fill in space the capacity of a cylinder of the sectional area and form of the end of the reflector; and before these instruments were generally known and had been submitted to trial, an unpropitious result from the use of them was predicted by the late celebrated Dr. Robison from the apprehension, first,

that owing to the small area which would be covered by the section of this cylinder of rays, which he anticipated would be formed, it would be extremely difficult to point it in the proper direction, so as to catch the eye of a mariner on the horizon, and secondly, that an almost infinite number would be requisite to fill the circumference of the surrounding space at the requisite distance. That distinguished philosopher had omitted to take into consideration the natural divergency of those rays, which owing to the flame of the light being *larger than a point* were necessarily situated *out* of the focus, and which, consequently on emergence, form the same angle with the axis after reflection, which they subtended before impact with a ray proceeding from the point of reflection to the true focus. Had it not been for this last unlooked for circumstance, these instruments, however interesting from their elegant application of scientific truth, would have been entirely useless as a practical means of illumination, and would have fully verified the unfavourable doubts entertained regarding them.—But to return; I have now to explain in what way a modification of these properties has been effected, so as to bring about the results which were had in view.

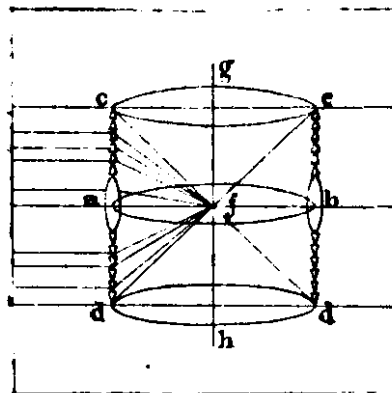
It will be observed, that by the above construction, the rays emanating from the focus are collected in every direction, both vertically and laterally. The first is evidently a desirable object, since it is obvious that all rays which emanate in directions however slightly inclined to the horizontal line, either upwards or downwards, can never reach it, except they be restored to the proper course by reflection; but in regard to the lateral divergency it is plain that no object whatever is gained by collecting them, since this very collection introduces the difficulty felt in the narrowness of the space filled by each reflector, and has to be compensated for and neutralized by the inconvenient and expensive necessity of multiplying the number of the instruments employed, and with them the number of lamps, reservoirs, and in fact all the other parts of the apparatus.

It occurred to me, therefore, that if an instrument could be devised capable of collecting the rays of light emanating from a central point *as regards their vertical divergence only*, leaving their lateral diffusion untouched, that I should then be able to effect a condensation of the beam to the utmost useful extent, without the introduction of the accompanying evil just pointed out, and that the application of such an instrument to a light whose agency was required to be seen throughout a wide space of the horizon, must effect the maximum of advantage of which its use was susceptible.

In M. Fresnel's beautiful dioptric light before alluded to, the principle here spoken of is carried into effect by placing the light in the centre of a cylinder formed by a series of separate zones of glass placed one above the other, each so shaped as to possess the property of refracting to the horizontal direction the rays impinging upon it from the central lamp. A vertical section of one of the sides of this cylinder, therefore, presents the ap-

pearance of a wall of prisms, which has the same property in dioptrics as was before stated to be peculiar in catoptrics to the parabolic mirror, namely, that in the plane of this section all the rays emanating from the central or focal point are refracted to the horizontal line, that is, a line perpendicular to the wall of prisms at its middle point.

This horizontal line, parallel to which the rays are collected, is in the parabolic mirror made the axis of rotation, and thus, as before explained, by becoming the common axis of all the sections, the whole of the rays become parallel to it, and to one another. In M Fresnel's dioptric arrangement, instead of making



this line the axis of rotation, in which case the prismatic section would by its revolution be formed into a polygonal lens, a line perpendicular to it, and parallel to the section, is made the axis, and the rotation of the section round it forms the cylinder, as shewn in the accompanying figure, where the axis is represented by *gh*. Here it will be quite obvious, that as the sides *c d c' d'* have the property of collecting all the rays emanating from the focus *f* on both opposite sides, and further, that the same sections are exhibited by cutting the cylinder in any other direction, it follows that the whole cylinder possesses the property of condensing all the beams proceeding from the focal point, as regards their vertical divergence only, and that as regards their circular dispersion, that is, their divergence from one another in the horizontal plane, they remain unaffected, and like mere unreflected rays, equally diffused.

In attempting to imitate this in catoptrics, it will be manifest from what has before been explained, that for the wall of prisms we must substitute the parabolic section; and it is necessary to remark also, that it is essential that the axis of rotation of the cylinder to be formed should pass through the focus of the section, that is through the focus of the parabola. The axis of rotation, therefore, becomes the parameter of the curve, or the focal ordinate; and were the dimensions similar to those adopted in all Fresnel's dioptric zones, whose focal distance is 3 feet, and the refraction confined to the lower part of the sphere of rays emanating from the light, by cutting off from the solid formed by the revolution, that portion which approaches the axis and occupies a vertical situation in respect to the light, a bulg-

ed cylinder would also be generated, of the accompany-



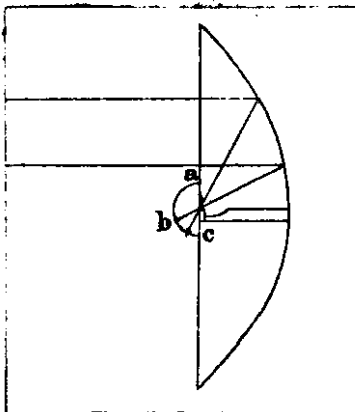
ing figure, which would much resemble a wine cask. But in the small reflectors which I am now speaking of, the whole of the curve intercepted by the parameter is used, instead of merely the zone whose section is *AB*; and the figure produced by its rotation is that shown by the dotted lines, the shape of the instrument itself being very like an empty canoe, or the half of a nine pin.

There is one great disadvantage in catoptrics, which will not fail to have already occurred to the mind of the intelligent reader; viz., that we cannot in this case, as when refracting the rays through a series of transparent zones, use the entire cylinder; one half of it is necessarily sacrificed in consequence of its interference with the efficiency of the other half; and hence it is impossible by this plan to take advantage of more than one half of the radiant light, and no reflector of this kind can fill more than 180° of the horizon.

This is no doubt a serious evil, theoretically, when we consider the economy of the rays of light, the object of which is, of course, to arrest every individual pencil of the luminous matter and turn it to good account. But practically it is not of so much consequence, except in those situations in which more than a semicircle of the horizon is required to be lighted; which rarely happens except in the few cases where a light house has to be established on an island. Under such circumstances the beneficial effect of a set of reflectors of the character above described, would be smaller, and the advantages of their use less, in comparison with a refracting apparatus in which the sacrifice above mentioned would be avoided, in the ratio of one half.*

As most light houses stand on the edge of a coast, and require only the means of illuminating one half of the circumference of the horizon, this drawback to perfection in the theoretical efficiency of this scheme is rarely felt in practice; and even then, the advantages of its adoption are so many and so great, that it is of little importance when compared with them; nor are we altogether without a remedy, for unless the size of the reflectors be very small, a partial recovery of the hemisphere of lost rays may be easily effected, by means of the adoption of

* The same objection would also be applicable to a set of dioptric lights, such as, for instance, a system, of M. Fresnel's cata dioptric lights of the 4th order, if used circularly to illuminate a complete horizon; in which case one half would interfere with the other. But a very efficient application of the system which I have proposed would be made by a series of these instruments, each backed by a hemispherical reflector, for the purpose of returning the rays which would be lost owing to the above cause, back again through the front, and thus doubling the radiation in that direction. Thus furnished, each of these instruments would be for all purposes one half more effective than a reflector; I have however addressed my remarks principally to the latter, they alone being capable of being manufactured in this country.



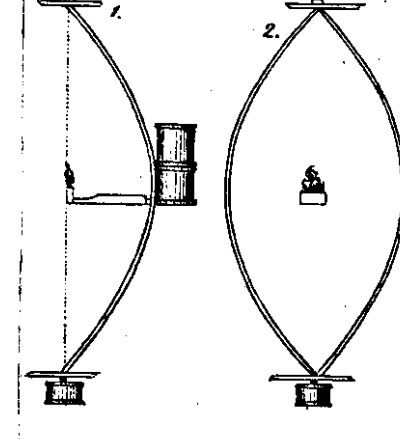
a small hemispherical reflector, represented by *a* *bc* in the annexed figure, in front of the lamp, and pointed inwards, as shown in the annexed section. This arrangement, which has been suggested for the common reflector by Mr. Barlow, has the effect of returning all the diverging rays which would have been diffused in front, back again

through the focus into the corresponding directions of the opposite hemisphere, whence they are diverted into their proper courses by the parabolic mirror.

The reflectors which have been hitherto used by me have been principally of the dimensions of two feet in height by 1 foot breadth, and 3 feet by 1½ feet. That is, of 6 inches and nine inches focal distance. When the size of the lantern of a light house will admit of it, it would be more effective, as well as economical, to use larger dimensions. The lamps which are fitted to the reflectors are necessarily of a peculiar kind, for on considering the properties of the double curve used for reflection, which it will be recollected is a parabola vertically, and a semicircle in its horizontal section, it will be observed, that all the reflected rays must pass through the axis of rotation, that is, through the parameter of the curve, the middle part of which is the focus, and contains the lamp; which, were its construction such as is commonly adopted, would very probably fill up a large portion of its height by its own body, drip-cup, and chimney—and thus, since the *whole* of the rays are obliged to converge and pass through this axis, they would nearly all meet with obstruction, and the entire efficiency of the instrument be destroyed. It is therefore indispensable that the burner and all the solid parts of the lamp inside the reflector should occupy as little bulk as possible, and although the use of a chimney would be less open to the same objection, yet since, in spite of its transparency, it could not fail to be some interruption to the free passage of the rays, and might very probably interfere with their correct diffusion, it would be highly desirable that it should be dispensed with. This desideratum is still further enhanced by the great difficulty and constant trouble which would accompany the attempt to keep up a constant supply of such fragile articles; the delay and uncertainty in procuring which, and the great inconvenience which would be met with in providing for the wants of numerous out stations, would impose an unceasing and vexatious trouble upon the Marine department.

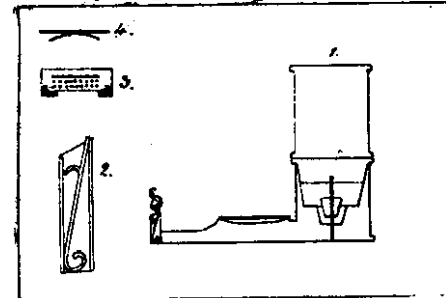
Many different kinds of lamps and burners have been tried, with a view of combining the desiderata above noticed, I shall here merely give a description of that which has been hitherto found most successful. In those last constructed, a cistern *a* *b* is fitted at the back of the reflector, into which drops a fountain reservoir si-

milar to those used with the common Argand lamps, and furnished like them with a valve &c.



A feeding pipe for supplying oil to the burner passes from the lower part of the cistern, through the head of the reflector, to the focus. This pipe is open at the top, and is about ¾ or ⅝ an inch broad, by 1 inch deep. Towards its extremity, where it is united to the burner, it is closed at top, and its form is changed

to a tapering one, shown in the accompanying figures, the object of which is to prevent the formation of a shadow in the lower parts of the reflector. When it reaches the focus it is joined to the burner, which is a flat



one, placed transversely across this pipe, and is ¼ inch in length (in the direction of the feeding pipe) 3 inches in breadth, (measured transversely to do) and an inch in height. The outer lip of this burner is ¼ inch below the inner one, so that the two sides appear with a slope. In other respects it is a mere empty trough. In order to secure and adjust the wick, a thin but stiff plate of brass, measuring in breadth 3 inches, (which is the breadth of the burner) by one inch in height, is turned up at one of its broad ends, so as to form a circular hinge which nearly fits the interior of the burner, and while the whole plate is quite moveable, (there being no pin to the hinge) keeps the lower part of it in contact with the front edge of the trough. In the middle of the front of the brass plate is provided a socket, into which fits transversely a small piece of clock spring, bent into the form of a curve extending outwards, so that when the plate, or "wick-holder" as it may be called, is fitted into the burner, this spring keeps its upper edge pressing against the inner edge of the burner. This tends to steady the wick, which is merely a slip of the common cotton manufactured for that purpose, wove in lengths of 50 or 100 feet by 3 inches broad, from which wicks of an inch long are cut, and merely secured in the burner by the pressure of the spring plate just described. A fresh wick is used daily, and the renewal takes place when the wick holder is removed for the purpose of cleaning the lamp, which is effected with ease, in consequence of the removal of the wick holder, and the simplicity of the parts. To guard against any accident oc-

curing to the spring, it is made moveable in the socket which joins it to the wick holder. Should it therefore be broken, or get out of order, it may be withdrawn, and a spare one substituted.

In these lamps the oil is regulated so as to stand at the level of the outer edge of the burner, and when thus trimmed, and the wick smoothly cut, and evenly adjusted, they will burn with a clear steady flame for 5 or 6 hours without being touched. This is without the assistance of any chimney. The breadth of the flame is 3 inches, and the height about $1\frac{1}{2}$ inch, and I have ascertained by experiment, that the illuminating power is equal in average effect to that of the Argand lamp used in the British light houses. The consumption of oil is rather less, being about $1\frac{1}{2}$ pints of cocoanut oil in 12 hours.

In speaking of the comparative illuminating powers of the Argand, and the above flat wick lamp as being equal, I ought not to omit the distinction which exists between their intensities. The Argand lamp (such as is used by the Trinity Corporation) has a flame of 1 inch diameter and $1\frac{1}{2}$ height; that is, showing a surface of $1\frac{1}{2}$ square inches in any horizontal direction. The flat burner lamp exhibits a flame of 3 inches by $1\frac{1}{2}$ height, or $3\frac{1}{2}$ square inches; but it must be observed that in the former every part of its surface exhibits the light of a double sheet of flame, which being shaped like a hollow cylinder is doubled in every aspect; every square inch of the visible flame of an Argand lamp is therefore equal in illuminating power to two of the simple flat burner I have just described, or in other words, its intensity is two fold greater; in addition to which there is a superiority in the combustion, when aided by the current of air induced by the chimney, which further assists in making up for the difference of surface.*

The flat burner lamp may indeed be considered as simply the circular flame of the Argand spread out, the length of its wick being very nearly the same as that of the circumference of the latter, and consequently the consumption of oil and illuminating effect is very nearly the same also. What little difference there is, arises from the combustion not being quite so rapid or intense in the flat as in the circular flame, for want of the chimney; but a saving in expenditure arises from there being no loss from the evaporation of unconsumed oil, which latter circumstance, added to a small difference in size, in favor of the flat burner, compensates for its deficiency in regard to the first point mentioned.

It thus appears, that the intensity of the lamp here spoken of, is only one half of that of the Argand lamp generally used on the coasts of Great Britain; and this regulates the intensity of the whole light, since the vividness of the superficial area of the mirror filled by the

rays, as seen from any position, could not exceed that of the original radiant, even were the reflection perfect.

In this climate, the want of intensity, when the illuminating power is the same, is of less consequence than in England, where a light is so frequently required to pierce the dense fogs which hang round their coasts; were it desirable, however, there would be no difficulty in doubling it, by using two flat burners, one behind the other; but it is doubtful whether, even with this addition, the combustion would be so perfect as to produce the brilliant white flame seen in the well trimmed Argand lamp, to effect which a glass chimney would be necessary. But though the intensity of the light is only one half, it must not be forgotten that the illuminating power is equal to the standard above taken, owing to the difference of size of the two flames, as above explained; and in the same way it may be demonstrated, that though the intensity of the reflected light bears the same ratio, yet that the illuminating efficiency of a series of mirrors of the construction I have described, is not only equal to that of an equal number of the old form, but, from a circumstance I shall now explain, much superior.

This circumstance is, that from the nature and shape of the flame, and the properties of the new reflector, none of the light is wasted; the reflection tending to propel the rays in a thin sheet, whose effects, could they be exhibited by a screen opposed to them on the horizon, would be to form a circular zone, or band of light encircling the mirrors, which is obviously the most useful possible disposition of the rays; while the common parabola, whose theoretical tendency is to propel them along its axis, practically disperses them to the form of a cone or pyramid, expanding in all directions, whose section would be similar to that of the focal light, which would be a rectangle of greater height than breadth. With the instruments now universally adopted in England, the form and dimensions of this pyramid are such, that the outside rays are projected in a direction which at the distance of 20 miles raises them upwards of 5 miles above the horizon, the intermediate rays falling at proportionate distances. From this cause, as may be conceived, much of the useful effect is lost.

A single reflector of the kind I have described when used in the back of a small lantern, suffices to answer the purpose of a beacon which is seen equally in all directions through half the horizon, to the distance of 15 or 20 miles in this climate, according to its elevation. The visible appearance to a spectator in any direction is that of a bar of light similar in shape to the front face of the reflector, only narrower; its breadth being somewhat more than the breadth of the flame, as seen from the same point, and its height the whole height of the reflector.† When two or three are combined, they

* Were the heights of the two flames equal, and the intensities of the single sheets of flame also of the same value, then the superiority of the circular over the flat wick burner would have the ratio of the circumference of a circle to its diameter, or be as 3.14 to 1—which ratio would exhibit their relative average intensities; but the difference of height and other practical circumstances reduce this ratio to the one before stated, which corresponds more nearly with experimental results.

† If the distance be small, this is distinctly seen; but farther off the appearance is that of a ball of fire, like the common reflector; in this case a strong magnifying power would exhibit the real figure of the light.

ought to be ranged parallel to one another, if intended for a light house on a coast; and circularly if meant to give light to an entire circumference of the horizon, as when placed on an island. When the reflector is of the size of 2 feet height by one in breadth, its power, as obtained by experiment, is equivalent to a multiplication of the effect of the lamp in its focus by 10 or 12,—when of 3 feet by 1½, it is, (as I calculate) increased to 15 or 16. That is, a lamp to which either of these reflectors is applied, is equal in illuminating power to 10 or 15 similar lamps unaided by reflection. Theoretically, the superficies of the illuminated part of the reflector may be calculated to be $\frac{3}{8}$ ds. of the area expressed by the breadth of the flame, multiplied by the height of the reflector, which would, with the small reflector, give $\frac{3}{8}$ ds. of 3×24 , or 48 square inches, as compared with the area of the flame (or $3\frac{1}{2}$ inches); and a comparison of these relative superficies gives 12.8 as the ratio of augmentation; but this, leaving no allowance for the practical loss of light in reflection, is rather confirmatory of the first than of the second of the experimental results above quoted, and that, as being the lowest, may be safely depended on.

In a number of these reflectors combined, the effects of all are added together, and this with the admirable advantage, that any trifling inequalities in the distribution by one mirror are corrected and equalised by all the rest. This is a point of great superiority in comparison with the British system of reflection, which, as will presently be shown, fails to produce a nearer approach to equality in its effects in various aspects, than such as is expressed by the ratio of 1 to 8, while this system can be demonstrated to produce a larger effect with the same number of mirrors, and the same expenditure, in conjunction with the long desired property of an absolute equality in distribution.

I have just had occasion to state, that a great irregularity exists in the distribution of light by the old reflectors, the illumination being very much weaker as seen in the direction of a line passing through the junction of two reflectors, than from the point immediately opposite to any one of them; and the inequalities in the value of the illuminating power are so great, that it is in some points less than *one eighth* of what it is in others. This inequality is due to a cause capable of easy explanation, though it would lead me too far at present to enter upon it; I may however say, that the principles are such that they may be reduced to calculation, which calculations are verified by experiment.

In order to establish a comparison as to the absolute powers of the two systems, let us compare the effects of 12 of the Trinity house reflectors, which is the number requisite to fill half the horizon, with 12 of the “periscopic kind” if I may so term them. The former are circular, and 21 inches over the lips, the latter of 18 inches in breadth by 3 feet in height.

The *maximum* effect of each of the common reflectors is represented by the area of its end, or 346 square inches, which is the area of the circle of flame which it will exhibit in the most *favorable* position; and this has to be multiplied by 2, making it equal to 692, to account

for the relative intensity of its light, as compared with the “periscopic” reflector.

The above is a calculation of the most favorable appearance of a series of 12 reflectors in any aspect; because only one can be seen at once, and the numerical measure above stated is that applicable to the most favourable view of it.

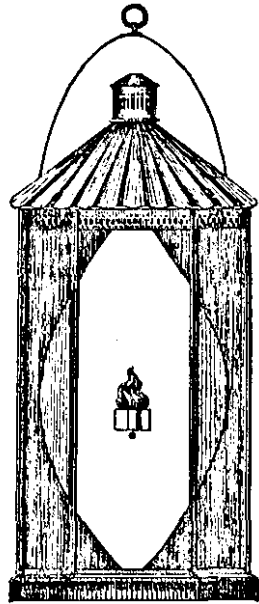
On the other hand a series of twelve 3ft. “periscopic” reflectors, exhibits in one view 12 bars of light, each of which measures $\frac{3}{8}$ ds. of 36×3 , or an area of 72 square inches, making altogether 864 inches, whose intensity is represented by unity. The relative illuminating powers therefore of the two systems are, of the common reflectors 692, and of the new ones 864; but the above is a representation of the *maximum* effect of the common parabola, and it has been found that the *minimum* is less than one eighth of this. The average effect is therefore only $\frac{4}{7}$ ths of the above, or to be expressed by $\frac{4}{7} \times 692$ or 389, whilst the average effect of the periscopic light is still represented by 864, the illuminating power being the same in all directions. With mirrors therefore of 3ft by $\frac{1}{2}$ ft an improvement is effected in the available power expressed by the ratio of 864 to 389, besides the independent advantages resulting from equality in distribution.

But the superiority of this principle will be still more plainly exhibited when it is carried into effect by means of dioptric instruments, because in respect to them a comparison can be made accompanied by the use of the same radiant in both; and the adoption of the hemispherical reflector with them economises a large number of rays which would otherwise be lost.—To test the system fairly it would be proper to construct instruments suited to it, but I have little doubt of the result of a trial of 24 common parabolic reflectors against 24 of Mr. Fresnel's semi-catadioptric lights of the 4th order, each supplied with argand lamps, and the latter backed by hemispherical reflectors, as proposed—(Note p. 144). The result of this experiment would, I have little doubt show, that the effect of the latter while absolutely constant, or uniform in all directions, would be superior to the *maximum* effect of the former; which would be found to range through all the gradations of illuminating power, varying from the nearest condition of equality with the dioptric lights of which it might be capable, down to the very low measure of reduction ($\frac{1}{8}$ th) before stated.

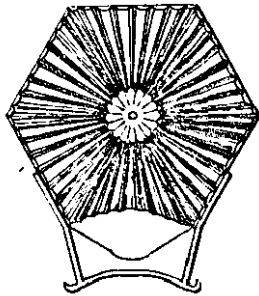
Now it is the uniformity of effect in all directions, which is by far the most valuable attribute, coupled with sufficient illuminating power, which can be possessed by any fixed light; and the high character which the French dioptric lights deservedly bear in this respect has, spite of disadvantages, forced them upon the notice and approval of the scientific authorities previously enlisted in support of the old system, and cleared the way for their introduction and general use. The grand objection however, which was long urged against the French system, and is still the most formidable argument against it, was derived from the obvious hazard and constant uncertainty accompanying any system which is entirely dependent upon any single instrument, more especially

*DRAWINGS of a FLAG STAFF LIGHT
Constructed for the Port of
COCHIN.*

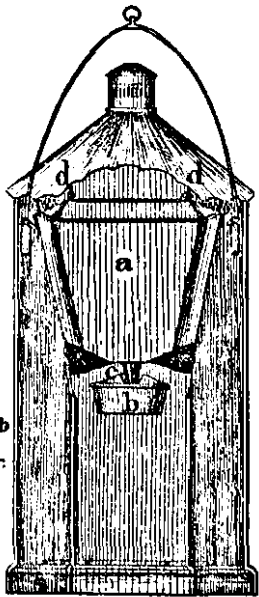
Front view



*Birds eye
view of top.*



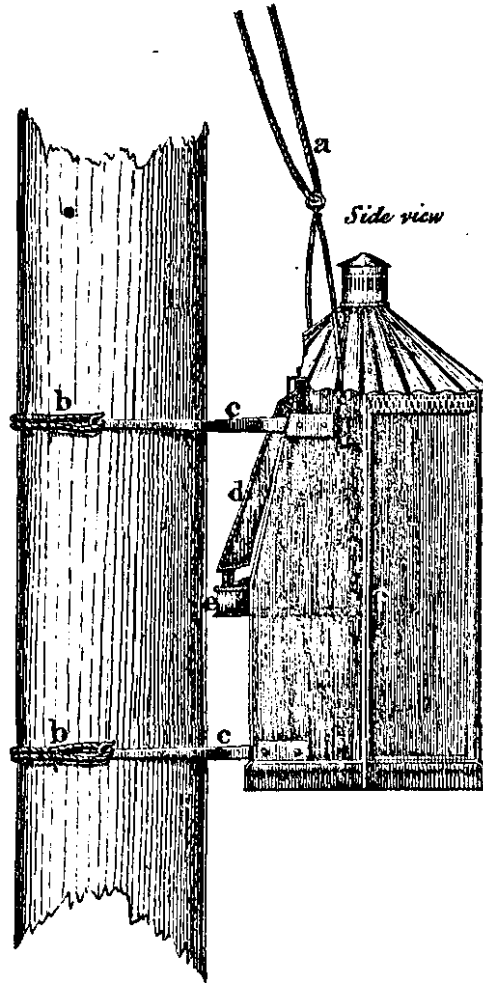
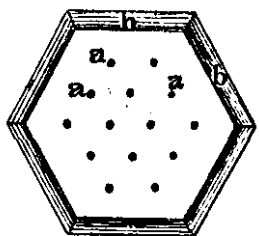
Back view.



- a Oil reservoir.
- b Cistern for do.
- c a cover to protect the Cistern
- d pins for supporting the reservoir.

*Plan of
the bottom.*

- a. a. a. air holes.
- b. b. passage for the air to
a side grating.



- a. Haulyards for hoisting and supporting the lantern.
- b lashings for do.
- c Arms for securing it in an upright position.
- d Oil reservoir.
- e Cistern.
- f the burner.



In the above suggestion of a trial of 24 of Mr. Fresnel's catadioptric lights of the 4th order against 24 reflectors of the common kind, that number has been proposed, in consequence of twenty-four reflectors being necessary to fill an entire circumference with light; as the best method of making a practical trial, both as to the comparative powers of the two lights in various aspects, and also as to the nature of the distribution by each, would be to mount each side by side on a frame capable of rotation, and then to view them both together whilst revolving. I am not aware whether the experimental establishment at Purfleet belonging to the Honourable Trinity Corporation, afford the means of making the trial in this manner, but if not, the interest which would attach to the subject, as well as the valuable consequences which promise to flow from it, would amply justify some expence to be incurred for the purpose.

In the construction of new dioptric instruments for the purpose of applying them in combination, it will be observed that the "useful effect", that is, the power as compared with the expence, is increased in proportion to the size of the instruments made use of—the only limits are the evil consequences arising from the too great diminution of the vertical divergence, and the necessity for adapting the dimensions in reference to the number employed and the size of the lantern in which they are to be placed. From what I know of the space afforded in some of the first class light-houses on the coasts of England, I should be of opinion that instruments of 3 to 5 feet in height by 15 to 28 inches diameter might be advantageously adopted; and of these a much smaller number would suffice to produce the same effects as are now derived from a large number of reflectors, both being lighted by the same lamps.

In this country it appears to me that a much smaller illuminating power answers every purpose, and I do not think that it will be found necessary in any situation, where the climate is such as it is on the Coromandel coast, to employ a larger number than six three feet reflectors, for a semicircumference of the horizon. The Madras light, which for the last fifty or more years consisted of twelve large lamps aided by 9 plain reflectors, has been recently improved by the substitution of 4 lamps and small sized reflectors (of 2 feet by 1 foot) and the effect is found to be at least four-fold superior to what it had ever been previously*, although when carefully managed, and attentively watched, upon the old system, it had been occasionally praised as a good light. A series of nine large reflectors, for a complete circle of the horizon, has been very recently constructed for an insular light off the port of Coringa, and I have no doubt will be found to be abundantly sufficient in power—no accounts have yet reached me of its erection and performance.

In fitting up a set of instruments for a complete circle of the horizon, it is preferable to use an even, to an

uneven number, as in the case last alluded to; because in a circular series of an even number of terms, each reflector is backed by a fellow in precise opposition to it, and these two, considered together, exactly fill up the whole circumference of the horizon between them, and create an uniform distribution of the light throughout it. Each pair does the same also, with the advantage, that the diameter joining the spaces filled by the two opposite reflectors falls in a different direction in the second pair from that of the first, and that of a third and fourth are also different; the effects of all the different pairs of reflectors thus, as it were, "breaking joint" with one another,—an arrangement which contributes to the utmost perfection in the distribution of the light. Each pair, also, taken separately, is complete in its effects, so that a modified application of the system may be made by reducing the number used, by pairs, which could not be done when the reflectors are not exactly opposed to one another, because the circumference being not quite filled by any two in such a disposition, a third is necessary to complete the distribution. Thus, if a partial employment of a circular series of 12 were desired, the efficiency would be quite complete if either 12-10-8-6-4 or 2 were used; but if only 11 composed the series, then either 11-8-5 or 3 must be employed. The one would allow of 6, the other of only 4 variations in power, and the distribution would also be more perfect in the former case.

In plate No. 7 is given a representation of the first trial which was made towards the construction of a flag-staff light. The arrangements for the lantern have since been very much improved, and the lashings which are there represented as necessary to secure the lantern to the mast have been dispensed with by a simple and self acting contrivance.

A double light of this kind, with small sized reflectors, has also been constructed for the port of Masulipatam, and this, with a view to increase the effect, has its two reflectors furnished with lamps, whose burners are of greater breadth, and consequently increased power. The same purpose might have been answered in a greater degree had the lamps been doubled, but this was not thought to be required, and was therefore avoided, with a view to save unnecessary complication.

In the construction of the reflectors the material which has been generally used has been, for those of the larger size a white kind of brass, containing a larger proportion of zinc than usual, and for the smaller, plated metal. All that have been as yet made use of have been supplied by Messrs. Gordon and Co., from templates prepared by myself, and I have found the figure which was given to them very correct, and the surface, more especially of the brass ones tolerably perfect. Plated metal reflectors are kept in condition by the use of a soft polishing powder, consisting of prepared chalk, brick dust, or any such substance, reduced to an impalpable power, and applied by means of chamois leather. The best and simplest mode

* The light is, upon the whole, more than five times superior to what it was, but this is in part due to other improvements—in the ventilation, the glazing, &c.

hitherto tried for giving a lustre to the brass reflectors is a native process, which consists, in fact, of the application of fine corundum powder. Each light-house is furnished with one large, and two or three smaller pieces of the corundum stone, and in order to apply them to use, the larger is placed on the floor, and a few drops of oil being poured on it, a smaller one is applied to it, and gently ground upon it for a few seconds, after which the oil assumes the appearance of a white cream; this is applied to the surface of the reflector, and rubbed over it with a piece of common serge: after the requisite effect has been produced, which is judged of by occasional examination, and by the change of colour which takes place in the oil, (turning black), it is removed, and the surface wiped as clean as possible with a cotton cloth, and afterwards finally polished with powdered ashes of cow dung, shaken on through a muslin bag, and chamois leather.

With these simple means the apparatus is easily kept in condition, even by natives—and the brass reflectors are perhaps better suited to their use than plated ones would be, if they are necessarily entrusted to their sole management. I have not had an opportunity of yet trying the comparative efficiency of the two metals, but I am of opinion, from what I have seen of both, that practically, there is not so much difference as might be anticipated. It is true, that under the best management, a higher lustre and a better reflection might be produced from the silver than brass; but under native management I think it is probable, that in practice, they would either employ the former with a very imperfect surface, or make so much use of the polish as very speedily to remove the plating altogether. It is a great advantage in the use of a solid metal, that the continued use of the rubber rather improves than injures them, and in all arrangements in which a provision is necessa-

ry to be made for the continued service of natives, we can not take too much pains to secure the fulfilment of our intended objects, by leaving as little to their judgment or care, as possible.

Before concluding this paper, I may refer to a caution which is important, both in regard to this, as to every species of light; but which is apt to be neglected, in consequence of its connection with the efficiency of the light not being apparent. I allude to the indispensable necessity of a careful provision for the free circulation of air through the building, without which precaution the lamps are apt to burn badly and smoke, and this is generally attributed to their faulty construction, the quality of the oil, &c. The usual plan for effecting the circulation, is to provide a turn cap and cow! for the roof, and to form apertures in the floor; but in the latter, one meets with two difficulties, first, if the apertures are too large, the air in the interior of the room is liable to be affected by gusts of wind, and secondly, during the monsoon apertures of any kind afford entrance to myriads of insects, which clog the oil and would entirely suffocate the lamps. I have hitherto found these difficulties completely obviated by perforating the floor of the building by a very great number of small holes, of about an inch diameter, in each of which a small tin tube of 3 or 4 inches length, bent in the middle at right angles, was affixed from below. These prevent the glare of light from being seen at a distance, and the apertures therefore do not attract the insects, and they have been hitherto found quite effectual in excluding them; had any further inconvenience been still felt, I had intended to have protected the mouth of each tube by a cover of wire gauze, but this has been found unnecessary at present. The number applied to the floor of a lantern of 6 feet diameter is about 3 or 4 dozen—but I am not sure that even more might not be applied with advantage.

DESCRIPTION OF A NEW HYDRO-PNEUMATIC LAMP

BY CAPTAIN J. T. SMITH.

1. The following is an account of a new species of lamp made up under my superintendence, of which I am induced to offer a description, both because it is in itself curious, and because the various arrangements combined by it form an useful exhibition of the hydrostatic principles upon which these instruments are dependent for success.

2. My object in setting about this undertaking, was the desire of constructing a lamp which should fulfil those conditions in which its light is required to radiate equally in all directions, throughout an *entire* circumference of the horizon; and I had more particularly in view its application as the means of generating light for the beautiful catadioptric Light house apparatus invented by M. Fresnel, or for a catoptric substitute for it which I had devised, which I was of opinion would be useful in many situations in India. These conditions require, that the burner of the lamp should be supplied with oil from a source *below* its own level; since, were it otherwise arranged, there would necessarily be either a reservoir on the same level with the burner, which would itself intercept the rays tending towards the horizon, in some or other meridian; or, were the reservoir of supply placed above, there must be a pipe passing down from it, and feeding the burner from below, which pipe would in the same way form an obstacle to the passage of the light in some direction.

3. M. Fresnel's catadioptric apparatus to which I allude, consists of a spheroid made up by the superposition of a number of circular zones, each of which has the property of refracting the rays of light which impinge upon it from the focus in the centre, so as to bring them to parallelism as regards their vertical divergence, but which, by reason of their circular figure and because their exterior and interior surfaces are parallel, or rather concentric, do not in any way act upon the rays as regards their divergence in the horizontal plane; from which properties the result ensues, that the whole of the luminous beams are flattened into a circular *sheet* of light, instead of the cylindrical or conical beam produced by the common reflecting paraboloid; and, if there be no interruption to the passage of the rays, the illumination produced is of exactly equal intensity in every direction, a property of the greatest value in Light house illumination.

4. The supply of the burner of a lamp by means of a reservoir placed altogether above its level, and communicating with it by a pipe, as above described, is un-

doubtedly a practicable plan, nor is the obstruction occasioned by the pipe a very serious objection, when it is adopted in the interior of a large Light house; as it may be conducted down one of the staunchions supporting the roof, and thus occasion no additional interruption to the passage of the rays: but in a smaller lantern this is obviously impracticable, both from the want of space for a reservoir within the roof, the want of size in the staunchions for the protection of a pipe of proper capacity, and the difficulty of guarding against the effects of the heat, should the reservoir be brought too near the influence of the current of hot air proceeding from the burner. Besides which, whatever be the space at command, there is a great practical evil in the want of compactness in the apparatus, owing to the parts being detached from one another, instead of the whole instrument being, (if one may use the expression) "self-contained" whence its erection and adjustment must in many cases be entrusted to others, and may chance to fail, spite of the utmost care and attention in the maker.

5. These reasons have long since led, in the French Light houses, which are now all lighted by radiation from a single focal lamp, to the use of a pump for feeding the burner from a reservoir below. This pump is moved by clock work upon precisely the same principle as Carcell's lamp; and it is the complexity and liability to derangement of this part of the apparatus which has long proved the greatest obstacle to the general introduction of M. Fresnel's very elegant and effective system of illumination.

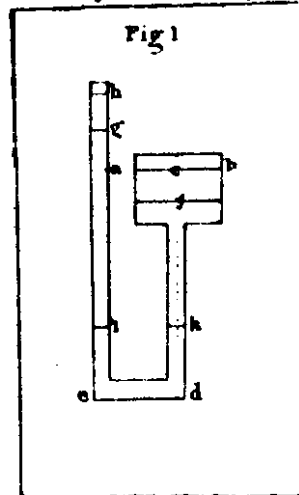
6. Other means have also been devised for accomplishing this object, and numberless patents have at various times been taken out, both in France and England, for self-supplying lamps of different kinds, and upon various principles; but, with the exception perhaps of Mr. Parker's Argyle lamp, all have been found inefficient, and useless in practice, and have been long since quite forgotten. One may indeed occasionally meet with a strange invention of this kind, but they are very rare, and but little known even by makers in London; being absolute mysteries to all others except those to whom they belong. Of the best of these contrivances which I have met with I shall here mention a few, by way of pointing out their defects, and thus exhibiting the difficulties to be overcome in their construction; and I shall then proceed to show in what manner these difficulties are met and overcome by the apparatus I have to describe.

7. Mr. Parker's Argyle lamp which I have just mentioned as one of the most successful speculations in this way, is constructed, I have no doubt, upon the same principle as the one I shall have to describe; but the necessity for closely packing all the parts together, and of reducing the dimensions to such a size as to suit it to table purposes, have given it a complexity which renders it difficult to understand, and manage properly; whence very few indeed of those sold by him have ever had a fair trial, and having often perhaps failed through the stupidity and want of attention of ignorant servants, have ruined the character of his invention. There is besides an important deficiency in them, which is essential to complete success, owing to their being provided with no means for adjusting themselves to temperature, so that a lamp removed suddenly from a cold room near a hot fire is liable to overflow and be put out. In addition to which, it is a practical inconvenience, that a great part of the oil put into it can never be removed, except by taking it to pieces and unsoldering a plate of metal covering an aperture left for that purpose.

8. Mr. Marcell's lamp in which the oil is expelled from a reservoir up the tube for supplying the burner by means of air condensed by a syringe, is liable to the above defect, of want of adaptation to different temperatures, just referred to in regard to Mr. Parker's; and the expansion which occasions overflow being that of condensed air, the effect of heat is so sudden, that the oil sometimes rushes out in a jet inundating the table, and perhaps discharging its contents upon persons in its neighbourhood.

9. Another kind of lamp is that, in which an outer column of a heavier fluid balances an inner one of oil, which according to the difference of their specific gravities is of greater height, and thus stands some distance above the level of the reservoir. The French make use of an hydrostatic lamp of this description, in which a solution of sulphate of zinc is used as a balance; and many other fluids have been tried, all subject to the same defects. These are, first, that since it is absolutely essential to the well burning of a lamp that the oil be continually maintained at the precise level in the burner (called the "flow") to which it has been adjusted by the maker, any change in the specific gravity of the oil used, introduces a corresponding change in the "flow" which if not met by a corresponding adjustment would completely ruin the effect. Secondly, that the balance, even if it should be correct at first, does not continue completely to answer the intended purpose of raising the oil to the required level, since, as the quantity of the latter diminishes and gives place to the balancing liquid, the height of that liquid as a column is necessarily lowered, and with it the height of the oil it counterbalances; thus after burning a short time the lamp becomes dim, and in a few hours would go out, were not the evil in some measure extenuated, by forming the upper part of the balancing column of very large area, so as to enable it to supply a considerable quantity with-

out a very serious depression. This will be more easily

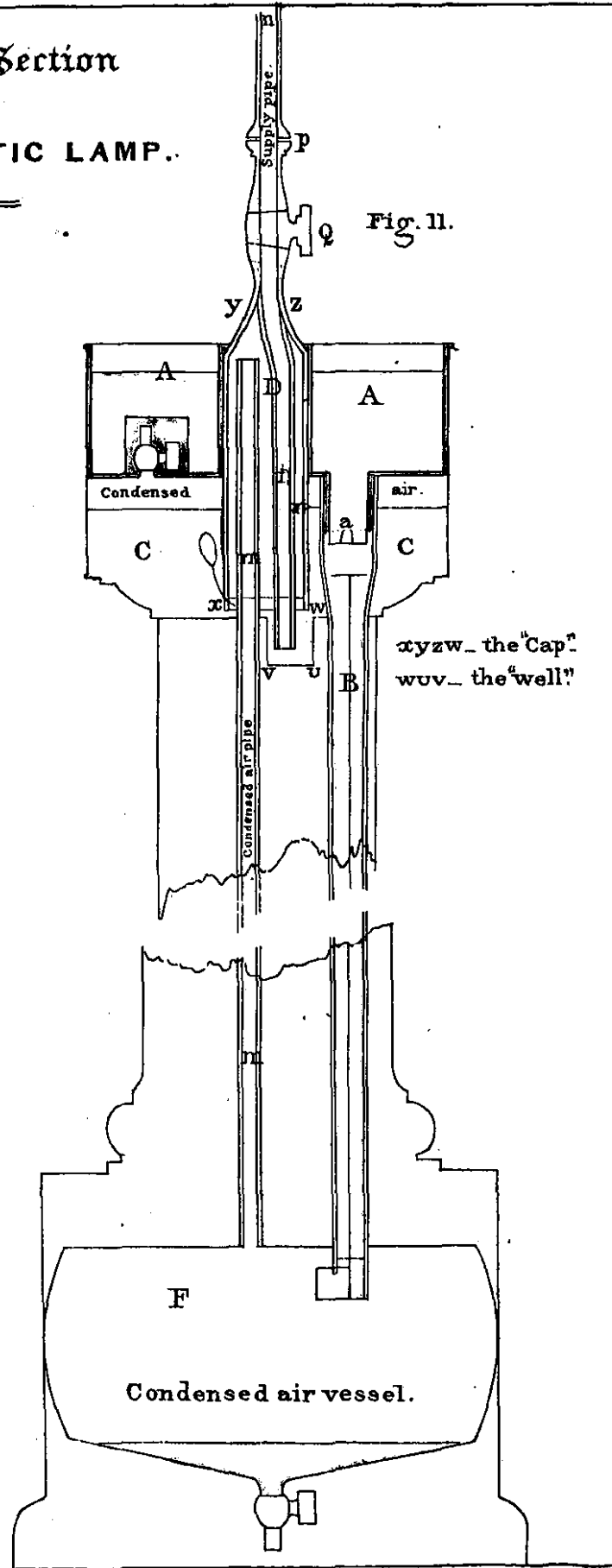
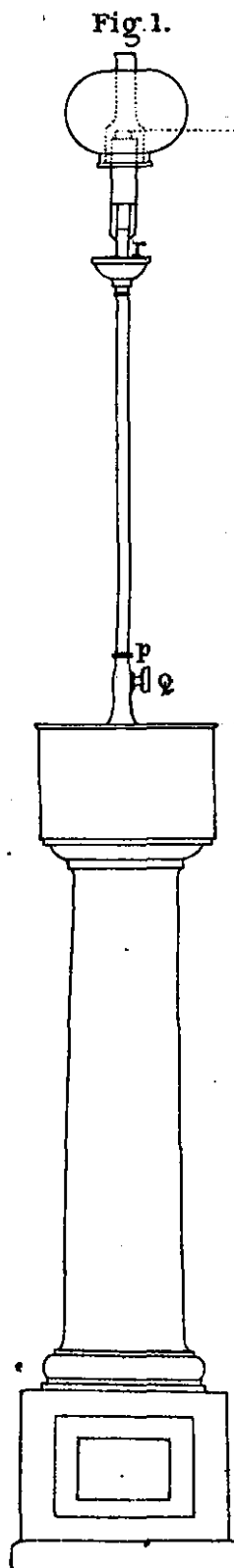


understood by reference to the annexed figure, where $a b$ represents the surface of the column of any heavy fluid, whose altitude is measured by the height $c d$. This at first balances a taller column $h e$ of oil, the the point h being that at which the consumption ought to take place. After a quantity of the oil however has been removed at h , it is evident, that as its place must have been supplied from below, with oil forced up by the pressure of the column $c d$, its abstraction must have been followed by a lowering of the surface $a b$ to some other level, such as f . But the column $f d$ is no longer a balance for $h e$, and will only support a shorter column, such as $g e$. Again, there is another cause for a gradual falling off in the effect, arising from the shortening of the potential altitude of the column $c d$, as part of its fluid rises in the pipe $h e$; for the total heights of the two columns being in the constant inverse ratio of the specific gravities of the two fluids, the excess of the lighter one, or the space $h a$, bears a constant ratio to the length of the column $c d$, as long as the whole of that column operates as a balance; but when a part of its effect is neutralised by the counterbalance occasioned by the ascent of a portion of it in the opposite leg, say for instance to the point i , the differential space $h a$ will be diminished, till it be in the same proportion to the remaining, or potential part $f k$ of the column $f d$, as it before bore to its entire length.

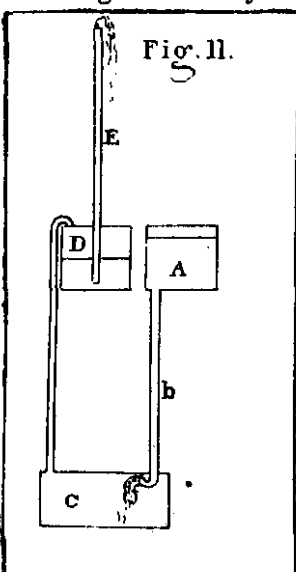
10. The necessity for the constant maintenance of the flow of the oil at the exact point suited to the burning of the lamp has been the grand impediment in all the hydrostatic contrivances of this kind which I have seen, no method having been discovered of freeing them from the defects just referred to, so that the lamps supplied by them necessarily lose their efficiency for want of a full supply, after burning for a short time. In regard to those lamps also in which the oil is forced up the tube of supply by the pressure of confined air, or by any other means, there is the same difficulty, owing to the gradual depression of surface of the oil to be raised, and the consequent continual variation of the potential altitude and pressure of the column to be overcome. This was one of the first obstacles which opposed itself to the construction of the lamp now to be described, and the mode by which it was overcome will be best explained in a detailed description of the whole contrivance.

11. The principle of the lamp is the well known one of the Hungarian machine, or of Hiero's fountain, and as this has already been pointed out by scientific authors as applicable to the purpose for which so many

Elevation and Section of a new HYDRO-PNEUMATIC LAMP.



other schemes have been tried in vain, it is the more surprising that it should never hitherto have been rendered practically available. In its simplest form the following is the theory of its action, *A* (fig. 2) is a cistern



open at the top and communicating by the pipe *b* with a close vessel *C*, which latter is air tight. There is a communication also from *C* to another vessel *D*, also air tight, but containing the fluid to be raised up the tube *E*, which is inserted at the top of it, and dips into the fluid very near to its bottom. The bottom of the tube *b* being recurved, and of very small diameter, permits the water from the reservoir *A* to flow into *C* without suffering the air to escape. A condensation therefore takes place in *C*, and also at the same time in *D*, by communication, and this condensed air pressing on the

surface of the fluid in *D* causes it to rise up the tube *E* till the pressure of the raised column *E* is equal to the pressure of the descending column *b*. In constructing a fountain upon this plan, a jet is substituted for the pipe *DE*, and the issue of water is prevented until previous condensation has taken place to the full extent. It is evident that the jet will merely continue to play as long as the water in the cistern *A* lasts, or until either the vessel *C* has become full, or that at *D* empty; and as it gradually reaches this termination, it is not of any great consequence whether the perpendicular rise of the stream be somewhat diminished or not; but in adapting the principle for the supply of oil to an argand lamp, it is of so much consequence that, as the consumption takes place, the "flow" should be invariably maintained at the exact level suited to it, that the $\frac{1}{16}$ part of an inch either in excess or defect would make a serious difference in regard to its efficiency. Thus specific contrivances become requisite, to obviate the various causes of irregularity before referred to; which necessarily increase the number of parts, and give it an appearance of complexity; and this evil was unfortunately very much further enhanced in the pattern I caused to be made, from my desire to accommodate all the parts to the external figure I had assumed, and also to conceal the internal structure from the scrutiny of those to whom it was to be exhibited.

12. A representation of the lamp is given in plate 8 which contains (Fig. 1.) the elevation, and (Fig. 11.) the section. In the latter,* *A* is a reservoir, upon the principle of the bird cage fountain, having a vent at *a*.

This reservoir fits loosely into the upper half of the head of the pillar, being of a round form, but pierced in the centre by a circular aperture through which passes a large thick pipe shown at *D* (*xyz*), having a stop-cock and joint just above it, by which it is connected with the vertical tube *pr* (Fig. 1.) supplying the lamp, and which latter I shall call the "supply pipe". When the reservoir is to be charged with oil, and the lamp used, the joint is unscrewed, and the reservoir *A*, after being filled, is dropped into its place over the pipe *D* and the stop-cock, and rests securely upon a partition forming the top of another close vessel *C* presently to be described, (into which the pipe *D* also passes.) By means of this reservoir *A* and its vent *a*, a constant supply of oil is kept up in a tube *B*, and this is invariably maintained at the precise level of *a* as long as the oil in the reservoir lasts. The tube *B* descends down the shaft of the column and is soldered into an air tight vessel represented by *F*, with which it communicates by an opening, which will be more particularly described hereafter, but the essential property of which is, that it permits the oil to flow into the vessel *B*, but will not suffer any air to pass out. Therefore, on pouring oil into the tube *B*, it will descend and continue to flow into the vessel *F*, till the air finding no escape becomes so much condensed as to resist the inward pressure of the oil composing the "balance column" *B*, and then no more could enter. Should any part of the air thus compressed be by any means suffered to escape, the consequence would be, that the tension of the remainder being diminished, it would no longer resist the balance column *B*, which would again force its way into *F* until equilibrium were restored. It must be recollected also, that the tension of the compressed air is always exactly equal to the pressure of the "balance column" *B*, and therefore, as long as the altitude of that column is by means of the fountain reservoir and its vent *a* maintained invariable, this tension will be absolutely constant. Now the condensation extends to the top of the air tight vessel *C*, with which a communication is open through the condensed air pipe *m* and the large inverted tube *xyzw*, through which latter a pipe *n* called the "supply pipe" passes, reaching so as nearly to touch the bottom of *C*.

13. Hence the pressure generated in the vessel *F* causes the oil to rise up this pipe *n*, to a height exactly equal to the "balance column," where it is constantly supported at a point so adjusted as to be the proper "flow" of the lamp attached to it. To obviate the difficulty which has been before referred to (in para 10,) arising from the gradual depression of the surface of the oil in *C*, by its continual abstraction to supply the consumption of the lamp, the following contrivance is adopted. The condensed air does not communicate directly with the whole interior surface of the oil, but the pipe conveying it passes up through the bottom of the

* It ought to be especially mentioned, that the two colours, red, and blue, shown in the section, both represent the oil occupying different parts; that mode having been adopted, in order that its passage from one to the other might be more distinctly traced.

vessel *C* into the wide tube *xyzw* before alluded to, which is an inch internal diameter, and is soldered, air tight, into the cover of *C*, descending within $\frac{1}{8}$ of an inch of its bottom, and rising a couple or more inches above it. This tube (*xyzw*) I shall call the "Cap." The condensed air first communicating with the interior of this cap, occupies its whole content, driving out the oil up the supply pipe to make room for it. The whole interior of the cap, therefore, is filled with condensed air, down to the level of a notch or vent at *x*, at which point it can escape into the upper part of the vessel *C*. Hence the surface of the oil underneath the cap, including that which surrounds the bottom of the supply pipe, can never rise higher than the level of the vent *x*, at which level it constantly stands, subject to the invariable pressure of the tension of the air in the vessel *F*. Whenever more oil is required to be forced up the supply pipe to feed the consumption by the lamp, it is not raised by lowering the surface *x*, for this would be impossible; but the instant that a sensible diminution takes place in the gravity of the supply column, the expansion of the condensed air superincumbent upon the oil in the vessel *C*, forces it up the tube from the body of the vessel, to supply the deficiency, while a corresponding expansion of the condensed air in the cap forces a bubble of air by the vent *x*, which restores the condensation; the tension of the air in the cap being restored by a transference from the vessel *F*, whose tension is repaired by the entrance of oil from the balance column *B*. Thus will it be seen, that while the tension or raising force is maintained constant under all circumstances, as explained in para 12, the weight of the column of supply, or force to be overcome, is also at all times precisely the same; since it is always expressed by the height of a column of oil standing at a fixed level above the surface at *x*, which surface is subject to no change, as long as the supply of oil in the reservoir lasts.

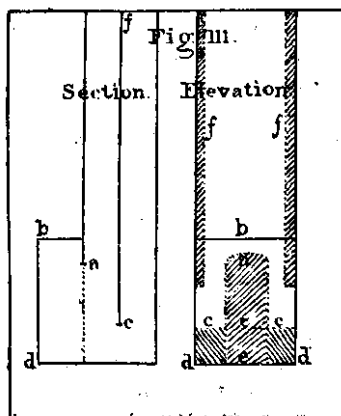
14. In this form the lamp was first made and experimentally tried, and in so far as the above theoretical explanation is concerned, it was found to answer its intended purpose perfectly. In order to make sure that the supply was constantly maintained, and at exactly the same level when the whole quantity was nearly exhausted, as at first, I fitted a brass tube to the connecting screw *p* at the top of the stop-cock, and having first made it somewhat too long, cut it off at the precise spot at which the water (with which the experiments were first made) stood. By now tightening the connecting screw *p* a little, the water stood with a convex elevation in the centre, of a semicircular form; a little bit of flannel being now placed on the top and allowed to hang over on each side, so as to act as a syphon, drained the reservoir completely. The same effect was produced when the water was drawn off by a small syphon, the short leg of which dipped only the $\frac{1}{16}$ part of an inch into the top of the pipe; showing, that the balancing power of the hydro-pneumatic series did not fall off, even at the very last, to such an extent as to shorten the column raised by $\frac{1}{16}$ inch.

15. At the time these experiments were made, however, I was led by them to discover a practical defect, to which I lost no time in applying a remedy. Previous to my observation of the evil occasioned by it, the bottom of the "supply pipe" had been made to terminate on a level with the vent *x*, and thus situated it answered its purpose fully, and drained the oil entirely down to that level; but the moment this was done, the condensed air gaining access to the bottom of it, rushed up the pipe, carrying the water or oil with it, spurting the whole of its contents about, while it gave vent to the whole of the condensed air in *C* and *F*. The remedy for this was very obvious, and was easily effected by prolonging the pipe, so that its lower end was much below the level of the vent *x*, and this was done by forming a little well in the bottom of the vessel *C* (represented by *VUW*), which allows the bottom of the pipe to descend an inch or more below the point where it before terminated. As the tension of the condensed air is invariable, it is plain that after the oil has been expended to the level of *x*, no more can be driven by it up the tube, for the reason before explained, viz: that by the further descent of the surface *x*, the potential altitude of the supply column would be increased, and its weight would thus be caused to exceed the pressure acting upon it. After making this slight alteration, therefore, no fault nor inconvenience from the above cause was met with; but there was still another practical difficulty to be overcome, which was found more formidable, arising from a cause which I have before mentioned as the chief defect in all the lamps yet made, in which condensed air is used; their want of adaptation to changes of temperature, and of which I had hitherto been ignorant.

16. All the experiments above detailed were only such as were of short duration, and when perfect success seemed by them to have been attained, the next step was to fit a burner to the apparatus, and by using oil, to try its effects as a lamp. This was accordingly done, and the whole appeared at first to act perfectly. The various reservoirs being large, the lamp burned with great steadiness until the supply was exhausted, which generally required about twenty-one hours; but after many repetitions, it was found that there was some latent cause of *irregularity* in its effects, since, though always equally charged at the first lighting, the supply sometimes only lasted twelve or fourteen hours, and sometimes even less. The cause of this was discovered by my happening on one occasion to be present during the burning of the lamp, and hearing a bubbling noise in the inside, which lasted for a few seconds and then ceased. Up to this time the pipe *B* had terminated in the interior of the vessel *F* by a recurved jet of the form, shown at *f* (fig. 2.), and on investigating the cause of the accident, I found that the air vessels having become heated, the tension of the contained air had become so much increased, as to overcome the pressure of the "balance column" *B*, which giving away, had released the whole of the imprisoned air, after which a fresh large descent of oil followed, to restore condensation. The most obvious mode of remedying this evil was

evidently similar to that applied to prevent the discharge spoken of (para 13.), but upon considering this I perceived, that such a remedy would entirely vitiate the principle of the contrivance, the grand object of which was to maintain the pressure *invariable* at all times, while the plan referred to would merely provide a check upon the consequences of its increase, by creating an extra resistance to act against it in its more compressed state. What was required was plainly some mode by which, on the occasion of exposure to heat, the vessel *F* might be made to *relieve* itself of its superabundant air, so as to prevent the tension ever rising, and yet not suffer more to escape than was necessary for that purpose; and the mode by which this was finally accomplished is the following.

17. The tube *B* was taken out, and a new one inserted which was of an inch diameter, and divided along its whole length into two semicylindrical spaces by a partition which fitted loosely into its place, and was soldered in at one or two points down the tube, having considerably large interstices between it and the sides in the other parts; thus, in spite of the partition, there was a free communication between the opposite portions of the tube, which was further increased by punching holes of $\frac{1}{16}$ inch diameter, about an inch apart, all the way down the partition. The object of this scheme was to prevent any bubbles of air, in their escape from *F* through the tube *B*, filling the whole of its interior, and thus relieving the air vessel *F* from the weight of oil pressing into it; while there should still be a free communication between the opposite parts, to allow the place of any bubble entering at one side to be immediately filled, as it passed upwards, with oil from the opposite side of the partition. At the foot of this new tube *B* a new arrangement was substituted for the recurved jet before applied; the pipe was closed at the bottom, and a vertical slit or opening cut adjacent



to it on one side, in front of which a trough or cistern was formed by soldering on a piece of tin in advance of it, to which the same plate that closed the tube also formed the bottom. This arrangement is represented in the section and elevation exhibited in the annexed figure (3.) in which *bd* represents the trough, *ae* the vertical slit or opening, and *cf* the partition or diaphragm crossing the tube, which, for the further security of free communication between the two parts, does not reach the plate closing the bottom of the tube, but stops short at *c, c, c*, about half-an-inch from it. The upper edge of the slit or aperture *a* is curved, and the highest point of this curve is exactly $\frac{1}{8}$ inch below the tip *b* of the trough in front of it. When the lamp is

charged, and during its operation, the oil entering by the aperture *a* flows over at *b* into the air vessel; but when any expansion from heat takes place, no sooner has the increased pressure driven the oil to the depth of $\frac{1}{8}$ of an inch below its usual level, than it finds an escape through the aperture *a*, and up one division of the tube *B*. By reason of the partition above described, it is incapable of filling the whole tube, and thus keeping the passage open, so as to escape altogether; and as the oil occupying the trough is never relieved from the weight of any part of the balance column, which is maintained unchanged by the pressure from the *hinder* part of the tube, the level of the oil at *a* is restored, the moment the escape of air has been sufficient to compensate for the increased tension, and every thing proceeds as before. On the application of cold instead of heat, the tension of the compressed air in *F* being merely diminished, no consequence ensues, except the descent of a small quantity more of oil into the vessel, to restore equilibrium, so that thus the instrument is capable of adjusting itself to whatever changes of temperature it may be subjected to.

18. This is the last alteration which has been found necessary to the final completion of the apparatus; and as it has now been subjected to many trials, and long continued experience, which have fully established its efficiency, I may venture to recommend it with confidence wheresoever it may be of use. The total height to which the oil is raised above the level of the reservoir of supply, is about 2 feet 6 inches. This is very much more than would probably be ever required in practice, but I was desirous in the first exhibition of the scheme, to anticipate all possibility of objection as to its capability of meeting the most difficult cases. The same principle, indeed, may be applied indefinitely, and the oil supplied at any height and in any quantity whatever, provided the different parts of the apparatus be made sufficiently capacious and strong.

19. In order to apply a test to its capability of bearing sudden additions of heat, I made many endeavours to cause it, (had it been possible), to release its condensed air, by wrapping long strips of very hot flexible zinc plate round the various parts of the column; but although, previous to the alteration, a discharge of the confined air might have been produced by the mere application of the warmth of the two hands, no effect was occasioned afterwards, beyond the successive release of a few small bubbles; and no kind of irregularity has ever since been observed in its action. It was for two or three months daily lighted at dusk, and burned till near midnight, at Mr. Deville's establishment in London, and whilst there inspected by many who were curious about these subjects. My intention in constructing it was to have exhibited it to the Honorable Trinity Corporation, to whom it was a desideratum, and by whom various unsuccessful projects for the same purpose had already been rejected; but the very great pressure of other business under which I laboured at the time of its completion, occupied my attention so fully whilst in London, that I had no opportunity of carrying this purpose into effect.

MEMORANDUM REGARDING THE CONSTRUCTION OF THE COMBACONUM BRIDGE, BY CAPTAIN C. E. FABER.

It is mortifying to remark how little has been done during half a century to remove the well deserved reproach brought by Mr. Burke against the British in their Eastern government. It still would not be easy to particularise instances of great and useful works, to prove that India has been for more than two generations under the administration of a highly civilized people, desirous of improving the condition of its subjects, and of giving them the benefit of the skill and science it has brought with it.

This defect is no where more visible than in the state of internal communication generally; and even the lines that may be cited as exceptions, in consequence of the large sums expended upon them, will often be found both in completeness and permanence, to fall far below the standard common in European countries. It is not indeed to be denied, that the rainy seasons and floods of India effect more general injury, and do more local damage, than roads are exposed to in a more temperate region; but after this admission, the charge of seldom maintaining what it has been costly to establish, may be made with but little fear, or hope of refutation. That wise economy in government which repairs a small injury before it becomes a great one, and which perpetuates to itself and its subjects the advantages due to the original outlay, has not yet been so conspicuous in India as could be desired.

But whilst these remarks suggest themselves to a very casual observer, there seems greater cause for regret in the number of obstacles still left to obstruct the merchant and the traveller, even on the roads that have received most attention. Small irrigating channels that can be covered by a tunnel or a flat drain, and petty streams that require one or two small arches are often treated as a part of the road, and enter into the general undertaking; whilst large streams and rivers are left untouched, as if the resources of Government, either in point of money or knowledge, were not adequate to overcome difficulties of such magnitude. (Vide note A.)

As it is a common opinion that the improvement of communication, and especially the facilitation of intercourse between communities separated by unfordable rivers, who may be mutually dependent upon each other's manufactures and produce, are amongst the greatest benefits which a Government can confer, it may not be amiss to enter into some examination of the peculiar circumstances of India, contrasted with European countries, in order to ascertain how far our local position and relative capabilities may justify, as it were, or account for, our comparative backwardness in this respect.

It is hardly possible to imagine a greater contrast than that offered by bridge projects for most of the rivers we have to deal with in tropical countries, and

those necessary for streams of a similar size in Great Britain. A slight consideration of the two cases will at once shew, to how great an extent the operations of skill, labour, and expense, naturally, as it were, supposed to be inseparable from bridge building, are curtailed in India; for nearly all those embarrassments and hindrances which uncertainty of weather, or interruption to navigation, and a stream perpetually flowing, throw around the English architect, are not so much as felt in a tropical country; where the bed of the river is dry for six months of the year; where the regularity of the seasons enables all previous arrangements to be fulfilled with exact precision; where no navigation is to be provided for; and where it is neither necessary to have coffer dams for the piers, nor trussed frames of timber for the centres. These are advantages peculiar to the erection of bridges as works of skill and expense, apart from the cheapness which they have in common with all other public constructions in India, in the prices of materials and labour. Hence, an obstacle of equal magnitude may be surmounted in an equally useful way, at a much smaller employment of money and professional skill; because the expedients requiring most cost and most science, (and of which there are no traces when the undertaking is finished), are unnecessary in the one case, and indispensable in the other. The problem, on the one hand, is only, within a given time fixed by the periodical alternation of seasons, to construct a suitable work in any way the projector may choose to adopt; on the other, the routine is one which involves hazard, difficulty, and expense; not so much requisite for the work *per se*, as for the peculiar circumstances under which that work must be constructed; the foundations and a great part of the pier being below the level of the water, provision being usually necessary for navigation, and always so, for the passage of moderate freshes, from liability to which, the British rivers are at no period of the year entirely exempt.

It is only by identifying oneself with the situation of an Engineer in these two cases, that an adequate value can be formed of the advantages of a tropical country for building such bridges as are most needed; and it may perhaps have happened, that the scarcity of such works in India has arisen, in some measure, from their construction having been viewed through a medium more suited to the country we have left, than to the one in which our lot is now cast. Unconsciously, and deterred by difficulties which they overrate, both the parties who have had to design and suggest, and those whose province it is to recommend and authorize, may have shrunk from a general prosecution and support of a class of undertakings, intimately associated in their minds with considerable cost, danger, and difficulties, requiring the

exertion of the most eminent professional acquirements. On looking at a well proportioned bridge, whether in or out of the tropics, the beholder will probably admit involuntarily, the same association of difficulty successfully surmounted, of skill usefully exerted, and of science happily applied; it is possible too, that even professional men may omit to inquire what facilities were met with; what demands on the resources of the architect were made; what expedients he was called upon to suggest; whether the bed, during the hot weather, were left nearly or entirely dry; whether he were able to multiply the props for the support of his centre, as much as he chose; whether the curve were of a nature leaving its central point always accessible; or whether on completion, the bridge were found in its actual details to correspond with the conditions of the design. Thus the contemplation of a finished bridge may often be accompanied by an exaggerated opinion of its executive difficulty; and additionally arduous must such undertakings appear to those that consider how much the country is in their favour, when they call to mind the artificers by whom the work is to be carried into execution, a race deriving, in the present day, all their skill from imitation, who are seldom well educated, and who are now called upon to perform what they have hitherto seen no specimen of, whilst their English instructors are seldom familiar with the language in which the various technicalities have to be conveyed.

But it is in the centre, or temporary mould on which the arches are to be turned, that the maximum of difficulty is usually supposed to lie, and it may easily be imagined with what solicitude the English architect must approach this part of his office, on the success of which the whole of his power to build agreeably to his own design depends. To construct a frame, which whilst it has no excess of materials or workmanship, has rigidity enough to bear without change of shape the enormous load it has to sustain, and so arranged as to admit of being lowered uniformly, in order to relieve it of all insistent weight, by an equal transfer to the two adjacent piers, may indeed be regarded as an occupation requiring more experience and practical knowledge than the desultory and promiscuous occupations of an Engineer in India may have afforded him the opportunity of acquiring, and in some measure Government may be supposed reluctant to give its full confidence to those, whose competence in such particulars has not been shewn by previous success; a few props of brick in mud, however, are sufficient to take away all cause for these apprehensions, and their consequences.

It has been partly the aim of the preceding observations to call attention in a particular manner to a want whose existence few will doubt who have journeyed during the rains, and which the frequent interruption of the communication by post during that season must have made familiar to all; an attempt has also been made to assign some reason for the deficiency, by conjecturing that those alike whose duty it is to propose, and those who have to authorise such measures, are dis-

couraged by an undue opinion of their costliness and difficulty. A few remarks of a general and practical nature will now be offered, in connection with a brief narrative of the construction of a brick bridge over the river Cauvery at Combaconum, which was built during the working seasons of 1832 and 1833.

Of the situation of the ancient town of Combaconum, containing 40,000 inhabitants, on the south bank of the river Cauvery, and of the highly cultivated and populous state of the immediate neighbourhood, as also of the province of Tanjore generally, little need be said; of the benefit also, conferred by building a bridge over a river sometimes 8 feet deep, cutting off all communication with the north western bank, except by means of a ferry boat, no doubt can be entertained. It is sufficient to observe, that it was determined to overcome this obstacle, and that the writer of these notes is enabled to communicate the nature and progress of the measures adopted for carrying this liberal and public spirited decision into effect.

As soon as the scite was fixed, a correct section of the stream was taken, on which the highest known rise of water was marked, and from which all the dimensions of the bridge were obtained. The piers were allowed a height equal to the usual freshes in the river, and the arcuation of the curves was expected to provide for the additional water way necessary during extraordinary freshes.

The project for the bridge was as follows, and no deviation took place, nor was any dimension altered after the commencement of the undertaking.

"The bridge to consist of 5 semi-elliptical arches of different spans, but springing from the same horizontal level—that of the centre to be 45, of the middle 38, and of the side arches to be 34 feet. The versed sines to be respectively 7. 9. 7. 3. and 6. 9.—the thickness at the crowns to be 2. 9. 2. 6. and 2. 3. The piers 8 feet in height, to have a batter of six inches on each side, and to be respectively 7 feet and 6. 6. thick at the springing point. Two feet to be allowed for the blocking course, and 4 feet for the parapet. The road way to be 19 feet in the clear. Foundations to be 8 feet deep. The cutwaters including an angle of 60° at the base or bed of the river, to diminish gradually, losing their saliency entirely at the height of the cornice; but having a projection of 6 inches from the general face of the bridge, as a relief, across the whole breadth of the piers."

A reference to the elevation and longitudinal section (figs. 2 plate 9 and 2 plate 10.) will convey a good idea of the general design; and the transverse section (fig. 1 plate 10.) will shew the curvilinear shape which the piers assumed, by the constantly varying dimensions of saliency, an agreeable peculiarity, for the suggestion of which the writer was indebted to a brother officer (Lieutenant Best.)

The excavations for the foundations were commenced in the middle of February 1832, and a firm stratum of blue clay was found before completing the full depth of 8 feet. There never was much interruption from water,

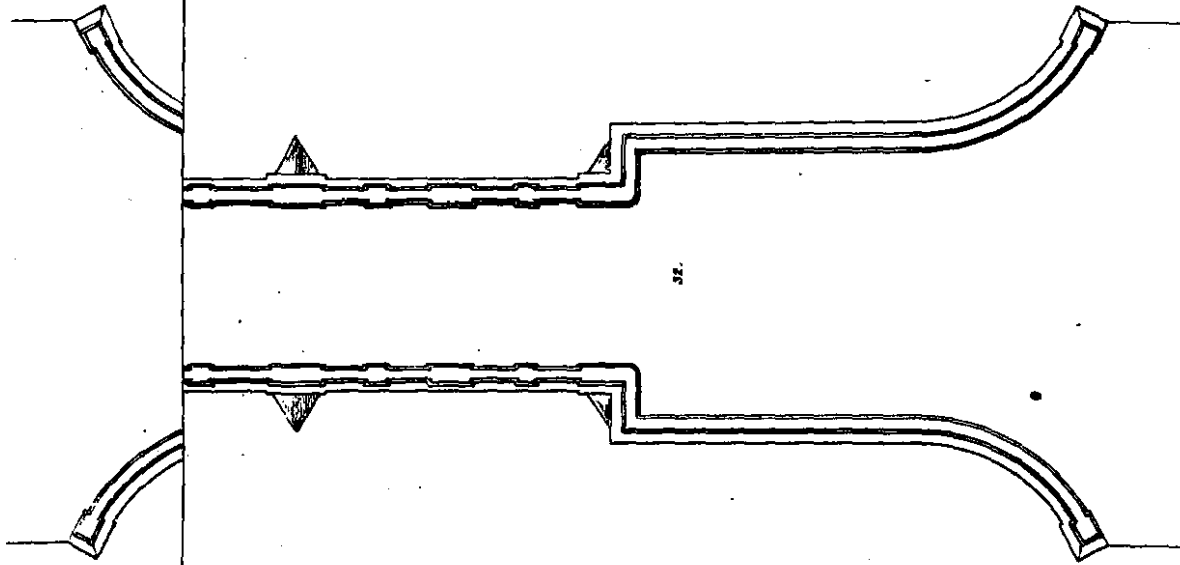
but a set of picottahs was kept at work all day, and during the last few hours of the night. A number of cubical blocks, according to the practice in Tanjore, of good masonry, consisting of 18 or 22 bricks, well built with mortar made of 2 measures of sand, and 1 of lime, had previously been prepared, and two courses of these were laid and carefully levelled, before the bricks were placed as usual in tiers. The mode of building these was by the common bond of headers and stretchers alternately, with a diagonal course in different directions every fourth or sixth range, as the workmen might happen to apply them. The foundations to the piers were completed by the end of April, and in the middle of May, the abutments and wing walls were raised to the height of the spring of the arches, and the latter were filled with-in, and supported without, by a loamy soil well rammed and beaten, carried up to the same level. In this state, matters were left for the freshes of 1832.

The examinations made in January 1833 were so far favorable, that no subsidence could be detected in any part of the work done during the preceding year; and operations were immediately resumed by raising the piers to their full height. During the progress of the whole work, great use was made both of fresh lime water and jaggery water; large vessels of pottery baked on purpose were variously placed for the convenience of the workmen, and each brick was immersed in lime water for one or two minutes before being handed to the masons; a small quantity was poured over the surface of the work in the evening also, and generally the same process was the preliminary to resuming work next morning. The jaggery water appears in favour with the artificers, as a solvent that makes their work quicker and more pleasant, and its use was neither encouraged nor prohibited. There was still a good deal of water in the river, but a bank of sand was sufficient to turn it into the two spaces on the south bank; and the northern piers were carried on without difficulty, by the assistance of balers with scoops made of palmyrah leaves, and this ceased to be necessary after the first three or four courses of bricks were laid. Immediately that the northern pier was completed, the centres were begun.

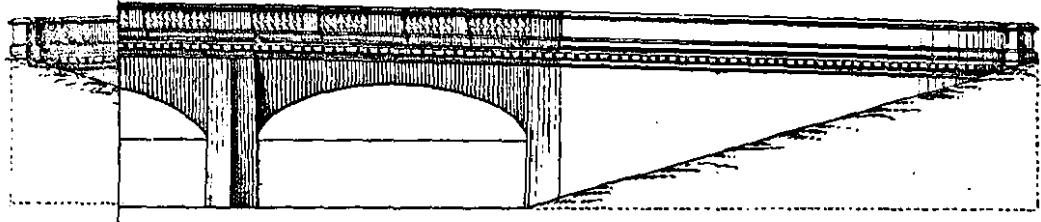
These consisted of two temporary piers built of brick in mud, and of a half pier of the same material, attached to each permanent pier and abutment. The same was built as a support on the other side of the pier. Wall plates of rough palmyrahs were placed on these transversely, and over each a number of logs was laid at intervals of about 5 inches, which intervals being filled with whole bricks laid loosely on the flat, (in order to be easily removed when the centre is to be struck), the whole composed a rough approximation to the outline of the arch. After some further degree of curvature had been given by an additional quantity of bricks in the centre of each of these logs, or chords, a line of split beetul tree was stretched from pier to pier for the transverse axis of the ellipse, and a perpendicular of the required height being set up for the semi-conjugate, a trammel of string, nailed in the foci, was used to obtain

the exact mould for the intrados of the arch. Half bricks and the fragments called "jelly" cemented with clay as stiff as could be worked were used for this purpose; and ultimately a coating of clay was laid over the whole of the stuffing, the flowing lines of the edges indicated by the trammel, being worked into an exact level of the width of the whole arch by stiff teak-wood rods of the required length, water being poured on in small quantities to lubricate the surface, and assist the rods in their office of removing all inequalities. Lastly, coarse, and then very fine sand were sprinkled over the entire surface. It was then left for two days, and on careful examination proved sufficiently correct to commence the arch, but, as might be expected, it was one tissue of cracks from the heat. A drawing of this rude and cheap centre is appended for reference. (Vide fig. 3 plate x.)

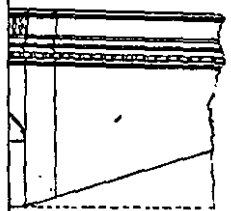
The arch bricks were of the size common at Madras, viz. 10 in. \times 4 in. \times 1 $\frac{1}{4}$ in., and in the northern arch they were at first directed to the centre of the ellipse, instead of being placed perpendicular to the curve. As soon as the arch work was put in hand, the crown of the centre was guarded from change of shape, by being loaded with the bricks collected for the supply of the bricklayers. In the belief that the proportions established during the former season would be still adhered to, no attention was paid to mixing the mortar, and on the 17th January the north arch was completed, over the top of which a space was built in for holding a pool of jaggery water, a common, and often a hurtful practice amongst native maistries. The second arch had been prosecuted simultaneously to the height necessary for counteracting the thrust of the north arch, and this also was completed on Friday the 25th January; but in this case the joints had been directed to the three centres of an arch *surbaissée*, or were made perpendicular to the curve at the points of application. On the 26th January, or 8 days after completion, the centre of the north arch was taken down, and the operation was finished before noon. Immediately that the removal was effected, the extrados of the arch was observed to be covered by cracks spreading in all directions, like the shooting lines made by a stone thrown violently on thick ice, and in a few minutes a space of 10 feet on each side of the crown in the lower tier, fell down bodily, leaving the upper course perfect; and which remained without subsidence until it was taken down 3 days afterwards. On examining the bricks that had fallen, it appeared that the mortar was still quite moist, easily compressed with the fingers, and that no induration had taken place, although the mortar had been applied 9 days. This unexpected result led to the discovery, that the maistry, a man from Madras, thinking the strength of mortar depended on the quantity of lime it contained, had reversed the former proportions, and allotted one of sand to two of chunam. It is possible, that had a greater length of time been allowed, this failure would not have happened, as the upper course from its greater exposure was quite dry and hard; and there is this disadvantage in the clumsy centre already described, that the water used by the



32.



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These consisted of two temporary piers built of brick in mud, and of a half pier of the same material, attached to each permanent pier and abutment. The same was built as a support on the other side of the pier. Wall plates of rough palmyrahs were placed on these transversely, and over each a number of logs was laid at intervals of about 5 inches, which intervals being filled with whole bricks laid loosely on the flat, (in order to be easily removed when the centre is to be struck), the whole composed a rough approximation to the outline of the arch. After some further degree of curvature had been given by an additional quantity of bricks in the centre of each of these logs, or chords, a line of split beetul tree was stretched from pier to pier for the transverse axis of the ellipse, and a perpendicular of the required height being set up for the semi-conjugate, a trammel of string, nailed in the foci, was used to obtain

the exact mould for the intrados of the arch. Half bricks and the fragments called "jelly" cemented with clay as stiff as could be worked were used for this purpose; and ultimately a coating of clay was laid over the whole of the stuffing, the flowing lines of the edges indicated by the trammel, being worked into an exact level of the width of the whole arch by stiff teak-wood rods of the required length, water being poured on in small quantities to lubricate the surface, and assist the rods in their office of removing all inequalities. Lastly, coarse, and then very fine sand were sprinkled over the entire surface. It was then left for two days, and on careful examination proved sufficiently correct to commence the arch, but, as might be expected, it was one tissue of cracks from the heat. A drawing of this rude and cheap centre is appended for reference. (Vide fig. 3 plate x.)

The arch bricks were of the size common at Madras, viz. 10 in. \times 4 in. \times 1 $\frac{1}{4}$ in., and in the northern arch they were at first directed to the centre of the ellipse, instead of being placed perpendicular to the curve. As soon as the arch work was put in hand, the crown of the centre was guarded from change of shape, by being loaded with the bricks collected for the supply of the bricklayers. In the belief that the proportions established during the former season would be still adhered to, no attention was paid to mixing the mortar, and on the 17th January the north arch was completed, over the top of which a space was built in for holding a pool of jaggery water, a common, and often a hurtful practice amongst native maistries. The second arch had been prosecuted simultaneously to the height necessary for counteracting the thrust of the north arch, and this also was completed on Friday the 25th January; but in this case the joints had been directed to the three centres of the *arche surbaissée*, or were made perpendicular to the curve at the points of application. On the 26th January, or 8 days after completion, the centre of the north arch was taken down, and the operation was finished before noon. Immediately that the removal was effected, the extrados of the arch was observed to be covered by cracks spreading in all directions, like the shooting lines made by a stone thrown violently on thick ice, and in a few minutes a space of 10 feet on each side of the crown in the lower tier, fell down bodily, leaving the upper course perfect; and which remained without subsidence until it was taken down 3 days afterwards. On examining the bricks that had fallen, it appeared that the mortar was still quite moist, easily compressed with the fingers, and that no induration had taken place, although the mortar had been applied 9 days. This unexpected result led to the discovery, that the maistry, a man from Madras, thinking the strength of mortar depended on the quantity of lime it contained, had reversed the former proportions, and allotted one of sand to two of chunam. It is possible, that had a greater length of time been allowed, this failure would not have happened, as the upper course from its greater exposure was quite dry and hard; and there is this disadvantage in the clumsy centre already described, that the water used by the

bricklayers in their work moistens the clay of the mould, and this being effectually screened from all heat and atmospheric influence, prevents or retards the crystallization of the mortar left in contact with it.

Operations were now commenced at the south side, and greater care was taken in shaping (vide Note B) and laying the bricks; the quantity of mortar allowed was also much diminished, in hopes of making the shrinking and play of the joints less. On the 8th February, 14 days after completion, the centre of the second north arch was struck; that is, as soon as the injured one was taken down and rebuilt. A considerable portion of the centre arch was also built in the mean while, and a considerable weight applied by building up the haunches to the spring of the Spandril arches; for as the crown of the arch cannot sink without forcing up the springs, this quantity of masonry is evidently a great stay and support. The centre was taken away before noon, and though cracks were seen on the surface of the extrados, for a few minutes after the removal was completed, yet there was no visible compression of the mortar between the bricks laid over the haunches, nor was there any depression of the arch detected during the remainder of the day.

After this, the work went on with great rapidity and success, and on the 16th of February the centre of the middle arch was struck. The same appearance of cracks was again exhibited, and in addition, a sinking of the crown was observed shortly after the arch was unproped, and which in the evening measured 4 inches.

The two south arches were completed and uncentred before the end of the month, care being taken to protect the piers from all danger of uneven thrust, by completing the centring and the arch on the one side, before the centre was struck on the other.

On Friday the 1st of March the arch first put in hand, that on the north side, was uncentred without further mishap, and the superstructure and filling in of earth were carried on with such rapidity during the following day, that on the morning of the 3rd a curricule was driven along the road way, in order to establish some confidence in the new work; the want of such a feeling having been ludicrously exhibited the preceding day by a mohout of one of the Rajah's elephants, who condemned his charge to a sudden lameness the moment a summons was sent for him to be ridden across the bridge.

During the concluding operations of the bridge, and probably for some time afterwards, there continued to be a good deal of unequal subsidence, the amount of which it may be interesting to notice, and which it will be most convenient to exhibit by an elevation taken for the purpose. (Vide fig. 3, plate ix.)

It will be seen from this, that the radius of curvature at the vertex of the centre arch was altered from 65 feet to 69.8 by the change of the versed sine from 7.9 as was intended, to 7.3 which it now is; attended by a loss of strength of 450 lbs on each superficial foot at the vertex; but those who may feel dis-

heartened at this result should bear in mind, that the bridge of Neuilly, built by the celebrated Perronet, sunk altogether 1 foot 11½ inches, that the radius of curvature was changed from 150 feet to 244, that a great part of this alteration of shape occurred whilst the arch was still incomplete, from the yielding of the centre, and finally, that many days were consumed in striking the centre. One remarkable demonstration was effected by this unexpected change, the deduction was undeniable, that it would be perfectly safe to build a semi-circular arch with a span of 488 feet abutting on piers 14 feet thick. (Vide Note D.)

The faultiness and unnecessary difficulty of the Combaconum bridge are very apparent; but with the exception of a small reduction in the height of the cornice, there does not seem to be any unnecessary expenditure of materials. Its appearance on completion in all its details, towards the end of May, was considered pleasing, and with the exception of filling up those cracks to which all brick bridges seem liable for the first three or four years after their construction, owing to the great proportion which the joints bear to the solid, it has not required any repair. The cost was between 10 and 11,000 Rupees.

The tendency of these notes is to shew how simple are the executive operations of bridge building in India, but it cannot be said that there are any reasons to exempt the architect from the preparation of a well considered design. He so far indeed continues to maintain an advantage in this respect, that the anticipations of difficulties in construction may tend, in European countries to the conception of a project which it may be easy to execute; but bearing in mind that the bridge when complete ought to be of an agreeable outline, whether its establishment may have been arduous or otherwise, he should be solicitous to make the final appearance as pleasing as circumstances may admit. Even in this respect, however, the difficulty is very limited, for there is seldom any better material than brick to be obtained, without a greater outlay than the occasion would warrant, and for the most part the streams alluded to in the early part of these remarks, as obstacles we ought to have surmounted long ago, are too small to require works having any pretensions to grandeur or magnificence.

Familiarity with a few proportions of various parts to the span, deduced from examples already before us, forming a kind of empirical rule, will perhaps be found, with occasional slight modification to locality of scite or character of stream, to be sufficient for the merely ordinary cases to which attention has been invited. Supposing brick be the material of the intended structure, the nearest uneven number to the quotient found by dividing the entire breadth of the river in feet by 45 may roughly be assumed for the number of arches. Taking the span, as may be thought proper, at any distance between 30 and 50 feet, the piers may have $\frac{1}{4}$; the thickness of arch $\frac{1}{4}$; and perhaps the versed sine $\frac{1}{4}$ of the span; it is not necessary to allude to the re-

maining dimensions, and it is supposed that the proportions above given, whilst not wanting in strength, do not involve waste of materials, or difficulty in execution.

A question has occasionally been discussed as to the comparative advantage of using small or large arches, and it is not difficult to shew, that it is equally bad economy to build very small, and to construct very large arches. If on the one hand, a bridge be regarded as an artificial platform, of greater or less thickness as its supports are nearer or further apart; so on the other hand, if brick be the material, this platform can *never* safely have a greater tenuity than 1 foot 6 inches, which does not require the piers to approach each other nearer than 30 feet; and any curtailment of this space involves the loss of the materials and labour thus uselessly expended in its abridgment. In respect to any greater span than the above, entailing additional thickness of platform, the decision would appear to depend chiefly on the fa-

cility which, in each particular case, may attend the construction of piers in the bed of the river; the expertness of the people to be employed in conducting such operations, and the character of the river under treatment, as to being liable, or otherwise, to occasional freshets, which may injure and interrupt the work. (Vide Note E.)

If usefulness were of necessity attended by difficulty, the details now submitted might perhaps be expected to deter others from undertaking what it is so easy to accomplish; bridges however are so much wanted, and are turned to such immediate and popular account, that the candid opinion of a single individual, who has himself found but little trouble, where he had been accustomed to look for both difficulty and anxiety, may tend, it is hoped, to make others put themselves in the way of obtaining similar experience, and arriving at the same conclusions.

NOTES.

NOTE A.—A handsome stone bridge of 8 arches, with a span of 64 feet, was built across the Mousee at Hydrabad in 1800, by Captain Oliphant of the Madras Engineers, the details of which structure will be found in the "Journal of the Asiatic Society" Vol. I. page 17. When Captain Douglas was resident at Tanjore, his highness the Rajah resolved to build a bridge across the Vennaur, which was completed under the superintendence of the Civil Engineer in the southern division in 1834 & 35, consisting of 5 arches of 58 feet span, and which is very highly spoken of. A still more useful undertaking is said to have been lately finished at Nagoor, across the mouth of the Vettaur, a tidal river of considerable size. A project of great importance is now on foot for throwing a brick bridge over the river Tambrapoorney, in the Sub-collector's range of the Tinnevely district, between the large towns of Ambasamoodrum and Kulladacoorchy; the design is for 9 arches of 45 feet span; and it has a peculiar character of interest, from the funds being provided by voluntary subscription amongst the very public spirited inhabitants of the district. It has already been reported for the information and decision of Government, that the contributions are in excess of the estimate, which is 16,000 Rupees. The zeal which has succeeded in giving this useful direction to a liberality so extensive, ought surely to be made generally known and imitated; the handsome subscription and the unwearied exercise of great local influence on the part of the Naib Sheristadar, a native of Tinnevely, should also be commemorated, even in so brief a notice as the present.

NOTE B.—There is a recommendation on this subject contained in one of the diaries for the Coimbatour district; the extract is as follows:

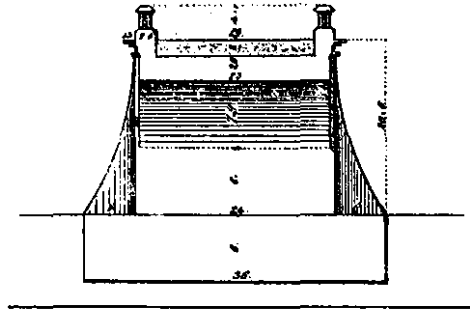
Extract in 1838 from the diary kept of the construction of the Coimbatour Sooboo Rayer bridge.

"I am inclined to think from the minute attention I have paid to this bridge, that instead of arch bricks being all burnt of one uniform rectangular size—viz. $10 \times 4\frac{1}{2} \times 1\frac{1}{2}$ they should be originally moulded with reference to their intended position in the arch. Grinding by the hand is otherwise necessary, in order to have even a moderate accuracy of workmanship; this process is very tedious and expensive, and during the operations a tenth at least of the bricks is broken. Supposing the courses of arch bricks to be placed alternately, lengthwise and edgewise, which is perhaps advisable, to prevent the two or more concentric curves which would otherwise be formed by each course of bricks, five sets of moulds should I think be used; three for those laid on edge, and two for the course laid on end. These moulds should be bevilled off, so that their slopes should converge in the ratio of the radii of the curve about to be constructed. This might easily be arranged by reference to the plan, and I feel sure that much time and expense would be saved and much truer workmanship obtained.

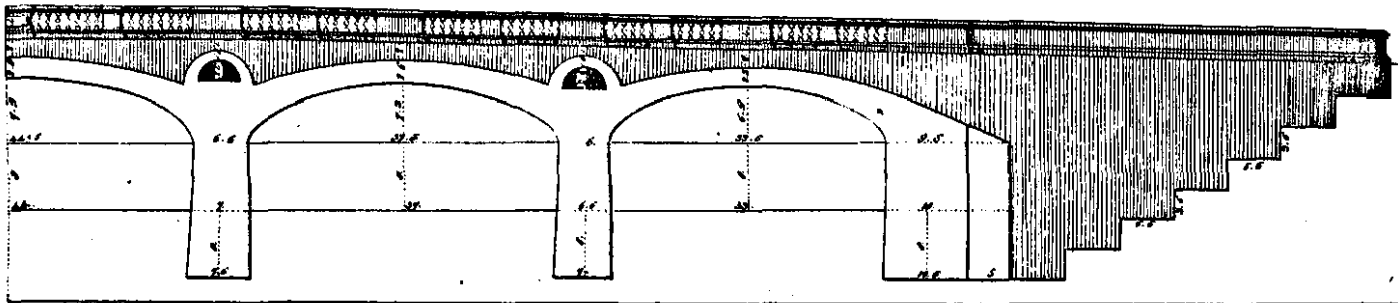
NOTE C.—The following table shews the times of the centres being struck, and the results, in a bridge built during the early part of the present year, over the Noel at Coimbatour, and which consists of three semi-elliptical

*Sections of the Combaconum Bridge
with an Elevation of the Centring.*

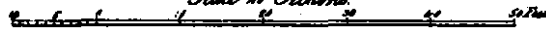
Transverse Section.



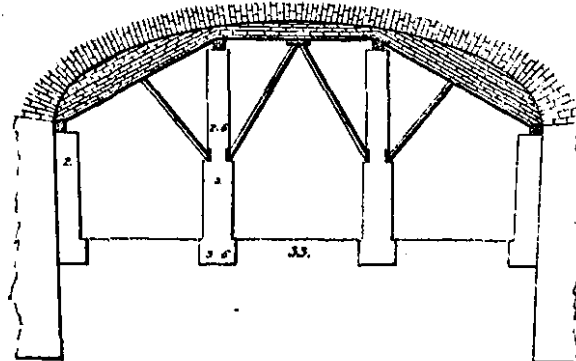
Longitudinal Section.



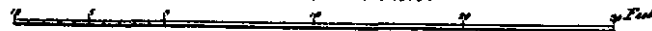
Scale to Sections.



Elevation of the Centres used in building the Bridge.



Scale to the Elevation.



arches of 36 feet span. In this case 3 inches were allowed in the temporary moulds, but the settling did not exceed 2 inches, and in those arches where the workmanship was of a better kind, from being last built, it was only 1 inch.

Arches.	Number of days built.	Height of versed sine after centres were struck.	
		F.	In.
North Arch.	11	9	1
Centre Do.	15	9	2
South Do.	10	9	2

The versed sine shewn in the sanctioned plan was 9 feet.

The centre to the south arch was struck, in the first instance, two days after completion, the sinking was very great and quite visible to the eye whilst taking place. Many of the lower bricks on each side of the key brick were squeezed out, and fell down; but for the great loading that prevented the haunches rising, this arch would have fallen. It remained about 20 days in this state, and was capable of bearing 1,400lbs. per superficial foot, but the versed sine having now changed to 8 feet 7 inches, being 8 inches lower than it was built, the arch in consequence became so shapeless and unsightly, that the deflected portion was removed and rebuilt; the injury to the curve however is still, and will always remain very conspicuous.

NOTE D.—In reading the article on Bridges written by Professor Robison, in his 1st Volume of Mechanical Philosophy, edited by Sir D. Brewster in 1821, one cannot but rejoice that the forebodings of the Professor have not yet been fulfilled. It is 40 years since the following passage was written, in the very able and interesting account of the Neuilly bridge, but more than sixty have passed since Perronet's chef d'œuvre was opened to the public. "It has the oppressive look of danger. It will not be of long duration. If any one of the arches fails, the rest must fall in a moment. An arch of Blackfriars bridge might be blown up without disturbing its neighbours."

NOTE E.—In these brief observations on a point by no means undeserving of careful examination, the question, like most others connected with public works in India, has been considered as a simple matter of comparative cost. If we can ever afford to administer some little gratification to the eye of an amateur, whilst we are consulting the convenience of the merchant, it would be advisable to adopt a more comprehensive span, emboldened by Colonel DeHavilland's experimental brick arch of 114 feet, still standing at Seringapatam.

REPORT UPON THE RIVERS CAUVERY AND COLLEROON BY CAPTAIN A. T. COTTON.

In my memorandum of the 28th of last month, I mentioned my purpose of preparing a more general report upon the further use that might be made of the Cauvery, but at the time I found it necessary to confine myself to that part of the subject connected with the undersluices, already sanctioned, to be built on Seringam. In my letter to the Principal Collector of Tanjore, dated the 7th instant, I considered some points respecting the controul of the water after it enters that district, which appeared to require immediate attention. Though still unable to accomplish any thing like a general report, I think it advisable to propose for consideration a very important part of the subject, without further delay; under the idea that the more and the sooner it is examined the better.

In considering how this noble river may be improved to the utmost, it immediately occurs, that our grand object must be, not to let its water run to waste into the sea. In high freshes an immense quantity is lost, because it comes down faster than it can be applied to use; in low freshes a smaller, but still very large quantity is lost, at the very time that it is most required, because it is on too low a level for the lands to be irrigated by it. In the first case our object is to gain time, in the second to gain height.

Of the first I propose to write but very shortly, but more fully of the second, because it appears that on the latter we have already sufficient information to form a tolerable judgment respecting it, and also because I think that more may be effected at the same expense and trouble.

I know of no way by which the first point may be gained, excepting the usual one of storing the water up in tanks till it is wanted. There is only one instance of this at present on an extended scale from the Cauvery or Colleroon, and that is in the district of south Arcot, where the Veeranut tank is filled from the Colleroon; the embankment is 12 miles long, and the contents I should suppose, from what I remember of it, about 200,000,000 cubic yards, or sufficient, if once filled only, for the perfecting of one crop on 20,000 vaylies, the revenue of which would be about 140,000 Rupees; it once yielded 180,000 but now it yields only 70,000. There are the remains of a still finer work of this kind in the northern Talooks of Trichinopoly, though it is not certain that it was ever completed. It should here be particularly remarked, that both before and under the Company's government, innumerable petty tanks have been constructed on almost every small stream in the country, where the supply of water was as precarious, as the small ex-

tent of country through which it flowed, and its being supplied only from one, and that the least certain monsoon, could make it; while this most valuable river, receiving the rains of a tract of country 500 miles in length, and filled by both monsoons, has been, excepting in the one instance of the Veeranut tank, altogether neglected in this respect.

The extent to which this kind of works, might be carried, may be seen from the following calculation: the stream of the Colleroon below the eastern end of Seringam may be taken at 800 yards broad, by 4 deep, in high freshes, giving a section of 3,200 yards, moving with an average revelocity of 6000 yards per hour, making a total of 19,200,000 cubic yards passing down per hour, or 480,000,000 cubic yards per day, which is sufficient to perfect a crop on 48,000 cawnies, and would produce a revenue of 336,000 Rupees, if applied to the purposes of irrigation. Out of this 480 million of cubic yards per day, the utmost that can be used for the present cultivation is 50 million, or one-24th part, all the rest running to waste, excepting what goes into the Veeranut tank, which might be filled in a single day. Hence it can never be said that there is not water enough; there is water sufficient for ten times all the present Nunjah cultivation under the Cauvery and Colleroon, yet there are lacs lost almost every year in Tanjore alone, from partially ruined crops, caused by want of water. An intelligent native, a large land-holder, told me he thought that the lands now cultivated in Tanjore would yield on an average every year $\frac{1}{3}$ more grain than at present, and another calculated it at $\frac{1}{2}$, if they had a full supply of water; and I have no doubt that it is not over-rated at $\frac{1}{2}$, from what I have seen and heard, for it is only a small part of the lands that are fully supplied.

If any thing of this sort is undertaken I should recommend, that at first it was so done as to complete the supply of lands already cultivated, rather than to water fresh lands; 2nd, that the tanks should not be made in the spots where the land is valuable, but where the land is of little value, and the declivity not great, so that an embankment of moderate height would retain a good breadth of water, or where there were natural features which would assist in forming the tank. I understand that just after the Cauvery clears the Ghauts, there is a place where the water might be led off without any great difficulty, or it might be thrown into one of the extensive valleys of the Salem district, and it should be let out into the river again as soon as the water in the channel becomes insufficient for the

cultivation. The value of water for irrigation may be taken at 3,000 cubic yards per Rupee, at least; that is, when it is applied to land that is not very valuable as Poonjah, but on some lands its value is not less than 1 Rupee per 1,000 cubic yards, and hence a tank of the capacity of the Veeranutairy would be worth 160,000 Rupees per year, supposing it was filled only once; but in fact it would usually be filled twice and emptied twice a year, and hence if it cost 320,000 Rupees it would yield 100 per cent.

Now the loss of Revenue this year in Tanjore alone, I believe, will be nearly as much as that. I have just sketched this out to shew what might be done in this way, and how absurd it is to lose lacs of Rupees of revenue while they might be saved by an expenditure of the amount lost in a single year, which there is no doubt might be done. The greatest quantity of water the Tanjore district ever requires is 40 million cubic yards per day, and hence, if there was water in the river, such a tank as Veeranutairy would supply it for 12 days; but excepting at the time when the freshes are usually in the river, it does not require half this quantity, and if, as is always the case, there is a considerable quantity in the river, such a tank would be found sufficient to complete the supply for not less than two months, which in almost every year would be enough to secure the whole crop.

But it is to the 2nd point viz., the saving of water in low freshes that I wish particularly to call the attention of Government, for the reasons already stated.

I should begin by calculating roughly the quantity of water lost at such times. On the 4th of last December I visited the Head of Seringam, there was at that time (by computation) passing down the

Cauvery.....	30,000,000	Cubic yards per day.
Wanted in do..	40,000,000	-----
Deficient.....	10,000,000	-----
In the Colleroon	24,000,000	-----
Wanted do....	6,000,000	-----
Superfluous....	18,000,000	-----

That is, while 18 million cubic yards per day were running to waste in the Colleroon, 10 millions additional were required in the Cauvery, the value of which at the least would be Rupees 3,300 per day. The water at that time was 2 feet below the level of the crown of the grand annicut. In reckoning the water at 3,300 cubic yards per Rupee, I state it at its lowest possible value; I stated above, that on lands that are of no value as Poonjah, the value of the water is not less than 1 Rupee per 1000 cubic yards, but when a crop is in danger from want of water, it may be worth much more, thus the crop is often lost for want of a single good watering, and a vaylie of paddy, of the gross value of 80 Rupees may be lost for want of 3,000 cubic yards of water, when the water would be worth 1 Rupee per 40 cubic yards, and it is in this way that

the water secured in low freshes would be so very valuable. It may be asked, if the water is ever worth so much, how the crop is lost in any case; in many cases the water cannot be got at all in large quantities; in many, wells must be dug and the water raised so high as to make it cost more than that sum; in many cases a great loss having been already sustained in cultivation and seed, and there being no certainty that one or two waterings will be all that will be required, the owner is afraid to risk more money on the crop; but in far the greater number of cases, probably, he is prevented by want of capital, for only a small proportion of the Meerassidars have any capital at all. A Meerassidar lately informed me, that he had this year watered many vaylies of land by the Picottah, and the statement he gave me shewed that the water cost him about 1 Rupee per 400 cubic yards, besides the price of the Picottahs; but he has now many vaylies of paddy that is either ruined already, or will be so shortly, but for which he cannot get water by any means. At this moment there is wanted in this district at least 60,000,000 cubic yards of water that the owners of the land would be glad to buy at the rate of from 200 cubic yards to 500 per Rupee, supposing they were to keep the whole crop themselves, and it would therefore be worth 105,000 Rupees; and ten days hence nearly as much more would be purchased at the same prices.

I think, therefore, that the advantage of any plan by which water can be saved in low freshes cannot be doubted, if it can be accomplished within a certain expense.

The two plans usually adopted for raising the water from the bed of the river to a sufficient level to answer the purposes of irrigation, are 1st, by carrying a portion of the stream through a channel having a less-fall than the surface of the country, till it has attained a level above that of the adjoining land; and 2nd, by damming up the river.

The first of these is preferable under certain circumstances, but it is very rarely indeed that the cost of the water in a river can be secured in this way, for, generally, the cutting at the head of the channel must be so deep, and the channel must be of such great length, to gain the required elevation, that it would be too expensive. This is the case with almost all the Cauvery and Colleroon channels, but especially it is the case with the Cauvery itself, when considered (which it really is), as a channel of irrigation leading off from the Agunda Cauvery and Colleroon, and which is the principle to be considered.

I think there is no possible way of raising the water in low freshes for the Tanjore district, except by having recourse to the 2nd plan mentioned above, and I am confident that this will be found to be both feasible, and unobjectionable.

Excepting the Uyacondum channel, which will not be injured, but perhaps a little benefited, the whole of the Agunda Cauvery and Colleroon may be divided into four classes; viz.,

1st. the Cauvery from the head of Seringam, containing the Seringam channels and all the Tanjore rivers;

2d. The Iyen Voykel and two other channels on the north bank of the Colleroon, in the Laulgoody Talook of Trichinopoly;

3d. The Munnyaur on the south side of the Colleroon in the Tanjore District; and

4th. The Vuddavaur and three smaller channels on the north bank in south Arcot.

Their revenues are as follows.

1st. Cauvery &c. about 3,500,000.

2d. Iyen Voykel &c. about 130,000.

3rd. Munnyaur &c. about ————

4th. Vuddavaur &c. about 100,000 at present, but formerly 220,000. I do not state the revenues exactly, but they are about in this proportion.

It is evident that if the plan of an annicut is adopted in one place, some arrangement must be made for supplying the other channels, different from that at present, because the upper annicut will cut off the supply from the lower channels.

The following arrangement might be made, in order to secure the supply to all the four classes above mentioned.

1st. An annicut across the Colleroon from the head of Seringam; from one end of this the Cauvery and Seringam channels would be supplied; and from the other end all the Laulgoody channels; to effect this it would be necessary to cut a head for the Iyenvoykel, which is one of the principal ones, from the annicut to its present head, a distance of about 8 miles.

2d. The Munnyaur might be supplied, partly from the Colleroon as at present, if necessary, (for the annicut at the head of Seringam would not keep the lower part of the river quite dry at any time,) but chiefly from the Cauvery, which flows on a much higher level, and is sufficiently capacious to carry a supply for the Munnyaur besides that required for its own cultivation, if the other rivers branching from it are not allowed to take more than their proper share.

3d. A second Annicut would be required at the head of the Vuddavaur, for the supply of that river and the three smaller channels which lead off within a few miles lower down the river.

For the annicut across the head of Seringam I should recommend a brick dam coped with stone, the crown of it about 3 feet above the deep bed of the river, with moveable posts and planks, for the purpose of raising it $1\frac{1}{2}$ feet more, making a total of $4\frac{1}{2}$ feet above the deep bed, when the planks are placed.

The three points to be examined respecting this work are—1st, the effects upon the river.

2d. The expense.

3d. The results that may be expected, as respects improved irrigation.

1st. The effects upon the river. In high freshes its main effect will be, by raising the surface of the water, to increase the danger of the banks being overtopped; this however will be much less than might at first be supposed. It must be particularly observed, that this is not like one of those cases where the dam entirely shuts up the whole channel of the river, and the irrigating channel is very small in comparison; hence, by reference to the accompanying section it will be seen, that the Cauvery is 858 yards broad, and the Colleroon 1,110 yards. The space occupied by the dam when the boards are away, will be only 250 square yards, while the whole contents of the section of water way, quite across the Agunda Cauvery, at an extreme fresh, is about 7000 square yards; hence the obstructed part of the water will be only one-thirteenth of the whole; the whole surface of the water must be raised $4\frac{1}{2}$ inches only, in order to make a section equal to the present one, and this would be the height to which the water would rise, supposing the velocity over the dam to be the same as it is at present without the dam; in stating it therefore at $4\frac{1}{2}$ inches, it is evident that we suppose the danger arising from this circumstance to be greater than it will really be. Immediately above, therefore, the water will be a little raised, but the velocity will be proportionally diminished, and a little way lower down the Cauvery any quantity of water that may be desired may be allowed to return into the Colleroon by a Calingalah, such as has been already recommended; indeed as the one proposed will allow a free water way of 450 yards, while the section occupied by the dam is only 250 yards, it is probable that this one Calingalah will be sufficient; especially as capacious undersluices have also been sanctioned not far from the spot.

In low freshes it will throw a large body of water into the Cauvery, and an abundant supply into the Laulgoody channels, and when the river is very low, it will throw the whole of it into those channels, if it is found desirable, or any portion may be let back into the Colleroon by the under sluices, at pleasure.

When I visited the head of Seringam on the 4th of December, as above stated, the 10 million cubic yards which were then wanted in Tanjore, would have been thrown in by a dam, and this could not be valued at less than 3,000 Rupees per day. At that time 18,000,000 yards, at least, were running to waste into the sea daily.

The effects of the dam, if quite complete, would be also to raise the level of the bed of the river, which if it was considered a disadvantage, might easily be obviated by making vents or undersluices in the dam; and to prevent the sand being carried into the Cauvery, there will be abundance of undersluices. The next effect will be to cut off all, or a portion of the waters of the river from the cultivation below; this can be obviated in no way that I am aware of, but by making, as mentioned above, a second annicut for the south Arcot channels.

2d. The expense.

The work may be a simple brick dam covered with cut stone, with a very narrow apron; for the overfall

from the crown of the annicut to the apron being only three feet, and the difference of level of the surface of the water above, from that below, being still less, no great strength of section will be required. If built at the present head of Seringam, it will be 1,100 yards in length, and will cost about 80,000 Rupees; if a little lower down, where the breadth is only 800 yards, about 60,000 Rupees.

The estimate, then, will stand thus—

Annicut at head of Seringam, at most....	80,000
Do. at head of Veeranutairy channel, about 800 yards long.....	60,000
Channels in Laulgoody.....	10,000
Do. in south Arcot.....	4,000
2 sets of undersluices, one at each Annicut.	6,000
Sluice in Cauvery, for supplying Munnayur.	4,000
Total Rupees..	<u>164,000</u>

This is of course a very rough estimate, and several additional items might be required.

3d. The results.

1st. The present cultivation of Tanjore would be entirely secured, except in extraordinarily bad years; not only would the crops be saved that are now lost entirely, but by far the greater part of the whole district would be made to produce larger crops; and in extraordinarily deficient years the amount saved by the dam would be far greater than in ordinary years.

2nd. Much land that is at present waste, or cultivated as Poonjay, might be irrigated; in the Munnargoody Talook there are some thousand vaylies of middling land that might be irrigated.

3d. The whole of the cultivation in Seringam, and in Laulgoody, and part of that near Trichinopoly, would be entirely secured, except in extraordinarily bad years.

4th. The cultivation under the Veeranutairy would be raised to its former amount.

I estimate the returns in money to Government as follows;

In Tanjore, from lands at present entered as	
Nunjay.....	200,000
Ditto, new cultivation.....	50,000
South Arcot, restoring original cultivation under Veeranutairy.....	100,000
Total..	<u>350,000</u>

Besides some addition in Trichinopoly.

I feel very confident that this estimate is much below what would be the real results. There would be an expense attending the new Nunjay cultivation in Tanjore, but it would not equal one years revenue, if the best

situations were selected. I have stated the probable increase at 50,000 Rupees, or 1,600 vaylies; but it is very probable that the supply of water would be sufficient to authorize a much greater extension.

I will conclude by attempting to answer an objection that I have heard made to such undertakings as this, viz. that the finances will not admit of such expensive works. To this it may be answered, that if they will admit of the losses that the revenue annually sustains from defective irrigation, they can certainly bear such an expenditure as this; for the annual loss in this division, beyond all doubt, far exceeds the capital sum above estimated; in this district alone, certainly, on an average of years, it cannot be estimated at less than 150,000 Rupees, at least, so far as I am able to judge. A very intelligent native, who rents lands to a very large amount, told me he thought, on an average, the lands entered as Nunjay in the district, if fully supplied with water, would yield 12 per cent more than at present. But of this the Principal Collector will be the proper judge. In south Arcot the Veeranutairy cultivation was in 1827 about 90,000 Rupees per annum, at which time a great proportion of the Ryots were threatening to leave the district, on account of the inadequate supply of water; since that, I hear it has declined to 70,000, whereas it was once 180,000 Rupees. And it must be recollected that a great part of these returns will be immediate: I have not the least doubt, that, if this work was completed in time for a July fresh, by the following April one half of the account, perhaps the whole, would have been paid into the treasury in additional revenue. A direct proof to this point is found in the circumstances of the late alterations at the head of Seringam, by which an additional supply of water was thrown into the Cauvery, in consequence of which a very large increase of grain was obtained in the same year. Another objection sometimes suggested is, that there is already too large a quantity of grain raised in the country; in the first place, this fact ought to be established if possible, and then I would answer; let a portion of the producers of grain, be converted into consumers, by undertaking, upon the strength of improved revenue, works for the improvement of internal communication, which are so urgently required. For this increase of revenue will not require a proportional increase of labour; on the contrary, in many cases it will greatly reduce the demand for it; for there is an immense expenditure of labour at present entirely occasioned by the difficulty of getting water, and a vast deal of labour is also lost in cultivating crops which ultimately fail; there are thousands of vaylies in this district at this moment, which have been fully cultivated and will yield no paddy at all. Besides all this, there is sufficient proof of the want being that of employment rather than of consumers, in the fact, that near the great towns, workmen may be procured in very large numbers without difficulty, at the rate of from 1½ to 2 annas per day, which is at present the value of from 1 to 1½ Madras seers of rice, such a labourer consuming from ¾ to 1 Madras seers. It must also be remembered, that in particular instances, we know of large bodies of culti-

vators having been deprived of their livelihood, of late years; for instance, the cultivators of 1,000 vaylies under the Vettar, and of 400 cawnies under the Veeranutairy in South Arcot &c.

Upon the whole I think the subject well worthy of attention, and I have therefore just sketched out the case, in order to do something towards a regular survey, if such should be required.

(Signed) A. T. COTTON,
Captain of Engineers,
Civil Engineer, Southern Division.

Tanjore Division,
Theroottala Poondy Talook,
OOPOOR, 29th January, 1834.

Civil Engineer's Department, 3rd Division.

To
The Inspector General,
of Civil Estimates,
Fort St. George.

SIR,

I have the honor to transmit four statements* respecting the produce of Tanjore with which I have been furnished by the Principal Collector, and from the examination of which I think some important conclusions may be drawn, respecting the irrigation of the district.

No. 1, 2 and 3 show the Dittum extent of cultivation, and the actual extent in Fuslies 42 and 43, under all the rivers in the district, divided into three heads, viz. those under the Colleroon, Cauvery, and Vennaur. The first object obtained by these returns, is the knowledge of the proportions of water required for each river. It appears, that the extent of cultivation under the Vennaur is to that under the Cauvery as 38 to 35, or about as 13 to 12, supposing the Vettaur to be supplied, as hitherto, from the Vennaur; but if by means of the Cundeyoor-cut, it should in future be supplied from the Codamoorty, the proportion would be as 28 to 46, or as 3 to 5 nearly, which would be a much more convenient proportion at present.

The second object is the comparison of the Fuslies 42 and 43, for the purpose of determining both the actual effects of the unequal distribution which took place in the last year, and also, generally, the effect of an inadequate supply of water upon the extent of cultivation. The latter, however, is more clearly shown by statement No. 4. It appears from these papers, that under the Cauvery—

The Dittum Beriz is.....	1,264,746	Rs.
The Beriz as per Cultivation of 42..	1,249,167	
Fusly 42 below Dittum.....	15,579	
The Beriz as per Cultivation of 43..	1,252,624	

Fusly 43 below Dittum.....	12,122
Fusly 42 below 43.....	3,457

Vennaur.

Dittum Beriz.....	1,300,416
Beriz as per Cultivation of 42.....	1,264,276
Fusly 42 below Dittum.....	36,140
Ditto as per Do. of 43.....	1,213,727
Fusly 43 below Dittum.....	86,689
Ditto below Fusly 42.....	50,549

From the comparison of these two statements it appears, that there was a difference between the Dittum and actual extent of cultivation under the Vennaur in Fusly 42, to the value of 36,000 Rupees of revenue; while under the Cauvery the difference was only to the value of 15,000 Rupees of revenue; and that in the following year viz. the last, the former was 86,000, and the latter only 12,000; hence it appears, that notwithstanding the deficiency in the total supply of water, the extent of cultivation under the Cauvery was actually greater in 43 than in 42, in consequence of the greater inequality of the supply of water to each of these two rivers. It also appears, that from a more defective supply of water to the Vennaur in 43, there was a reduction of the extent of cultivation to the value of 50,000 Rupees revenue below that of the former year, which was itself 36,000 Rupees below the Dittum. This is good ground to judge of the effect of an increased supply of water, because we are enabled to form the comparison without having recourse to two different seasons, which would leave room to doubt how far the effect was produced by difference of weather; thus in the same season the Cauvery cultivation exceeding that of the preceding year to the extent of 3,000 Rupees, while that of the Vennaur falls short 50,000, proves clearly that it is solely

* Part of these statements having been unfortunately lost, thus rendering the set incomplete, it has been thought inadvisable to print the remainder, more especially as the results shown by them are fully detailed in the course of this report.

owing to the greater or less supply of water. It must be particularly observed, that this does not shew the whole loss of produce, but only the deficiency in the extent of cultivation; the actual revenue will be much less under the Vennaur, on account of the prodigious extent of land on which the crops withered, which I saw myself; and the deficiency in the actual produce is even greater than that of the revenue, because the high prices make up for part of the deficiency of produce.

It becomes next an important question, how far the total revenue of the district is affected by an imperfect distribution, as for instance, whether in the last year the revenue would have been greater than, the same as, or even less than it was, if there had been a perfect distribution. Nothing but close observation and experience can, I apprehend, settle this point; but in my opinion, so far as I can judge at present, in abundant and average years, the greatest revenue would be produced by a perfect distribution. In very deficient years I am doubtful whether this would be the case; but it appears to me, that much more may be done by husbanding the water to the utmost, than might at first be supposed; that is, that a supply far below what is usually applied is sufficient to save the crop, and effect a pretty good produce of grain, and hence that it often happens, that the water which in one part of the district is making a difference of 10 per Cent in the produce of a field, might in another part be applied to a field where the crop was perishing, and make the difference between a total failure and moderate produce. There is however a much shorter way of settling this point, viz. by considering the rights of the people, which I think make it imperative on Government to distribute the water as fairly as possible to the different rivers. Such an extraordinary power over individual property as the charge of the rivers gives to the Circar, certainly ought to be used with great caution. Had we estates in Tanjore, we should be very sensible of this, when we found that in a very dear year, it wholly depended upon the Circar whether we were buyers only, or sellers only.

Statement No. 4 is a very important paper, showing an approximation to the total difference between the dittum and actual gross produce of the Nunjah lands for eight successive years; the full difference could not easily be ascertained. In this statement the calculation is made on the supposition that those villages which paid their full assessment produced an average crop, whereas it is evident, that in years of high prices this will give the produce much above the truth, because many villages are enabled in these years to pay the full rent, though the produce was very deficient. But by this method of calculation, which will give the deficiency below the truth, it was

in Fusly 1235.....	860,000	Cullums.
6.....	500,000	————
7.....	1,200,000	————
8.....	1,900,000	————
9.....	1,600,000	————
40.....	1,500,000	————

1.....	900,000	Cullums.
2.....	1,000,000	————
	9,460,000	————
Average of 8 years	1,180,000	————

The value of which at the Voloongoo rate, would be about 590,000 Rupees, of which perhaps 250,000 would be the amount to which the revenue would be affected. From all I can learn by enquiry it appears, that almost the whole of this deficiency is caused by the want of water; and it must be remembered, that the dittum itself has been settled upon what is considered a good supply of water, as the district has been hitherto watered; whereas an abundant supply might make the lands produce even beyond the dittum amount. It appears hence, that the revenue might be increased not less than 2 lacs on the present Nunjah lands, by the simply throwing in more water, and without any additional works within the district, but on the contrary with a less expenditure than at present, as it would not be necessary to be so particular in the distribution; and about 2½ lacs besides might be added to the income of the Meerassidars, the benefit of which would of course be felt in the Public Treasury. This statement therefore agrees well enough with what I have formerly mentioned in my diary, that an intelligent Meerassidar who had several hundred vaylies of lands in different parts of the district told me, that he supposed a full supply of water would increase the produce 12 per Cent, or 10½ lacs of Cullums. I find from the Annicut returns, and measurements I have taken of the water in the Colleroon and Cauvery, that if all the water which at present passes down the former, beyond what its cultivation requires, were turned into the latter, such a year as the worst that has occurred in the last 20, (as respects the number of days on which the water was at a certain height) would be much above what the average actually was, and nearly equal to the best of those 20 years. It is from these considerations that I have come to the conclusion, that money expended upon works for throwing more water into the district will produce much more than any thing that can be done within the district. How far the under-slucies may affect the supply of water cannot yet be determined; but in the course of this year I hope something may be ascertained on this point: it must be observed however, that if they do in any good degree accomplish what is desirable, something must be done for Laulgoody, as the difficulty of throwing a sufficient supply into it, would be greatly increased by lowering the surface of the Colleroon so much. An annicut across the head of the Colleroon would be the most effectual work, and it would not only increase the revenue of Tanjore, but also of Seringam, Laulgoody, and part of Conaud, in Trichinopoly. Such a work might be constructed for about 50,000 Rupees, and I think, would produce greater returns than ten times the sum spent within the district. I have long purposed forwarding a particular report upon this matter, but have postponed it till I could

visit South Arcot, and ascertain more particularly the circumstances of the Colleroon irrigation in that district, which must be considered before determining upon an annicut at the head of the Colleroon; but the forwarding of these statements has led me to touch upon it now; and as the decision upon almost every case that comes before me, would be affected by such a work being in contemplation, and the ordinary and occasional Estimates of works within the district might be greatly reduced for two or three years, I thought it as well at once respectfully to request your attention to the point. It is probable that the ordinary and occasional Estimates of the year in which an annicut was constructed would

be so much reduced, as that the total expenditure, including the annicut, would not exceed the sum usually expended at present, and indeed it would be necessary to defer every work that could possibly be dispensed with, (even the clearing out of village channels), till the actual results were known.

I have the honor to be,

Sir,

Your most obedient Servant
A. T. COTTON, Captain
Civil Engineer, 3d Division.

Tanjore District, }
MERRATOOR, }
7th July 1834. }

To

The Inspector General
of Civil Estimates,

Madras.

SIR,

1. With reference to the enclosed copy of a letter, dated 25th July 1834 from the Civil Engineer, 3d Division, I have the honor to transmit the accompanying letter dated 15th July 1834, to your address, from the same officer.

2. Captain Cotton's proposal for the construction of an annicut across the head of the Colleroon having been matured in communication with myself, and the data on which he has calculated the advantages to be expected from it, in a revenue point of view in this district, having been furnished from my Cutcherry, little remains for me but to express my opinion of the correctness of the inferences which he has drawn from them.

3. The object of the work is to increase the supply of water to the wet lands in low freshes, the deficiency of which is manifest from the large remissions made every year on wet lands, the crops of which have suffered from want of water, and from the number of villages which remain under Amauny, being unable to yield their grain assessment, chiefly from the same cause.

4. The greater this increase the better, so long as the banks of the rivers are not endangered by high freshes—and this seems to be abundantly provided for by the proposed level of the annicut, which will scarcely affect the river in high freshes—by the sluices proposed in the work itself,—by the 4 sets of undersluices, and by the Calingula at the head of Seringam, which have all been constructed within the last few years. These works also provide abundantly for the supply that may be necessary for the lands dependant on the Colleroon.

5. A collateral advantage of an increased supply of water alluded to by Captain Cotton is of very great importance, viz. the increased opportunities it will afford of

making use of the undersluices to remove accumulations of sand from the bed of the Cauvery.

6. I do not consider that the expected saving of revenue is over-estimated at a lac of Rupees annually on the Seycal lands, besides what may be expected from the gradual extension of the cultivation of waste and of a second crop; and, as Captain Cotton observes, it is no small advantage that such part of this return as is to be expected from ensuring the crops on the lands already under cultivation, will of course be immediate, since it requires no increase of either labour or capital.

7. The amount of the estimate is large in itself, but by no means so as compared with the advantages expected from it; and as its effect must be very largely to increase the general supply of the district, although the degree in which it will affect particular branches of the irrigation cannot be anticipated with accuracy, it will undoubtedly entirely supersede the necessity of some, and call for the modification of other works of partial operation, now in contemplation to make the most of the present scanty supply. The execution of all such works would therefore, of course, be suspended till after one year's experience of the effects of the annicut, and the ordinary and occasional expenditure kept within the usual amount.

8. It may be necessary to add, that this project has the entire approbation of the natives, who have been consulted; and who, with all their deficiencies in science, are no mean judges of matters of irrigation. I have therefore no hesitation in giving it my unreserved approval, and trust that it may be speedily submitted for the sanction of Government.

I have the honor to be

Sir,

Your most obedient Servant,

TANJOBE.
NEGAPATAM,
6th August 1834.

J. M. KINDERSLEY,
Principal Collector.

REPORT BY CAPTAIN A. T. COTTON.

Civil Engineer's Department 3d Division.

To
The Inspector General
of Civil Estimates
Fort St. George.

SIR,

1st. I have, I believe, more than once referred in my Diaries and other papers, to the great waste of water in the Colleroon, from its not being sufficiently under controul, in consequence of which a very great proportion escapes into the Sea, at the time that it is wanted for the Nunjay lands; so that many thousand Vaylies of paddy become partially or wholly unproductive almost every year, while there is still water enough in the Agunda Cauvery; it was with a view to remedy this, that some of the works were planned, which have been executed of late years; viz. the closing of the Govindoo Calagum, and the construction of the undersluices at the head of Seringam.

2d. The former was certainly very beneficial, and in the first year greatly overpaid the expence of the work; as will be seen by referring to the Principal Collector's letter accompanying the Civil Engineer's Report on the Cauvery, dated 29th November 1832; where it is stated that the Talooks under the Cauvery produced no less than 165,000 Cullums more than the preceding year, which in the Principal Collector's judgment was mainly owing to the closing of the Govindoo Calagum; and my observations upon the river and district satisfy me that this conclusion was correct. But the effect of this measure could not be permanent, for it was by means of this opening that the sand from the head of the Cauvery was carried into the Colleroon, and consequently after being closed for some time, the sand would again gradually accumulate, and the proportion of water entering the Cauvery be gradually reduced to its former amount, which effect has already been almost or entirely produced.

3d. The undersluices now under execution at the head of Seringam, or just completed, are calculated to remedy this, by enabling us to let off or retain the water at pleasure; and that they will in a few years have a very great effect in this respect, as well as in preventing the danger and inconvenience arising from too much sand passing down into the lower part of the Cauvery, I have no doubt; but after considering the case very many times, and indeed rarely passing a day without giving some attention to the subject, I feel satisfied that the construction of an annicut across the head of the Colleroon is the only effectual, and in every respect advisable work, for economizing the water during low and moderate freshes. Before entering further upon this part of the subject, I will give a statement of the extent of cultivation, and the quantity of water required for it under the different rivers.

	<i>Under the Cauvery.</i>		
	Vaylies.	Rs.	<i>Cubic Yards water required per hour.</i>
In Trichinopoly about	2,500	100,000	
In Tanjore.....	74,000	3,000,000	
	76,500	3,100,000	1,530,000
<i>Under the Colleroon.</i>			
In Trichinopoly	5,500	250,000	
In Tanjore.....	10,500	450,000	
In South Arcot.....	9,000	400,000	
	25,000	1,100,000	500,000
	101,500	4,200,000	2,030,000

The total extent, therefore, is about 101,500 Vaylies, a full supply of water for which would be about 2,000,000 Cubic yards per hour. By actual measurements I have ascertained that there is about this quantity of water in the Agunda Cauvery when the water at the Grand Annicut is within $\frac{3}{4}$ feet of the crown of that work; at present, in moderate freshes, the water that comes down the Agunda Cauvery divides nearly equally, half going down the Cauvery, and half down the Colleroon.

	Cub. yds. per hour.	Sufficient for Vaylie.	Act. ext. Vaylie.	Quantity of water req.
In the Colleroon	1,000,000	50,000	19,500	390,000
In the Cauvery	1,000,000	50,000	76,500	1,530,000

Hence while 600,000 Cubic yards per hour are running to waste into the Sea by the Colleroon, the same quantity is required to complete the supply in the Cauvery. Again, Tanjore is not considered abundantly supplied, that is, under the present imperfect distribution of its water, till the river rises to $1\frac{1}{2}$ foot above the Crown of the Grand Annicut; at which time there are in the Colleroon 3,000,000 Cubic yards, while the quantity required is 400,000; the remaining 2,600,000 flowing into the Sea, excepting a very small part which is received into the Veeranum Tank in South Arcot; hence Tanjore does not get an abundant supply till there is nearly 2,600,000 Cubic yards, more water in the Agunda Cauvery than is wanted for all the cultivation under both rivers. That there is therefore a most important and valuable supply of water constantly lost there can be no doubt, and the next point to be ascertained is, the reality and extent of advantage to be obtained by preventing this waste.

1st. It appears by returns of the gross produce of the Tanjore District (on the lands at present entered as Nunjay) so far as it could be ascertained, that the difference between the actual and Dittum produce is on an

visit South Arcot, and ascertain more particularly the circumstances of the Colleroon irrigation in that district, which must be considered before determining upon an annicut at the head of the Colleroon; but the forwarding of these statements has led me to touch upon it now; and as the decision upon almost every case that comes before me, would be affected by such a work being in contemplation, and the ordinary and occasional Estimates of works within the district might be greatly reduced for two or three years, I thought it as well at once respectfully to request your attention to the point. It is probable that the ordinary and occasional Estimates of the year in which an annicut was constructed would

be so much reduced, as that the total expenditure, including the annicut, would not exceed the sum usually expended at present, and indeed it would be necessary to defer every work that could possibly be dispensed with, (even the clearing out of village channels), till the actual results were known.

I have the honor to be,

Sir,

Tanjore District, }
MERRATOOR, }
7th July 1834. }

Your most obedient Servant
A. T. COTTON, Captain
Civil Engineer, 3d Division.

To
The Inspector General
of Civil Estimates,
Madras.

SIR,

1. With reference to the enclosed copy of a letter, dated 25th July 1834 from the Civil Engineer, 3d Division, I have the honor to transmit the accompanying letter dated 15th July 1834, to your address, from the same officer.

2. Captain Cotton's proposal for the construction of an annicut across the head of the Colleroon having been matured in communication with myself, and the data on which he has calculated the advantages to be expected from it, in a revenue point of view in this district, having been furnished from my Cutcherry, little remains for me but to express my opinion of the correctness of the inferences which he has drawn from them.

3. The object of the work is to increase the supply of water to the wet lands in low freshes, the deficiency of which is manifest from the large remissions made every year on wet lands, the crops of which have suffered from want of water, and from the number of villages which remain under Amauny, being unable to yield their grain assessment, chiefly from the same cause.

4. The greater this increase the better, so long as the banks of the rivers are not endangered by high freshes—and this seems to be abundantly provided for by the proposed level of the annicut, which will scarcely affect the river in high freshes—by the sluices proposed in the work itself,—by the 4 sets of undersluices, and by the Calingula at the head of Seringam, which have all been constructed within the last few years. These works also provide abundantly for the supply that may be necessary for the lands dependant on the Colleroon.

5. A collateral advantage of an increased supply of water alluded to by Captain Cotton is of very great importance, viz. the increased opportunities it will afford of

making use of the undersluices to remove accumulations of sand from the bed of the Cauvery.

6. I do not consider that the expected saving of revenue is over-estimated at a lac of Rupees annually on the Seycal lands, besides what may be expected from the gradual extension of the cultivation of waste and of a second crop; and, as Captain Cotton observes, it is no small advantage that such part of this return as is to be expected from ensuring the crops on the lands already under cultivation, will of course be immediate, since it requires no increase of either labour or capital.

7. The amount of the estimate is large in itself, but by no means so as compared with the advantages expected from it; and as its effect must be very largely to increase the general supply of the district, although the degree in which it will affect particular branches of the irrigation cannot be anticipated with accuracy, it will undoubtedly entirely supersede the necessity of some, and call for the modification of other works of partial operation, now in contemplation to make the most of the present scanty supply. The execution of all such works would therefore, of course, be suspended till after one year's experience of the effects of the annicut, and the ordinary and occasional expenditure kept within the usual amount.

8. It may be necessary to add, that this project has the entire approbation of the natives, who have been consulted; and who, with all their deficiencies in science, are no mean judges of matters of irrigation. I have therefore no hesitation in giving it my unreserved approval, and trust that it may be speedily submitted for the sanction of Government.

I have the honor to be

Sir,

TANJORE.
NEGAPATAM,
6th August 1834.

Your most obedient Servant,
J. M. KINDERSLEY,
Principal Collector.

REPORT BY CAPTAIN A. T. COTTON.

Civil Engineer's Department 3d Division.
 To *The Inspector General*
of Civil Estimates
Fort St. George.

SIR,

1st. I have, I believe, more than once referred in my Diaries and other papers, to the great waste of water in the Colleroon, from its not being sufficiently under controul, in consequence of which a very great proportion escapes into the Sea, at the time that it is wanted for the Nunjay lands; so that many thousand Vaylies of paddy become partially or wholly unproductive almost every year, while there is still water enough in the Agunda Cauvery; it was with a view to remedy this, that some of the works were planned, which have been executed of late years; viz. the closing of the Govindoo Calagum, and the construction of the undersluices at the head of Seringam.

2d. The former was certainly very beneficial, and in the first year greatly overpaid the expence of the work; as will be seen by referring to the Principal Collector's letter accompanying the Civil Engineer's Report on the Cauvery, dated 29th November 1832; where it is stated that the Talooks under the Cauvery produced no less than 165,000 Cullums more than the preceding year, which in the Principal Collector's judgment was mainly owing to the closing of the Govindoo Calagum; and my observations upon the river and district satisfy me that this conclusion was correct. But the effect of this measure could not be permanent, for it was by means of this opening that the sand from the head of the Cauvery was carried into the Colleroon, and consequently after being closed for some time, the sand would again gradually accumulate, and the proportion of water entering the Cauvery be gradually reduced to its former amount, which effect has already been almost or entirely produced.

3d. The undersluices now under execution at the head of Seringam, or just completed, are calculated to remedy this, by enabling us to let off or retain the water at pleasure; and that they will in a few years have a very great effect in this respect, as well as in preventing the danger and inconvenience arising from too much sand passing down into the lower part of the Cauvery, I have no doubt; but after considering the case very many times, and indeed rarely passing a day without giving some attention to the subject, I feel satisfied that the construction of an annicut across the head of the Colleroon is the only effectual, and in every respect advisable work, for economizing the water during low and moderate freshes. Before entering further upon this part of the subject, I will give a statement of the extent of cultivation, and the quantity of water required for it under the different rivers.

	<i>Under the Cauvery.</i>		<i>Cubic Yards water required per hour.</i>
	<i>Vaylies.</i>	<i>Rs.</i>	
In Trichinopoly about	2,500	100,000	
In Tanjore.....	74,000	3,000,000	
	76,500	3,100,000	1,530,000
	<i>Under the Colleroon.</i>		
In Trichinopoly	5,500	250,000	
In Tanjore.....	10,500	450,000	
In South Arcot.....	9,000	400,000	
	25,000	1,100,000	500,000
	101,500	4,200,000	2,030,000

The total extent, therefore, is about 101,500 Vaylies, a full supply of water for which would be about 2,000,000 Cubic yards per hour. By actual measurements I have ascertained that there is about this quantity of water in the Agunda Cauvery when the water at the Grand Annicut is within $\frac{3}{4}$ feet of the crown of that work; at present, in moderate freshes, the water that comes down the Agunda Cauvery divides nearly equally, half going down the Cauvery, and half down the Colleroon.

	<i>Cub. yds. per hour.</i>	<i>Sufficient for Vaylie.</i>	<i>Act. ext. Vaylie.</i>	<i>Quantity of water req.</i>
In the Colleroon	1,000,000	50,000	19,500	390,000
In the Cauvery	1,000,000	50,000	76,500	1,530,000

Hence while 600,000 Cubic yards per hour are running to waste into the Sea by the Colleroon, the same quantity is required to complete the supply in the Cauvery. Again, Tanjore is not considered abundantly supplied, that is, under the present imperfect distribution of its water, till the river rises to $1\frac{1}{2}$ foot above the Crown of the Grand Annicut; at which time there are in the Colleroon 3,000,000 Cubic yards, while the quantity required is 400,000; the remaining 2,600,000 flowing into the Sea, excepting a very small part which is received into the Veeranum Tank in South Arcot; hence Tanjore does not get an abundant supply till there is nearly 2,600,000 Cubic yards, more water in the Agunda Cauvery than is wanted for all the cultivation under both rivers. That there is therefore a most important and valuable supply of water constantly lost there can be no doubt, and the next point to be ascertained is, the reality and extent of advantage to be obtained by preventing this waste.

1st. It appears by returns of the gross produce of the Tanjore District (on the lands at present entered as Nunjay) so far as it could be ascertained, that the difference between the actual and Dittum produce is on an

average certainly more than 1,200,000 Cullums, worth 6 lacs of Rupees; the Government share of which would be 3 lacs, besides the other 3 lacs, a considerable portion of which would find its way into the Treasury in the shape of duties &c. Copies of the returns here referred to were forwarded to the Inspector General on the 7th July.

2d. That this difference is chiefly, if not entirely, owing to the defective supply of water, is clearly proved from the same returns, which shew that last year the Cauvery cultivation exceeded that of the preceding year by 3,000 Rupees, while that of the Vennaur had fallen off to the amount of 50,000 Rupees; and as this difference of the ratio of produce under the two rivers occurred in the same season, it is clear that it must have been wholly owing to the unequal distribution of the supply of water; that is, other circumstances being the same, the produce is increased by an increased supply of water.

3d. To determine the value of any quantity of additional water thrown into the district, we may take the value of the produce of a Vaylie of Paddy at 80 Rupees, and as this requires about 75,000 Cubic yards of water to bring it to perfection, 1,000 Cubic yards per Rupee may be taken as the lowest value; when the crop is perishing it may be worth five or ten times that sum. I calculated on one occasion, when I found a Merrassidar watering his fields by means of a Pacottah, that it cost him more than 1 Rupee per 400 Cubic yards. Hence from the abovementioned calculation of the quantity of water in each river, when it is $\frac{3}{4}$ feet below the Grand Annicut, it appears that water of the value at least of 14,400 Rupees per day is lost; and this is the greatest quantity that it could be necessary to transfer from one river to the other; if the distribution were carefully adjusted.

4th It is next to be ascertained, on how many days the water does now reach a certain height in the Cauvery, and how many more it will be brought to that height, if no water were permitted to escape into the Sea; thus in the year 1833, the water was up to the crown of the Grand Annicut, or above it, on 66 days; and it might have been raised to that height, still leaving a sufficient supply for the Colleroon, on 30 additional days; and in 1831, when the actual number of days was 47, it might have been raised to that height on 48 additional days, thus more than doubling the number on which there would have been a pretty good supply for the whole district. Again in the year 1831, it appears that the water was at the height of $1\frac{1}{2}$ feet above the crown, (the greatest height that can be required), on 10 days, and that it might have been raised to that height on 37 additional days, increasing the number of days nearly five-fold; this was an unusual year in that respect, but on an average the number of days on which it would rise to that height, might be doubled. Upon the whole, additional water might be thrown into the district with advantage, and without taking too much from the Colleroon, on about 100 days in the year, the whole time

of cultivation being 240 days, and the time occupied in the cultivation of the main crop being about 150 days, on 50 of which there is generally an ample supply. It should be observed that all these calculations suppose that sufficient water will be left in the Colleroon for a full supply for the cultivation under that river, but if the water was distributed proportionally to all the different rivers, Tanjore would be still further benefitted; thus I find, that taking an average year, there was water enough on about 160 days, to afford $\frac{2}{3}$ of a full supply to the whole of the Cauvery and Colleroon cultivation, if it had been proportionally distributed. But perhaps the best judgment of the effect of preventing the water from running to waste may be formed, by taking for example one day during the most critical time of the year in Tanjore, viz. between the two Monsoons, or what is called the "September drought;" I find, that on the worst day of that period, for a series of years, the water rose to within 3 feet 8 inches of the crown of the Grand Annicut; Tanjore then received about $\frac{1}{3}$ of a full supply, whereas there was in the Agunda Cauvery $\frac{1}{3}$ of a full supply for all the cultivation; probably there was as much running into the Sea at that time as would have increased the Tanjore portion, from $\frac{1}{3}$ to $\frac{2}{3}$, or to the extent of 200,000 Cubic yards per hour, which at that critical time would be certainly worth 10,000 Rupees per day.

4th. I think from these statements a very tolerable judgment may be formed of the prodigious effect of any work that would give the Government the entire command of the water during the low and moderate freshes, as respects Tanjore; its effect upon Trichinopoly will be more complete, because the channels in that District bearing only a small proportion to the size of the river, their supply will be always abundant; and this brings me to one of the principal advantages which the Annicut will possess over any other work, viz. that it will almost entirely put an end to the disputes which have arisen between Tanjore and Trichinopoly, respecting the extension of the Head of Seringam &c.; for the Lall-goody Channels will be led off from the Annicut, and thus rendered secure of a supply of water as long as there is any at all in the river, and the annual expense of 2 or 3,000 Rupees upon Corumboos will be saved; a sum which, trifling as it is, compared with the other advantages to be expected, is of itself actually almost sufficient to make the construction of an annicut advisable. The Vyacondam, the largest of the Trichinopoly channels, which leads off from the South bank of the Agunda Cauvery, about 8 miles above the head of Seringam also, would be somewhat benefitted by the proposed Annicut. I should here also mention another very important effect of the annicut; and that is, that the whole crop would be brought so forward, both by enabling them to cultivate sooner, and also by diminishing the chance of the growth of the crop being checked by scarcity of water, as to make the harvest on a very great portion of the lands nearly a month earlier than it is at present, and so to leave a much more abundant supply for the two crop lands during January and February.

For in the month of June and July, a great quantity of water is allowed to run to waste, because the Ryots cannot be certain of a continued supply sufficiently abundant to make it prudent for them to begin the cultivation; but if the supply were increased in those months, a great proportion of the lands might be cultivated earlier, with safety; and again, much of the crop which is not ultimately lost is greatly retarded in its growth, and its produce diminished, by an inadequate supply of water during the "September drought."

5th. The benefits to be expected, therefore, from an annicut may be divided into the following;

1st. An increased supply of water in Tanjore on 100 days, (counting those only on which the supply was deficient,) the quantity varying from nothing to 1,500,000 Cubic yards per hour, or averaging 500,000 Cubic yards per hour, and amounting in all to 1,200 million, or $\frac{1}{3}$ of the total quantity that Tanjore receives at present on an average, viz. 6,000 Million.

2d. It would entirely put an end to all disputes about the extension of the head of Seringam &c.

3d. It would free the Trichinopoly Ryots of Laulgoody entirely, and those of Seringam and part of Co-naud in some measure, from the trouble and expense of making Corumboos, and render the supply of water to their lands almost certain.

4th. It would enable the people to use the early and partial freshes to a much greater extent than at present, and make the crop more rapid in its growth, and by both the harvest would be earlier, and consequently a more abundant supply would be left for the late lands.

5th. It will greatly increase the effect of the under-slucices; both by enabling us to open them oftener, and also by giving a greater head of water; and hence there will be a more complete controul over the level of the bed of the Cauvery, which is very important.

6th. With respect to the actual amount of increase of revenue, I have not any doubt that the following sums may be safely reckoned upon, viz.

In Tanjore.....	100,000
In Trichinopoly....	15,000

Total.. 115,000 Rs.

That is, from the lands at present cultivated, and on the same crops; and I think also that besides this much land may be converted from one crop to two crop land, and much Poonjay may be converted into Nunjay.

7th. The expense of the work will of course depend much upon the materials of which it may be thought advisable to construct it; the Estimate I have prepared amounts to Rupees 76,450—9—0.

viz. Annicut.....	67,911..12..0
Sluice and new head to Iyea Voikal in Trichinopoly	8,538..13..0

Total Rupees.. 76,450.. 9..0

The materials I propose, are brick for the foundation and retaining walls in front and rear, rough stone and

clay for the body of the work, and cut stone for the crown and the lining of the sluices; of which sluices I propose to have 14 in different parts of the Annicut. There is great abundance of stones within $1\frac{1}{2}$ miles of the place, and they are much preferable to brick, on account of the difficulty of getting a sufficient quantity of wood to burn the latter. The expense of the work might be reduced 9,000 Rupees, by omitting the coping of cut stone, and reducing the breadth of the dam one yard. The Grand Annicut has no stone coping, being covered with jelly throughout, which requires repairs every three or four years; the stone therefore might be omitted without danger, though not without inconvenience; and I am not sure that there would be any disadvantage in reducing the breadth 1 yard. It might be finished with jelly at first, and afterwards covered with cut stone, if it appeared desirable, with but little greater expense than it would take to complete it with cut stone at once. There are already on the spot 4 lacs of bricks and 1,500 Cubic feet of stone remaining from the works lately constructed near the head of Seringam.

8th. With respect to the scite, I find a most convenient one about 100 yards below the obelisk lately erected at the head of Seringam; the channel being there divided into three parts by two islands, which would greatly facilitate the work; first, by enabling us to close one part at a time, and so to begin very early in the year, and to be quite independent of any such freshes as ordinarily occur during the dry months; this would give us 6 complete months for the execution of the work; and secondly, by affording us convenient situations for the accumulation of materials. They would also greatly assist us in draining the foundations. The section herewith forwarded was taken immediately at the obelisk, and only differs from that of the scite above mentioned, in having a second island in about the position shewn by the dotted line.

9th. I have given such a height to the Annicut, as will, so far as I am yet able to judge, exactly correspond with the Grand Annicut, that is, that when the water is even with the top of the planks of the one, it will be so also at the other. This I cannot determine with precision till the high freshes arise, when I purpose making accurate sections &c. It must however be remembered in doing this, that something must be allowed for the lowering of the head of the Cauvery by means of the new under-slucices, which will enable us to make the annicut rather lower than would appear necessary in the present state of the bed.

10th. With reference to the large sum required for this work, it may at once be provided for, in a great measure, by reducing the annual Estimate for Tanjore and Trichinopoly to nearly or entirely the amount. Every work in the former district, and in one Talook of the latter, may be postponed, excepting those which are emergent; and it will be necessary to suspend a very great number of works, some of them as being rendered quite useless by the Annicut, and some as being so much affected by the change in the state of the river, that it would be im-

possible to plan them till the effects of the annicut had been actually witnessed; thus works to the amount of about 50,000 Rupees in Tanjore, and 5,000 Rupees in Trichinopoly, might be deferred, a great portion of which would probably not be required at all. It would at least be well worth while to suspend the clearing of the irrigation channels for one year, rather than give up a work which promises such great results. The average expense of Maramut in these two districts is about 130,000 Rupees, the amount might be confined for the next year to 75,000 or less.

11th. I must particularly observe, that there will be this great difference between this and all ordinary plans for the improvement of the irrigation, viz. *that the returns will be immediate*; the water is to be applied to lands already in cultivation, and fully stocked, and the labour and capital required will be less, instead of more than formerly, and hence, within the first ten months from the completion of the work, one year's amount of increase will be paid into the Treasury; this is completely proved by the fact mentioned above, that in consequence of the additional water thrown into the Cauvery, an additional produce of 160,000 Cullums, yielding to Government a revenue of about 40,000 Rupees was obtained the same year. I have scarcely a doubt, that if this work is constructed, an addition of a lac of Rupees will be paid into the Treasury by the following July.

12th. Several objections to this work have occurred to me; I will mention those that might appear most serious;

1st. The supply will be cut off from the lower part of the Colleroon; to this the answer is, that whatever quantity may be required, may be let off by means of the different sluices; the Annicut being only intended to reserve that which at present is entirely wasted, by escaping into the sea; but on this point I propose to write more particularly when I report upon the works in that part of the Division.

2d. It will raise the water in high freshes, and endanger the banks of the river above. How very small an effect it will have in this way is easily seen, by referring to the section, where it will be found that though the obstruction caused by the dam is great in low freshes, it bears but a small proportion to the whole section in the extreme freshes, which is the only time it could do any harm. For it must not only raise the surface of the Colleroon, but also of the Cauvery; the whole section being about 5,500 square yards, and the section obstructed 1,050, or less than $\frac{1}{5}$; and hence such a head of water as would increase the velocity at that point $\frac{1}{2}$, would be sufficient, viz. 1,200 yards per hour; or 1 foot per second; and this would be produced by a head of water of $\frac{1}{2}$ inch; this may be judged of by comparing the case of a bridge

whose piers were $\frac{1}{2}$ the breadth of the arches, standing in a current of about $3\frac{1}{2}$ miles per hour.

3d. It will throw more water into the Cauvery in high freshes, and endanger the banks in Tanjore—provision is already made for this by the new Calingulah on Seringam, which would let off many times as much as the additional water thrown in.

4th. The sand will be obstructed and diverted into the Cauvery—provision is made for this by 14 sluices in the annicut, and the extensive undersluices just finished.

13th. In conclusion I beg to state, that I have given this subject great attention, and that I have very fully, freely, and repeatedly discussed it with every person whom I have had opportunities of consulting on the subject; especially I have, in the main, the full approval of the Principal Collector of Tanjore, and the Collector of Trichinopoly, with both of whom I have had many conversations about it. And I do not hesitate to say, that in my judgment, equal results could not be produced by an expenditure of 5 lacs within the district of Tanjore, nor by an expenditure of three lacs in the most favorable tract that could be found in the Carnatic elsewhere; except at the head of the Vuddavaur in South Arcot, where a similar work would doubtless produce great, though not equal results.

14th. There is no obstacle to the execution of this work next year, there are already 4 lacs of bricks which may be made into cubes at any time, and a good stock of stones can be collected in the course of 2 or 3 months; a quantity of cut stone is also ready; the only thing which it would be desirable to make before the monsoon, are well bricks sufficient for the first part of the work. It would be also desirable that it should be taken into early consideration, because almost every decision respecting works in Tanjore and part of Trichinopoly must be affected by the determination on this point.

15th. I have endeavoured to avoid entering too much into detail in this letter, but I believe I have given all the information necessary; and if any particular point has not been sufficiently dwelt upon, I beg that you will do me the honor to call for my further explanation respecting it.

I have the honor to be,

Sir,

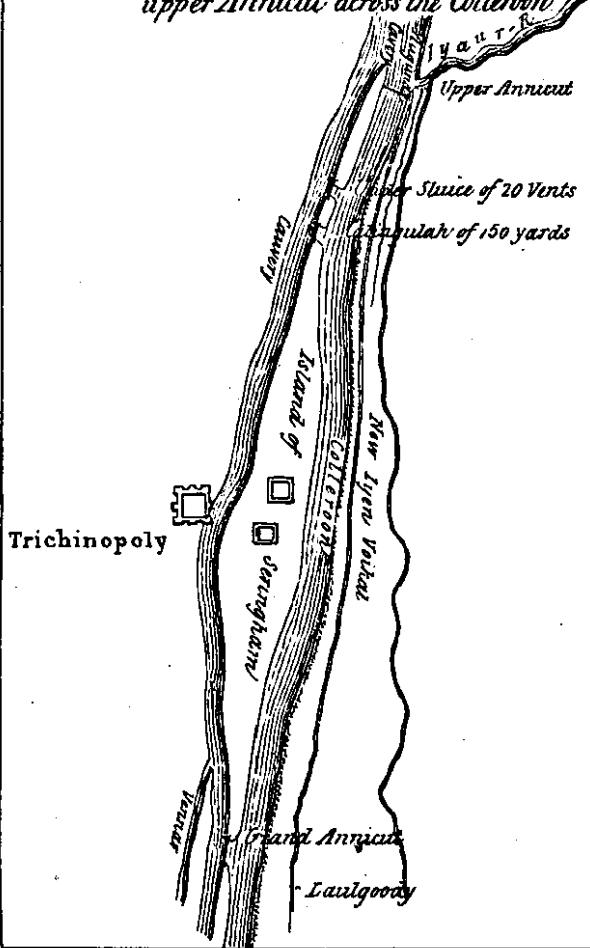
Your most obedient Servant,

A. T. COTTON,

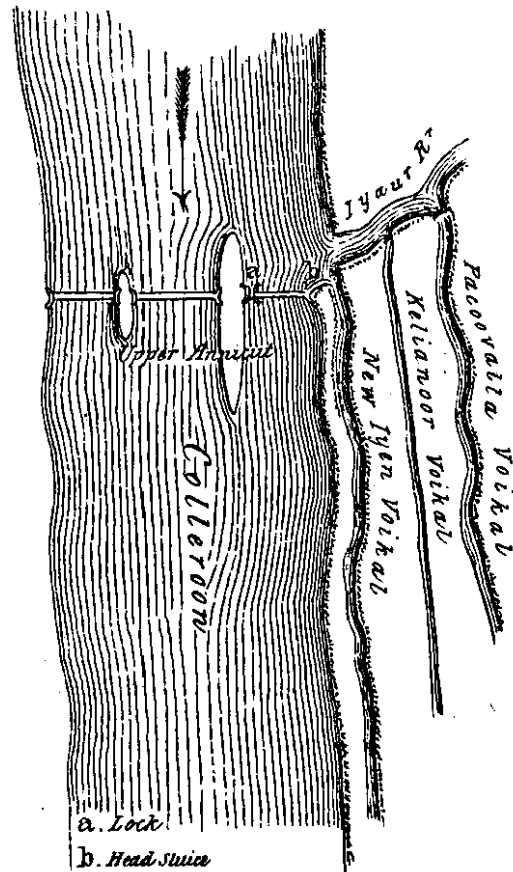
Captain, and Civil Engineer, 3d Division.

Tanjore District.
COMBACONUM TALOOK }
NEELATHOOR }
15th July 1834.

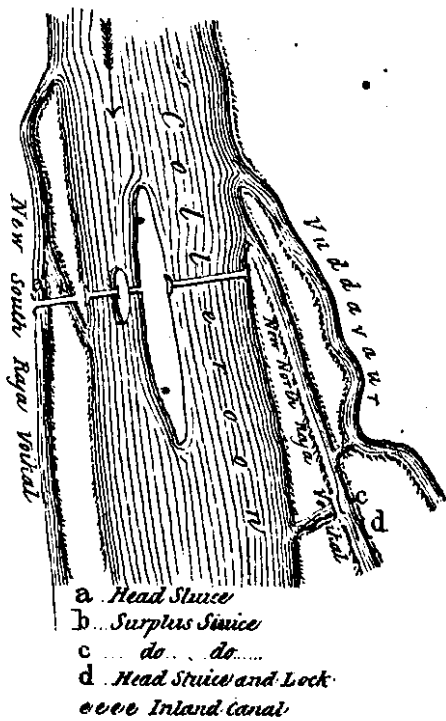
Sketch shewing the position of the upper Annicut across the Colleroon



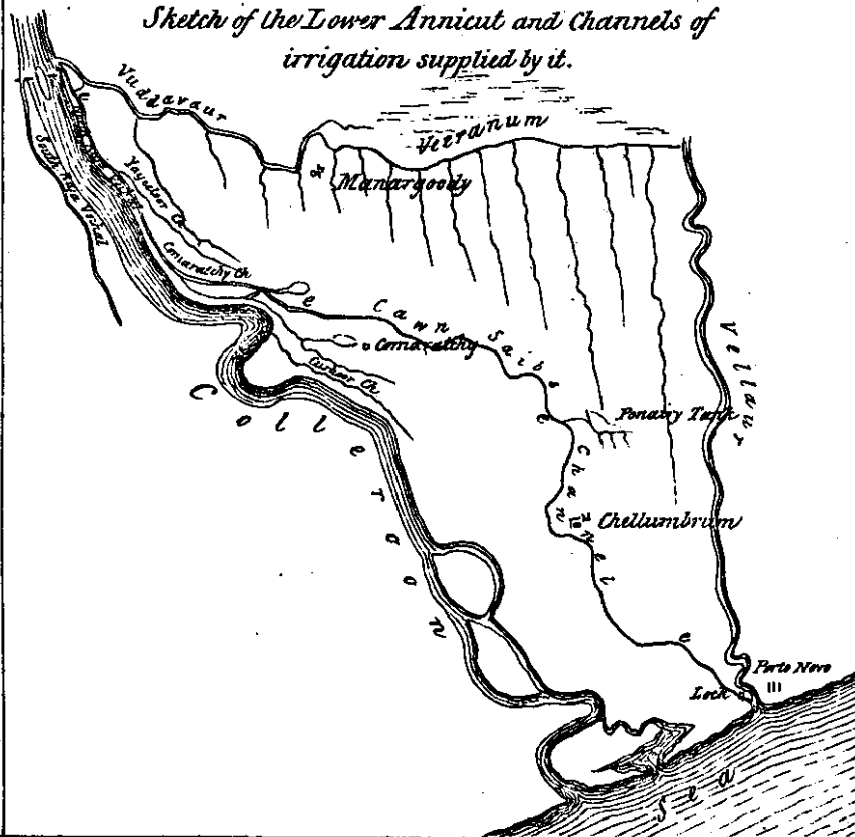
Upper Annicut on a large scale.



Lower Annicut on a large scale



Sketch of the Lower Annicut and Channels of irrigation supplied by it.



REPORT BY CAPTAIN A. T. COTTON.

To

*The Inspector General
of Civil Estimates,
Fort St. George.*

SIR,

I have the honor to transmit a report upon the two Southern Talooks of South Arcot.

Though this report is very far from being complete, it is still of greater length than was desirable for the present purpose, but I considered it very necessary to leave such an account of these Talooks on record, as might serve in some measure as a guide to new Collectors or Civil Engineers on taking charge of the district or Division, in order that they might as soon as possible obtain a knowledge of the different works upon which the Revenue is almost entirely dependent; I now propose to give a more general view of the case.

These Talooks containing nothing but alluvial soil, are capable of being entirely cultivated as Nunjay, and they have accordingly been better provided with the means of irrigation than any other tract in the Carnatic.

The supply of water is almost entirely drawn from the Colleroon, by river channels; but these are supported by the largest tank in the country, being when full 25 miles in circumference. This Tank is partly supplied from the Colleroon, but the present channel is not sufficiently large to fill it. It always receives a considerable supply from the local rains in the North East Monsoon, but with both these helps it is not filled every year. On by far the greater part of the land there is at present only one crop; the seed beds are generally prepared in the end of July and in August, and the crop is cut in February. The cultivation is therefore begun by the water from the South West Monsoon, but the securing the crop entirely depends upon the North East Monsoon. In this respect they are circumstanced similarly to Tanjore, being dependent upon the same river, but in two respects they have greatly the advantage of that district. 1st. The waters of the Agunda Cauvery divide nearly equally at the head of Seringam, one half having to supply nearly all Tanjore, or nearly 100,000 Vaylies, the other only these Talooks and a small part of Tanjore, about 10,000 Vaylies. 2d. They have, as above stated, the aid of a vast Tank.

By the Annicut returns it appears, that there is always abundant water in the Colleroon for these Talooks during the time of cultivation.

They may also be said to be circumstanced similarly to the other Talooks in South Arcot &c., as being dependent on the North East Monsoon, but the great difference between them and others is, that they are not dependent upon the local rains, but on a river which flows through so great an extent of country, that it always obtains a

supply of water in some part of its course, even in the most unfavourable Monsoons.

The following is a statement of the amount of Revenue collected in several years.

Average of first three Years of Company's

Management.....	203,000
Fusly 1238.....	141,000
1239.....	195,000
1240.....	163,000
1241.....	105,000
1242.....	144,000
1243.....	173,000
	921,000

Average of last six years..... 153,000
Estimated for 1234..... 230,000

From this it appears, 1st. That the average of the last 6 years, is 50,000 Rupees less than that of the first 3 years of the Company's Management.

2d. That in Fusly 41, it was 98,000 Rupees less than the average of the first 3 years; 3d. That the estimated amount of the present year is 125,000 Rupees more than the revenue of 41, and 90,000 above the average of the last 3 years. Yet in all these years there has been abundance of water in the Colleroon, and the rapid increase of revenue in the last years shews, that it was not kept down by the want of population or capital. Upon a most careful enquiry into the state of these Talooks, I am quite satisfied, that with the supply of water procurable, if the irrigation works had been kept in any tolerable order, there would have been a steady revenue of 300,000 Rs. during the last 6 years, being in all nearly 9 lacs of Rupees more than was collected; but I feel confident, that had they been properly attended to from the beginning of the Company's management, they would during the last 6 years have yielded 12 lacs more than they have. The fact that Tanjore, dependent upon the same river, but under far less favourable circumstances, has regularly advanced, shews plainly what ought to have been the case with these Talooks.

The real and undoubted cause of the deficiency is, principally, the want of a proper care to have the heads of the channels cleared out, and the Coroomboos (or temporary embankments in the bed of the river) constructed at proper times.

That much of the evils may be remedied by attending to these things in future, is proved by the increase of revenue which has taken place under the present Principal Collector, and which is entirely owing to the improved management in those points; but the only complete and effectual plan for securing the irrigation of these Talooks, is the construction of the proposed Annicut at the head of the Vuddavaur, with the subordinate

works attached to it, and by means of which also, the District of Tanjore will be most materially benefited; immediately in two respects, and ultimately in a third.—

1st. By giving the complete command of the water in the lower part of the Colleroon it will enable us to direct the greatest possible quantity into Tanjore by the Cauvery. 2d. By throwing a larger supply of water into the Veeraunum Tank in the high freshes, it will make these Talooks more independent of the river in the latter part of the season, and so leave a larger proportion of the water of Agunda Cauvery disposable for Tanjore; and, 3d. A channel may be carried off from the Southern end of the Annicut, to improve the irrigation of the North East Talooks of Tanjore, and to irrigate about 3000 Vaylies at present waste in that part of the District.

I however consider, that with respect to the two Talooks alone, no work will answer so well as the proposed Annicut. I cannot estimate the future revenue, if it is constructed, at less than 300,000 Rupees, or 110,000 more than the average of the last 6 years, and I think it may continue to increase up to 4 lacs, or more, if the other works mentioned in the accompanying report are executed; for the following reasons:

1st. All the Natives in the Talooks agree in saying that they once yielded 5 or 6 lacs;

2d. They yielded 2 lacs after a long season of anarchy and misrule.

3d. Since that time the population has certainly much increased.

4th. There are not less than 35,000 Cawnies, that I know of, fit for Nunjay (besides Manniems) and I am sure that there are many more; the revenue of this extent of Nunjay, would be 3½ lacs, besides which there would be some Poonjay, I do not therefore hesitate to reckon that, at the very least, the proposed work will cause an increase of 1 lac upon the average of the last 6 years, besides generally improving the state of the people, and so increasing the other branches of revenue, and besides the

advantages to Tanjore. The amount of the estimate for the Annicut, Rajah Voykal &c. is 135,236—1—6 Rs.

The other advantages of the Annicut, besides the increase to the revenue are, that it will be a permanent work, and consequently it will diminish the Annual Expences, and the trouble of constructing the Coroomboos, clearing the heads of channels &c. Also, in excavating the Rajah Voykal, 12 miles of the River bank will be put in complete order.

The plan also provides for a great improvement in the water-communication for the trade, arrangements being made for the boats passing by the channels from the Annicut to Porto Novo, in which line there will be a constant supply of water for about 8 months in the year, with the means of tracking, and freedom from many of the disadvantages of the river navigation.

I cannot conclude this letter without recommending the state of these Talooks to the most serious consideration of the Board, as showing most clearly how very far the irrigation has been from obtaining that degree of care which it requires. That such should have been the result of 30 years of peace under the Company's management, in Talooks which require nothing but water to make them most productive, and a supply of water being at hand, shows certainly that much may be done yet to improve the Tank Department, and that there is little room to doubt that the expense of an increased number of Officers, Surveyors &c. to manage the irrigation would be very much less than that hitherto incurred in loss of revenue, without taking into consideration the vast amount of distress among the people, which such fluctuations of revenue most certainly indicate.

I have the honor to be,

Sir,

Your most obedient Servant,

(Signed) A. T. COTTON, *Captain,*
Civil Engineer, 3d Division.

MADRAS, }
3d June 1835. }

REPORT UPON THE IRRIGATION OF THE TALOOKS OF CHELLUMBRUM AND MAUNARGOODY IN SOUTH ARCOT.

These, the most southern Talooks of Arcot, are bounded by the Colleroon on the south, the Vellaur on the north, and the Sea on the east, the western side being bounded by Woorapolliam. Their extent is about 25 miles from east to west, and 12 miles from north to south, on an average. A considerable portion near the coast is covered with jungle and sand, and being flooded by the salt water, is unfit for cultivation; but all the rest is alluvial soil of middling and good quality, a great portion of it fit for Poonjay cultivation, and the whole fit for Nunjay, if supplied with water. The most remarkable circumstance in these Talooks is, the great difference in their state from that of those in the opposite side of

the Colleroon; the population, cultivation, and appearance in the latter being so much greater than in the former, though the former have a vast advantage both in point of the source of their supply of water and in the nature of the works of irrigation. From what information I could obtain on the spot, I conclude, that the revenue once obtained from these Talooks was 5 or 6 lacs of Rupees. This is highly probable from the extent of land which appears to have been formerly cultivated, and also from the revenue realized at the time the Company took them under their own management, viz. Rupees 210,911—0—1. It is well known that all the countries north of the Colleroon have been reduced to a state much

below their former condition by the Polygar and Mysore wars, and hence you may conclude, that the revenue realized soon after the conclusion of that period of confusion, was much less than that realized before it commenced.

I cannot be certain of the extent of Nunjay land at the most flourishing period, but I should suppose it was not less than 50,000 Cawnies, and probably considerably more. I have accounts of about 35,000 Cawnies, and have seen a great extent besides.

I conclude from the revenue, that about 25,000 Cawnies of Nunjay land were assessed when the Company assumed charge, besides about 5,000 Cawnies of Enam lands. The least quantity that appears ever to have been cultivated was in 1831, when only about 6,500 Cawnies were cultivated.

These Talooks have of late years been almost entirely supplied by the Coleroon, but they have formerly also received a small supply from the Vellaur; at present they receive none from the latter river, and all to whom I spoke on the subject agree in wishing to get it from the Coleroon, because the water brought by the Vellaur is

impregnated with lime, and is on that account less fit for the purposes of irrigation. The following Table of collections, extracted from the Principal Collector's letter of the 22d December 1834, will show the fluctuations since the Company took them in charge.

	Amount of settlement.				Balance remaining uncultivated, and those remitted.				Net collections.			
	Ms.	Rs.	A.	P.	Ms.	Rs.	A.	P.	Ms.	Rs.	A.	P.
Fusly 1215	210,911	0	1		0	0	0		210,911	0	1	
" 1216	176,970	2	9		0	0	0		176,970	2	9	
" 1217	220,328	9	7		0	0	0		220,328	9	7	
Total..	608,209	12	5		0	0	0		608,209	12	5	
Average	202,736	9	5		0	0	0		202,736	9	5	
" 1218	216,509	5	6		3,490	6	0		213,019	1	6	
" 1219	220,379	7	1		51,391	1	7		168,988	5	6	
" 1220	224,563	8	8		28,295	1	0		196,268	7	8	
Total..	661,452	5	3		3,176	6	7		578,275	14	8	
Average	220,484	1	9		27,225	7	6		192,758	10	3	

		Amount of settlement.				Balance remaining uncultivated, and those remitted.				Net collections.			
		Ms.	Rs.	A.	P.	Ms.	Rs.	R.	P.	Ms.	R.	A.	P.
Fusly 1221	N. B. This is not the amount of Teerwah of the lands actually cultivated in each year but the amount of the rent.	118,054	5	6		2,915	4	4		115,139	1	2	
" 1222		155,425	13	8		1,668	11	8		153,757	2	0	
" 1223		182,774	0	6		1,905	5	10		180,868	10	8	
" 1224		194,499	13	0		5,015	8	1		189,484	4	11	
" 1225		191,901	2	6		4,810	5	9		187,090	12	9	
" 1226		202,454	12	10		2,302	8	6		200,152	4	4	
" 1227		208,505	11	2		1,928	9	7		206,577	1	7	
" 1228		209,995	1	3		17,986	4	5		192,008	12	10	
" 1229		218,015	0	10		20,983	7	11		197,031	8	11	
" 1230		218,746	13	3		17,135	15	6		201,610	13	9	
Total..		1,900,372	10	6		76,652	1	7		1,823,720	8	11	
Average		190,037	4	3		7,666	3	4		182,372	0	11	
" 1231		158,129	8	2		10,153	3	2		147,976	5	0	
" 1232		215,579	12	4		2,309	12	2		213,270	0	2	
" 1233		172,131	3	1		1,048	5	10		171,082	13	3	
" 1234		196,505	10	0		7,562	11	10		188,942	14	2	
" 1235		205,954	1	3		8,006	7	5		197,947	9	10	
" 1236		195,339	15	6		16,781	5	0		178,558	10	6	
" 1237		150,960	6	4		3,013	6	5		147,946	15	11	
" 1238		143,966	8	4		2,685	15	7		141,280	8	9	
" 1239		197,573	0	4		2,105	6	5		195,467	9	11	
" 1240		168,082	10	6		5,217	5	10		162,865	4	8	
" 1241		148,519	13	9		3,085	1	7		145,434	12	2	
" 1242		184,232	12	3		130	7	11		184,102	4	4	
" 1243		213,443	6	10		425	9	7		213,017	13	3	
Total from Fusly 1241 to 1243		546,196	0	10		3,641	3	1		542,554	13	9	
Average		182,065	5	7		1,213	11	8		180,851	9	11	
Estimate for Fusly 1244		270,000	0	0		0	0	0		0	0	0	

Upon this statement of the collections I have to remark, that almost all the revenue is derived from lands registered as Nunjay, and only cultivated as Poonjay, when they cannot obtain water; and secondly, that I find by the tables of the height of water at the Grand Annicut, there is scarcely a year in which there is not 18 or more times as much water in the Colleroon, during a sufficient number of days in succession for the great crop on the whole of the lands, and hence the revenue being almost wholly derived from Nunjay lands, and there being almost if not quite every year, a sufficiency of water in the river, it follows that the fluctuations of the revenue indicate almost exactly the comparative efficiency or inefficiency of the works of irrigation.

However, in comparing the state of these Talooks with those of Tanjore, it will be necessary to observe, first, that, as I believe, the assessment in South Arcot, at least on the better class of lands, is higher, and secondly, (which certainly has a material influence upon the prosperity of the Talooks,) the lands are in South Arcot considered as belonging to the Circar, and hence all sales are obliged to be made privately, and no body feels that kind of security in his possession of land, which will induce him to improve it to the utmost.

I must further remark, that in the worst year in the above Table, viz. 1,241, when hardly 7,400 Cawnies were cultivated, not only was there abundance of water in the Colleroon, but there was much more than in 43 and 44, as the following table will shew.

HEIGHTS OF WATER AT THE GRAND ANNICUT.

	General average of 20 years.		1831.		1832.		1833.		1834.	
			above.	below.	above.	below.	above.	below.	above.	below.
June	B	2 8 $\frac{3}{8}$	0 0	1 4	0 0	1 17	0 0	2 2	0 0	1 6
July	A	0 1 $\frac{3}{8}$	0 0	0 11	2 1	0 0	0 11	0 0	0 0	0 7
August	A	0 9 $\frac{1}{2}$	0 8	0 0	1 12	0 0	0 0	0 10	0 11	0 0
September	B	0 3 $\frac{7}{8}$	0 0	0 3 $\frac{1}{2}$	0 0	0 6	0 0	0 2	0 0	0 5
October	B	0 1 $\frac{7}{16}$	0 3 $\frac{3}{16}$	0 0	0 13 $\frac{3}{8}$	0 0	0 16 $\frac{1}{4}$	0 0	0 0	0 8
November	B	0 10 $\frac{2}{16}$	0 0	0 10	0 0	1 15	0 0	0 13	0 0	2 5
December	B	1 12 $\frac{3}{8}$	0 0	1 4	0 0	2 16	0 0	2 13	0 0	3 2
January	B	1 12 $\frac{1}{8}$	0 0	2 11	0 0	3 10	0 0	3 16	0 0	3 14
			11 $\frac{3}{16}$	6 7 $\frac{3}{8}$	4 8	10 10	1 9	9 10	0 11	12 3
			6 $\frac{13}{16}$	11 $\frac{3}{16}$		4 8		1 9		11
			8)6	8)5 4 $\frac{2}{16}$		8)6 2		8)8 1		5)11 10
			0 13 $\frac{3}{8}$	0 13		0 14 $\frac{1}{2}$		1 0 $\frac{1}{2}$		1 8

In the source from which these Talooks are supplied with water, they have a vast advantage over Tanjore; the waters of the Agunda Cauvery are divided nearly equally, one half going to supply about 95,000 Vaylies under the Cauvery, and the other half about 10,000 Vaylies at present cultivated under the Colleroon; the Colleroon also receiving, between the head of Seringam, a great quantity of surplus water from the lands watered by the Cauvery. Hence, when there is only half a supply in the whole Cauvery for Tanjore, there is nearly five times enough in the Colleroon for its cultivation.

The principal works of Irrigation are, in Maunargoody,

- 1st. The Vuddavaur Channel.
- 2d. The Veeraunum Tank.
- 8d. The Vialoor Channel.

- In Chellumbrum,
- 1st. The Comaratchy Channel.
 - 2d. The Cawn Saib Ditto.
 - 3d. The Curpoor Ditto.
 - 4th. The Oolaur Ditto.
 - 5th. The Ponneiry.

There are other works of less consequence.

The following Table shews the Ayacut cultivation and revenue under each work, and the same for each of the last few years. The Vuddavaur conveys water from the Colleroon to the Veeraunum, but the fall is so small, that when the Veeraunum is full, the water in it is on a level with the head of the channel, so that if there was no water in the river, the Vuddavaur cultivation would be supplied by the Veeraunum, till it was nearly all expended; they are therefore to be considered as one work.

Ayacut	Vuddavaur and Veeraunum.		Vayloor Channel.		Comaratchy Channel.		Cawn Saib Channel.		Curpoor Channel.		Poonneiry.	
	Culti- vation.	Reve- nue.	Culti- vation.	Reve- nue.	Culti- vation.	Reve- nue.	Culti- vation.	Reve- nue.	Culti- vation.	Reve- nue.	Culti- vation.	Reve- nue.
	17,487	78,451	1,600	1,500,00	2,159	24,486	4,412	47,436	1,440	13,650	6,000	50,000
	Caw.	Rupees.	Caw.	Rupees.	Caw.	Rups.	Caw.	Rups.	Caw.	Rups.	Caw.	Rups.
Fusly 1239	6,804	78,009	1,000	8,000	929	10,362	1,422	14,415	1,015	9,690	423	3,905
40	6,439	72,717	900	7,000	275	2,826	754	6,239	732	6,987	229	2,552
41	5,241	49,181	900	7,000	189	1,718	531	4,428	466	4,329	77	629
42	7,882	72,212	1,000	8,000	482	4,923	1,538	13,788	723	6,696	93	1,094
43	9,132	89,158	1,100	11,090	458	4,760	1,706	16,529	928	9,987	122	1,038
44	11,632	1,29,000	0	0	1,567	17,447	2,084	21,505	1,130	18,081	397	3,620

Fusly.	Total of Munnargoody Talook.		Manniem cultiva- tion.	Under the Vayloor chan- nel belonging to Trichi- nopoly.		Total of Chellum- brum.		Manniem cultiva- tion.	Total culti- vation ex- cept Man- niem.
	Caw.	Rs.		Caw.	Rs.	Caw.	Rs.		
	18,287	1,85,951	2,500	800	7,500	14,011	1,35,572	2,500	31,098
1239	7,300	82,000		500	4,000	3,589	38,372		8,389
40	6,900	76,200		450	3,500	1,990	18,604		9,340
41	5,700	52,700		450	3,500	1,270	11,004		7,420
42	8,400	76,000		530	4,000	2,836	26,501		11,336
43	9,700	94,500		550	5,500	3,204	31,314		13,464
44	12,200	135,000		600	6,000	5,178	52,653		17,978

From this table of 31,000 Cawnies, must be deducted 5,500 Cawnies formerly watered by the Ponneiry, but which I believe have not been cultivated since the company took the Talooks; leaving 25,500 Cawnies for the extent of land that may be watered by the works which are now in use; adding to this 500 Cawnies Manniem lands, makes a total of 30,500 Cawnies, for which water ought to be provided ultimately. The cultivation in 1241 was as low as 7,400 Cawnies, instead of 25,500. It has now increased to 18,000 Cawnies, or nearly $\frac{2}{3}$ of the whole, omitting the Ponneiry. From all the information I could obtain there seems no reason to doubt, that in a few years the lands would be fully cultivated, if water was provided, and hence reckoning 4 Cubic Yards per hour per Cawnie, the greatest quantity that can be required is 122,000 Cubic Yards per hour.

The following is an Estimate of the water required in each Month, as far as I could collect from the information of some of the principal Merassidars.

	Cubic Yds. of water.
1st May to 1st June.	
225 Cawnies of Seed bed for Cuddoopoo Car Crop at 4 Cubic yards per Cawnie..900 per hour.	
1st June to 5th June.	
1,275 Cawnies of seed bed for Chumba and Peeshanum Crop....	5,100
225 Cawnies of Do. for Cuddoopoo Car Crop	900
	<hr/> 6,000
5th June to 20th July.	
4,500 Cawnies of Cuddoopoo Car planted out	18,000

1,275 Do. of Chumba and Peeshanum Seed bed	5,100
	<hr/> 23,100

20th July to 5th September.	
4,500 Cawnies of Cuddoopoo Car plant- ed out	18,000
25,500 Do. of Chumba and Peeshanum planted out	102,000
	<hr/> 120,000

After the 5th September no water is required for Cud-
doopoo Car Crop, which is reaped in the beginning
of October.

From 5th of September to 20th November.	
25,500 Cawnies of Chumba and Peeshanum planted out	102,000

From 20th November to 20th December.	
25,500 Cawnies of Chumba and Peeshanum at 3 Cubic yards per Cawnie	76,500

The Chumba crop, 6,000 Cawnies, requires no water af-
ter the 20th December, being cut towards the end
of January.

From 20th December to 20th January.	
19,500 Cawnies of Peeshanum planted out, at 3 Cubic yards	58,500

Or the quantities may thus be stated.

	Cub. Yds. per hour.	
May	900	37,000
June	20,000	200,000
July	30,000	2,000,000
August	120,000	2,400,000
September	100,000	1,400,000
October	100,000	1,900,000
November	100,000	1,400,000
December	75,000	510,000
January	60,000	150,000

Of course nothing like exactness is pretended, tho' the dates are given; however, this Table is quite sufficient to enable us to judge of the quantity of water required throughout the season. The quantity of 4 Cubic Yards per hour has been proved in various ways to be about the quantity actually consumed on a large extent of lands, where the surplus water from the western lands, is again brought on the fields to the Eastward in the earlier parts of the season, when the weather is hot, the crop not grown up, and the ground not so completely saturated. Respecting the quantity I have allowed for the latter part of the season, I am not so certain; I have allowed 3 Cubic Yards per Cawnie per hour, but I am inclined to think that on the average of the alluvial lands, it will be much less than this, and certainly on some lands a very small quantity of water is required when they have been fully saturated, and the ground is completely shaded by the crop.

Thus for the whole of the lands in these Talooks, exclusive of the Ponneiry lands, 120,000 Cubic Yards is the most that can be required at a time, which might be conveyed by a Channel 30 yards broad, 2 yards depth of water, and with a velocity of 2,000 yards per hour, which is about the mean velocity in the Vuddavaur, when 6 feet deep. Of this quantity about $\frac{2}{3}$ is required for the Vuddavaur and Veersunum, and $\frac{1}{3}$ for the other Channels, which would therefore require a Raja Voykal Channel 10 yards broad and 2 deep, supposing its fall was the same as that of the Vuddavaur, but as the fall would be greater, the velocity would be about 2,500 Yards per hour, and hence a breadth of 8 Yards would be sufficient.

I will now make some remarks upon each of the works above enumerated.

The Vuddavaur, it will be seen by the Plan, is about $14\frac{1}{2}$ Miles long, 18 Yards broad at the head, and diminishing after the first mile to 12 Yards, and gradually to 10 Yards. For the first one mile the cutting is about $3\frac{1}{2}$ Yards deep, for the next two miles about $2\frac{1}{2}$ Yards, and towards the end about 3 Yards, but the last part of the Channel is a good deal raised by the deposition of mud.

The upper part for three miles, was cleared out to about the original depth last year. The head of this Channel was formerly carried about three miles higher up the river; the present head was probably cut to avoid the expense of clearing out so great a length of Channel, it was however a ruinous expedient, for a head of water of 6 feet was thus lost, and the supply proportionally diminished.

The fall of the channel for the first four miles is now one foot per mile; with the old head the fall of the first

7 miles must have been about $1\frac{1}{2}$ feet per mile, which would give an increased velocity of about $\frac{1}{2}$, that is, a Channel of the same capacity would convey about $\frac{1}{2}$ more water than it does at present. I should however now prefer widening the present head, to clearing out the old one. About $\frac{1}{2}$ a mile from the head are the wing and side walls of a sluice constructed in 1821 or 22, for the purpose of shutting out the river water when necessary. I am not aware what the reason was for which it was considered necessary to build this work, but I conclude it was done with the intention of preventing breaches in the Veersunum Tank, and if so, it was certainly a mistake, for the Tank is not breached by the water from the Colleroon, but by that from the Vellaur, and the rain which falls in its immediate neighbourhood. This seems to be evident from a comparison of the capacity of the Channel with the size of the Tank. The water passing down the channel, in an extreme fresh is,

$$22 \times 4\frac{1}{2} \times 3000 = 297,000 \text{ Cubic Yards}$$

per hour, or 7,000,000 per day. The Tank will contain about 70,000,000 Cubic Yards at the level at which the Calingulas are opened, and not less than 110,000,000 before it bursts, so that it would take 10 days of extreme fresh to fill the Tank entirely, even if the Calingulas and sluices were kept shut. It very rarely happens that the Colleroon and the Vellaur are extremely full at the same time, the heavy freshes in the former almost always happening in August from the South West Monsoon, and in the latter in general in consequence of violent storms in the Carnatic, which have occurred either in April or November. However, whatever was the cause of the construction of the sluice, it has been hitherto worse than useless. The people had been very anxious to have it removed, and in 1827, when I visited the spot, I was so far satisfied of its injurious effects, that I recommended the removal of the Cross stones to the Vents, though I had not sufficient knowledge of the localities nor sufficient experience, to know exactly the real state of the case. A few years after, the late Civil Engineer removed the piers, and left nothing but the side and wing walls. This is one of the works which has convinced me of the impossibility of the Tank Department being as efficient as it ought to be, without a more systematic enquiry into the circumstances of the irrigation works than has hitherto been attempted. From the great extent of a Civil Engineer's range, he cannot become in any tolerable degree acquainted with the local circumstances and the defects of the works in less time than several years, and as it seems impossible to avoid the constant change of Officers, the best remedy appears to be, that such a circumstantial report upon all important works should be prepared, as that both Collectors and Civil Engineers may, on taking charge, be enabled to inform themselves at once of their nature, dangers, defects, &c. It is with this view, that I wish to go into detail as much as my present information will admit, in this report.

The difference of levels of the deep bed of the Colleroon, and the bottom of the Vuddavaur &c. are as follows;

Deep bed of Colleroon below bed of Vuddavaur at its head.	2½ feet
Fall of Vuddavaur in first 4 miles.	4 feet
Do. 12 miles.	10 feet
Do. Do. 14½ miles near Calingula of Tank. Channel in the bed of the Tank.	12 feet level
Fall from Do. to the deep bed of the Vellaur.	2½ feet
Depth of water in Colleroon in extreme fresh.	18 feet
Depth of water in Vuddavaur Do.	15½ feet
Deep bed of Colleroon above Western or high level Calingula.	½ foot
Crown of Calingula above bed of Channel near it.	9 feet
Height of water when upper Calingula is opened above crown of Do.	3 feet
General level of deep part of bed of tank below crown of upper Calingula.	5 feet
Do. Do. below deep bed of Colleroon.	4½ feet
Height of water in Tank above crown of upper Calingula, when it bursts.	7 feet
Greatest height of water in Tank above deep bed of Colleroon.	6½ feet
Difference of level between surface of Colleroon in an extreme fresh and surface of Tank when it bursts, (¾ feet per mile.)	11½ feet
Level of deep bed of Tank above bed of the Channel in its bed.	3 to 4 feet
Height of surface of Tank above deep bed of Colleroon, when the Calingula is first opened.	2½ feet
General depth of water in deep part of Tank when it bursts.	12 feet
Do. Do. when Calingula is first opened.	8 feet
Height of Crown of upper Calingula above deep bed of Vellaur.	11 feet
Do. of surface of water in Tank when Calingula is first opened, above deep bed of Vellaur.	14 feet
Do. extreme height of surface of Tank above Do.	18 feet
* Extreme depth of Vellaur about.	16 feet
Deep bed of Colleroon above deep bed of Vellaur.	12 feet

The general level of the deep part of the tank is level with the bed of the channel at 8 miles from its head, west of which point there are 10 Sluices in the bank of the Channel. When there is one yard water in the deep part of the Tank, the surface is level with the bed of the channel at 5 miles from its head, above which there are 6 sluices. From this table it will be seen,

1st. That in an extreme fresh in the Colleroon, there will be a fall of only ¾ foot per mile when the Tank is quite full, and hence the velocity in the Channel will be less than would at first be supposed.

2d. That almost the whole of the channel cultivation may be supplied from the Tank, as long as there is any moderate quantity of water in it.

3d. That as it generally happens that the floods in the Vellaur happen when the Colleroon is very low, the Channel acts as a Calingula, helping to relieve the Tank, and not to increase the water in it; for if there is less than 6½ feet water in the Colleroon, the water flows from

the Tank into that river, before the bund gives way.

4th. It appears that the surface of the Tank before it bursts is always above the level of the Vellaur, and consequently, that an extensive Calingula at the North end might very much diminish the danger of breaches.

5th. It is evident that to deepen the Channel in the bed of the Tank, or the last few miles of the Vuddavaur will make exceeding little difference in the supply of water, which must mainly depend upon the breadth and depth of the first 6 miles of the Vuddavaur; this must be particularly observed, because much money has hitherto been expended without much benefit, excepting as it raised and strengthened the bund of the Tank, and because the Meerassidars think that it is a matter of much importance to keep the channel in the Tank deep, and they have said to me, that, 10,000 Rupees a year ought to be expended upon this work, so little are they able to judge of the case.

Many other useful inferences may be drawn from this table of levels, but it is not necessary to mention more here.

The embankment of the Vuddavaur is generally abundantly high and strong, being formed of very strong earth, but in one or two places towards the Tank it is a little too low, and it will be raised there this year. The channel is cut thro' a very dense jungle, which if left to itself grows so strong on the sides of the Channel, as greatly to obstruct the flow of the water in the Channel itself; and much more, when the water rises above the level of the ground on which the jungle grows, which it does in many places, when there is more than 6 feet water in the head of the Channel. Two or three years ago the Civil Engineer had all the jungle cut on the sides of the Channel, and for several miles to a considerable breadth East and West of it, which was of great use, and I think it would be advisable to keep a clear space of not less than 40 yards broad the whole length of the Channel, which would cost but little, and have a material effect in increasing the supply during the high freshes, which is so very desirable.

The Vuddavaur and Veeraunum Cultivation thus has advantages which scarcely any other cultivation in the Country has; viz; 1st it is supplied by the most certain river in the Carnatic —

2d. It is very small in comparison with the size of the river, so that as long as there is about 1½ feet water in the river there is a full supply for the Vuddavaur. It appears from the Annicut returns of the last 20 years, that there is always every year abundance of water during the whole season of cultivation, or the average of these 20 years shows that in general there is from 2½ to 70 times as much as they require from 1st June to the 20th January, before and after which the quantity required is very small.

3d. Besides being supplied by the most certain of the rivers, it has the largest tank in the country, and that supplied from the same river.

From these things it is most certain, that if the works of Irrigation are properly managed, these lands would be the last in the whole country to want water.

The principal defects in these works at present are, 1st, The upper part of the Vuddavaur is too narrow

being quite disproportioned to the size of the Tank ; it ought to be of such dimensions as almost to ensure the Tank being filled up every fresh, and particularly in November and the beginning of December, in order to provide a supply when the river gets very low; and whatever water can be stored up in this Tank for the latter part of the season will be most valuable, because it will enable us to turn so much more water into Tanjore, where there is always too little at that time. If it were 30 yards broad at the head, the quantity passing down it in a good fresh would be,

$$30 \times 3 \times 2,500 = 225,000 \text{ per hour}$$

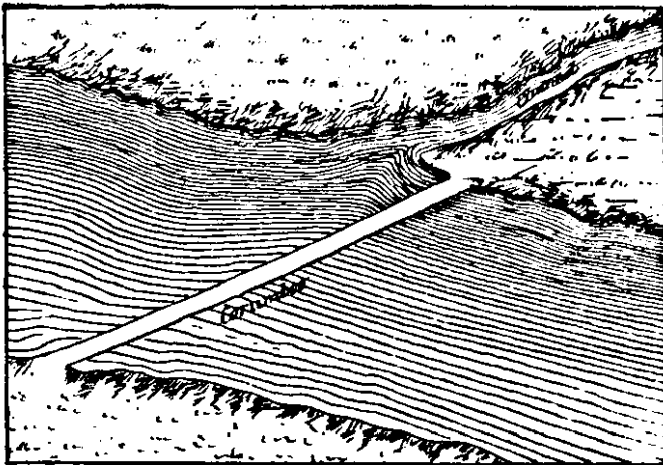
or 5,500,000 per day; and in an extreme fresh,

$$32 \times 4\frac{1}{2} \times 3,000 = 432,000 \text{ per hour}$$

or 10,000,000 per day, and it would then take 15 days with the first, and 8 days with the second height of water to fill the Tank; or if it was already half full, 7½ days with the first, and 4 days of the second to fill it up. This breadth, however, viz. 30 Yards, is more than it would be advisable to give it at present. If the breadth was increased to 30 yards at the head, and gradually diminishing to 15 at the lower end, the Estimate for widening it would be about $10 \times 2\frac{1}{2} \times 2,600 = 625,000$ at 10 pice = Rs. 32,500 0 0.

2d. The thickness of the Jungle on each side of the channel, which prevents the free flow of the water when it spreads beyond the bank of the channel, this may be corrected at a moderate expense.

I know of no other material defect in this work.



It will be proper in this place to explain, the method of filling the channel in the low freshes by means of a Corumboo. The bed of the channel near its head is, when cleared out, about 2 feet 6 inches above the level of the deep bed of the Colleroon; hence no water enters it, till the Colleroon is more than that depth, unless it is forced in by means of an embankment. When the depth in the Colleroon is 2½ feet, there may be about 200,000 Cubic Yards per hour passing down it, which is from 2 to 3 times as much as the channel requires; if the channel is neglected, there may therefore be no water in it, while there is a most abundant supply in the river. About the end of December it is generally necessary to begin the Corumboo, which consists of a bank

of sand intermixed with brushwood or grass. It is carried up obliquely across the bed of the river, and as soon as the stream is sufficiently small to enable them to close it by means of timbers and long fascines of straw &c. the Corumboo is completed, so as to turn the whole of the water into the channel, as represented in the figure.

It is evident that this cannot be accomplished till the body of the water in the river is very small. The Corumboo so constructed in the beginning of January, and which may cost 4 or 500 Rupees, often remains uninjured until the following freshes in May and June, and turns the water into the channel as long as the quantity that comes down is moderate. It becomes too serious a work to make the Corumboo more than about 5 feet high, and therefore it cannot throw more than 2½ ft. water into the channel, which gives 30,000 Cubic Yards per hour. This is with the present breadth of Channel. But it is evident, that whilst the stream of water is very small, the Corumboo answers almost perfectly the purpose of an Annicut. Hence also it is evident, that the construction of an Annicut at the head of Seringam need not in the least degree injure the cultivation of South Arcot. Just as much water as they can turn into the channel, by means of the Corumboo, may still be left in the Colleroon, and more would be of no use to them. But on the other hand an Annicut at the head of Seringam may be of material use to them, for by shutting its sluices, the water may be kept as low as possible while the Corumboo is constructing, which would enable them to close it much earlier than they possibly can at present.

Thus, supposing there was 4 feet water in the Colleroon on the 15th of December, the quantity passing down would be 70,000 Cubic Yards per hour, but as they could not construct a Corumboo in this stream, there would be only 1½ feet of water, or about 15,000 Cubic Yards per hour, or ½ of the quantity required in the Vuddavaur; there would then be about 650,000 Cubic Yards in the Cauvery, or ¼ of a full supply for Tanjore, and 685,000 Cubic Yards would be flowing to waste into the sea. Now at this time if there was an Annicut at the head of Seringam, Tanjore might be fully supplied, and the stream of the Colleroon lowered so much as to enable them to construct the Corumboo, by which means the water in the Vuddavaur might be made 2½ feet deep instead of 1½. This is a fair representation of circumstances, in the middle of December, and shows most clearly, that not only would an Annicut, double the supply to Tanjore and save 650,000 Cubic Yards of water per hour from running to waste, but that the supply to the Vuddavaur would be increased from 15,000 to 25,000 Cubic Yards per hour. And with respect to the supply to the Vuddavaur when there is more water than this in the Colleroon, as for instance, when there is 6 feet of water, supposing it were lowered to 5 feet by the quantity turned into Tanjore, this might easily be compensated by widening the head of the Vuddavaur.

If there happens a fresh in the hot months, the whole Corumboo is destroyed, and it is then necessary to reconstruct it in the beginning of May, to throw water into the channel if the early freshes, continue moderate.

Thus it is only necessary, in general, to construct the Corumboo once in the year, but sometimes twice.

It is next to be shown wherein the Corumboo is a defective work; that is, in what respect it will not answer instead of a regular Annicut.

1st. There may be only $\frac{1}{4}$ or $\frac{1}{10}$ of a supply of water in the channel, and yet there may be so large a body of water in the river, that the Corumboo cannot be closed; and at this time the crops may be seriously injured, if not destroyed.

2d. It cannot be made so high as to throw in a full supply, without vast trouble and expense.

Thus, to raise the water in the channel to the depth of 4 or 5 feet, the Corumboo must be made 10 or 12 feet high in the deep part of the river, which is a very great embankment to make on a foundation of sand.

3d. It cannot be used at all to assist in filling the Tank, whereas an Annicut would allow no water to pass till there was not only a full supply for the cultivation, but a considerable surplus besides flowing into the Tank. The Annicut would always increase the depth of water in the channel about $\frac{1}{2}$ a foot in the highest freshes, and 3 feet in the low ones.

4th. It is a work which requires to be continually renewed, and at that time of the year when the people are much wanted in the fields. In this country it is of far more consequence that work should be constructed on a permanent plan than in England, it being so much more difficult to get any work executed on emergency, on account of the extreme inertness of the people.

In short, an Annicut would, in the common course of things, render the whole irrigation of these Talooks quite secure. The supply of water is abundant, and therefore it is wholly owing to the defective state of the irrigation works if the whole revenue is not realized.

It appears to me, that the above account of the Corumboo proves completely, that there is no shadow of a reason for these Talooks suffering by the construction of the Seringam Annicut, but on the contrary, that it will be of use to them by facilitating the construction of the Corumboo. I do not mean to say that it is impossible that the Annicut should injure them, because of course by keeping the under sluices always shut it might injure them materially, but if we are never to construct a work, if there is any possibility of making an improper use of it, it is clear that we must do nothing.

Why should not these sluices be shut or opened as requisite, as well as every other Sluice and Calingula in the country? Indeed, it would be less liable to be unskillfully managed than any other work whatever, because so important an Annicut, must have the attention of all the Collectors and Civil Engineers concerned in it, directed first to it.

VEERAUNUM TANK.

The Veeraunum Tank has a bund about 10 miles long, and when filled to the level at which the Calingulas are opened, it is 25 miles in circumference, and more than that filled to the height at which it bursts.

Parallel with the bank in the bed of the Tank is a Channel, which forms the continuation of the Vudda-

vaur; such a channel is called the Totie of the Tank. The bed of it is on a level. It is about 17 yards broad and $1\frac{1}{2}$ deep. The deepest part of the Tank, excepting the Totie, has about 9 feet water in it when the Calingula is opened, and 13 feet when the bund gives way. The average depth is about 6 feet water when the Calingula is opened; and the surface at that time contains about 35,000,000 Square yards, or nearly 12 Square miles. The bed of the Totie is probably about the level of the original surface of the ground; the bed of the Tank appears to have risen in some part 9 feet, and on an average probably about 4 feet; hence the capacity of the Tank has been diminished about 40 million Cubic yards of the whole, which has made a very great difference in its value. It is evident that the Totie is of no use, except to prevent the water being wasted, by spreading over the bed of the Tank while there is yet only a small supply in the Vuddavaur, and some can be spared for filling the Tank. As long as there is any water in the bed of the Tank, the Totie is of no use. It has been customary in former years to lay out large sums in deepening the Totie, but on consideration it will be seen that this is matter of very small importance; the state of the Totie can have scarcely any perceptible effect on the quantity of water entering the head of the channel, which is 15 miles from the nearest end of it; the only thing required of the Totie is, that it should be sufficiently capacious to secure to the cultivation at the northern end of the bund a fair share of the water, so far as it can produce this effect, it is of use; but as it is, and must be on a dead level, this can never be completely effected but by shutting the southern sluices at intervals, and this forms a very important part of the management of these works by the Talook authorities. The great advantage which has been gained by clearing the Totie is, that the bund has been continually raised and strengthened, and it is now generally so high, that with a very little additional work, it might be made to contain 1 yard more water with safety, which would increase its capacity from 70 to 100 millions. This is a most desirable improvement, and should be effected as soon as possible, but some arrangements must be made about the villages above the Tank, which would be flooded.

The Tank has three very fine Calingulas at the South end, the surplus water from which flows into the Coleroon, near Chellumbrum. They are very capacious, and abundantly sufficient for all occasions, excepting those violent storms which bring down the contents of all the Tanks to the westward in one body, flooding the whole country to the depth of several feet. They are well constructed, and generally in good order. Two of them are very rarely opened, and the other often remains shut for two or three years together, in consequence of the tank not filling. There is no Calingula at the north end, though it is close to the Vellaur, and it would appear that this end would on that account have been chosen rather than the southern. I believe the true reason why it was not, is that the Vellaur was formerly a very small stream, for all whom I questioned about it stated that the channel of the Vellaur had wonderfully increased in breadth and depth even in the last 50 years

and this is perfectly borne out by what I observed of the nature of the soil, &c.

There are 18 Sluices in the bund of the Tank, some very large, and most in good order; but several at the north end have been disused since the supply of water has been so deficient. I have not at present a particular report upon each of these works.

The principal advantages of this work are,

1st. Its great capacity; a work of this extent not only requires much less per Cent to keep it in order than smaller works, but it is also much more secure from breaches. Many storms which will burst an ordinarily large tank, do not last long enough to fill this so much as to render it necessary to open the Calingula.

2d. It has a partial supply from the Colleroon; there are scarcely half a dozen tanks below the Ghauts which are filled by the south west Monsoon. And hence, while almost all the tanks in the country get but little water before October, this has its largest supply from the river in July and August, and it has a second supply during the north east Monsoon.

Its defects are,

1st. That owing to the narrowness of the Vuddavaur, it does not get one tenth of the supply it might have from the Colleroon, and is in a great measure dependent upon the local rains. Thus in an extreme fresh in the Colleroon, when about 600 million Cubic yards of water flow into the sea daily, the tank gets only about $5\frac{1}{2}$ millions of yards in a day. Consequently, it is never filled by the south west Monsoon, and very often not in the north east Monsoon also. The value of this important work is therefore diminished one half, merely by not having the channel proportioned to it. This is a very important point. The Veeraunum might with ease be made a most valuable deposit of water for the supply of Tanjore in the low freshes, which is a grand desideratum for that district. By simply increasing the capacity of the Vuddavaur, with or without an Annicut, and raising a small part of the bund, the Veeraunum, might always secure 100 million Cubic yards of water during the high freshes, and as this would render the South Arcot Talooks independent of the river in the low freshes, the whole of the Agunda Cauvery water might then be diverted into Tanjore and Trichinopoly. In this way 100 million Cubic yards of water might be reserved for Tanjore, which would be sufficient to give an abundant watering to 33,000 vaylies, or $\frac{1}{3}$ of the whole lands of the District, and of the crops that are lost, perhaps $\frac{1}{6}$ are lost from want of one such watering. By reference to the table of water required for these Talooks, it appears, that after the 1st December about 90 million Cubic yards of water are required to secure the crop, so that if the tank were filled up to that time, it would not be necessary afterwards to let any water pass the head of Seringam.

The Second defect is, that it is not perfectly secured from breaches. I made the most particular enquiries respecting the causes of the Tank's bursting, in order to find if possible how a remedy might be applied. It appears that in 1809, it burst in 32 places, the bund being at that time much lower than it is at present. The water

came entirely by the Valley of the Vellaur, and not from the Colleroon in any considerable quantity. There was continued rain both in the neighbourhood and to the westward; hundreds of tanks were burst, and the whole country flooded. It happened in December.

The next time that much damage was done was not till 1826, in the month of April, when it will be remembered thousands of tanks were burst in the Carnatic, and 10 inches of rain fell in some places in 24 hours.

This was the greatest flood the people had any knowledge of. The country above the tank is perfectly flat, and it was covered for many miles in breadth to the depth of from 3 to 5 feet. The tank was quite empty before the storm, the water began to enter it just before day break; by 7 o'clock it had opened the Calingulas, and by 10 A. M. there were four breaches, so that in about 6 hours not less than 100 million Cubic yards of water entered the Tank; in all, about 200 yards length of the bund was carried away. From 10 A. M. it began to fall, and by sunset, it had fallen 5 feet, but it continued to flow over the Calingulas for three days. The great breaches were near the south end. There was only one near the north end. Upon the most particular enquiry I was satisfied, that on this occasion the surface of the tank was above the level of the Vellaur at the north end, and hence an extended Calingula there might greatly tend to diminish the danger of breaches. And it might be constructed at a moderate expense. The danger might also be much diminished by increasing the capacity of the tank. Thus at no great expense the Tank might be made to contain 150 millions of Cubic yards before it bursts, and if there was in addition to the present Calingulas, a new one at the north end 100 yards long, and 6 feet below the top of the bund, there would be a stream flowing off of 200 Square yards of Section more than at present, while the Tank was filling to the top of the bank. There would then be about 4 million Cubic yards an hour passing over the Calingulas, besides 150 millions which it would require to fill the Tank before it burst. The mischief caused by so great an accumulation of water as this escaping and spreading over a thickly populated district is so great, that it is very well worth while to go to a considerable expense to prevent it. I should suppose that the whole of the works now mentioned, viz. widening the Vuddavaur, raising the bund of the tank, (so as to make it contain 100 million Cubic yards before the Calingulas are opened, and 150 before it bursts) and a Calingula at the north end 100 yards long, would cost about 40,000 Rupees, besides the 14,000 sanctioned this year for the Vuddavaur.

I know of no other serious defect in this work. A considerable part of the bund is revetted with stone, but it is almost entirely covered by the earth which has been thrown upon the bund, clearly showing that it is not necessary.

The total Revenue of Munnargoody was in 1807, Rs. 110,172.

In 1829	Rs. 109,000		
" 30	96,000	Jaghire Rev.	
" 31	52,000	27,000	79,000

In 1832	82,000	27,000	109,000
" 33	99,000	27,000	126,000
" 34	131,000	27,000	158,000

"Who could suppose from this table, showing such great fluctuations, that the lands were almost entirely dependent upon the best supplied river in the country, supported by a most capacious tank. No lands filled by a tank wholly dependent upon the local rains could show greater fluctuations. In all these years the quantity of water in the river was abundant. From the most minute enquiry I have no doubt, that the Revenue could at once be raised to 2 lacs, and secured at that, and that in the course of 6 or 8 years it might be raised to 2½ lacs, and both the Tassildar and the principal Meerassidars are of that opinion. I cannot think, that in the 6 last years there has been lost to Government directly, less than 6 lacs of Rupees in this one talook, besides the increase of revenue indirectly from the Meerassidars becoming richer; to say nothing of the difference in the comfort and prosperity of the people. The surplus waters from these lands pass off by the Mana Voykal, into the Cawn Sahib's Voykal, and over a Calingula in that work into a large Oopenaur, which falls into the Colleroon near Chellumbrum. The draining is in a very imperfect state, and requires to be carefully examined into. The principal defects are these; first, the Mana Voykal runs for a considerable distance nearly due north, and consequently it has very little fall, besides which, through neglect, it has become nearly filled up with sand; it requires to be dug out for about 3½ miles long, 10 yards broad, and 1½ yards deep, according to the Meerassidar's statement, but I have not inspected it myself; and perhaps a new cut might be made with advantage in an easterly direction; 2d. The quantity of surplus water is so great that it breaches Cawn Sahib's channel, near the Calingula which was built to relieve it, but which is not nearly long enough; and Thirdly, the Oopenaur not being provided with a sluice where it enters the river, the water in high freshes spreads all over that part of the country to the level of the river, and what is more, in the dry season, when the tide comes up the river, the salt water extends far up the Oopenaur, and spoils all the fresh water in the neighbourhood.

The remaining works of irrigation in these Talooks are of less importance, and do not require such detailed remarks as the preceding.

WATER COMMUNICATION BETWEEN THE COLLEROON AND VELLAUR.

This is the last subject which it seems necessary to mention in this report.

Two Cuts have been made at different times to communicate between the two rivers very near the sea, and as from the want of a current and the drifting of the sand they have filled up again, they have been several times cleared out again. I had inspected the ground and had hoped before this to have had such levels taken, as would have enabled me to fix upon a more satisfactory line, but I have not yet effected this.

But with respect to the trade from the upper part of

the Colleroon and the Cauvery, I am now pretty well satisfied, that the most advisable plan is to bring the boats by the head of the Vuddavaur and the proposed Raja Voykal and Cawn Sahib's Voykal into the Vellaur near Porto Novo. The advantages of this line, and the causes which render it necessary are as follows.

1st. The construction of the Vuddavaur Annicut will deprive the lower part of the river of so much water, as considerably to diminish the number of days in which the Boats could pass, and though the trade is itself of so very small importance in comparison with the irrigation (and still less so the mere diminution of the number of days in which the river is open) that the former ought certainly to give way to the latter, if both cannot be provided for, yet it is also very desirable not merely to preserve, but if possible greatly to improve the communications. In this point there will be a material difference between the Seringam and the Vuddavaur Annicuts, a considerable quantity of water way must always be allowed to pass the former, for the supply of the lower cultivation, but it will be necessary to stop the whole of the water at the latter work in many days, when there is not more in the whole stream of the Agunda Cauvery than Tanjore and South Arcot require.

2d. The water being much more confined in the Cawn Sahib's channel, than in the bed of the Colleroon, a much smaller quantity will be sufficient to allow of the Boats passing. Thus, it would happen on many days that there was 3 feet water in the channel, when in the present state of things there is not more than a few inches in the river.

I calculate, that by the channel the communication would be open without a day's intermission from the 1st of July to the middle or end of January, which I suppose to be from 60 to 100 days more than is at present by the river.

3d. A lock can be constructed at less expense and can be more easily kept clear of sand at the head of the Raja Voykal, ¼ a mile down the Vuddavaur, than it could in the Annicut.

4th. The channel will form a much more convenient water communication than the river, with exception to the management of the Boats, as the water will be kept at a nearly uniform height, and there will be every facility for tracking up and down. The Current will be about 1½ miles per hour. The channels will also be safe from squalls &c. Indeed they will in every respect form a superior line of water communication.

These advantages seem clearly to point out the best plan for providing for the trade.

The works that will be required to open this line are, 1st. The construction of a Lock at the head of the Raja Voykal, which as I have said will cost less than one in the Annicut.

2d. The Comaratchy channel must be carried under Cawn Sahib's channel instead of over it, as at present, a new undersluice will be required for this, the Estimate for which is Rupees 876—15—1½.

3d. I think that the Bridge by which the Chellumbrum road is conveyed over Cawn Sahib's channel has not

sufficient waterway, and in that case it must be altered, but the expense will be inconsiderable.

Besides these it may be necessary to cut away a few bunds, and perhaps in some parts to widen the channel, though from what I have seen of it I do not apprehend that there will be any great expense under this head.

I will conclude with a rough Estimate of the sums which I would recommend to be expended on these Talooks, and if they appear large, it will only be necessary to compare them with those that have been lost of late years, solely from the inefficient state of the irrigation works.

Works immediately required, and for which an Estimate is now forwarded.

Vuddavaur Annicut	Rs.	100,870	11	0
Surplus Sluice in Vuddavaur	"	1,606	10	9
Head Sluice to Raja Voykal	"	1,929	1	6
Excavating Raja Voykal & constructing Bridges		25,564	15	0
Raising South bank of Colleroon above Annicut		2,500	0	9
	Rupees	131,471	6	3

And for the Trade.

Lock at head of Raja Voykal	Rs.	2,887	12	1½
Under Sluice for Comaratchy Channel		876	15	1½
Altering Bridge in Chellumbrum Road about 300		0	0	0
	Rupees	4,064	11	3
Add for alterations and additions which it is possible may be found advisable		10,000	0	0
	Rupees	14,064	11	3

Total of Both „ 145,536 1 6

Of which about 48,500 will be required this year, 48,500 next year, and the remainder in the following.

Works for securing a larger quantity of water in the freshes, and for more effectually relieving the

VEERAUNUM TANK.

Widening Vuddavaur Channel	12,558	12	0
Raising Bund of Tank &c. and North Canalingula	40,000	0	0
Removing Villages from bed of Tank	6,000	0	0
	Rupees	57,558	12 0

WORKS FOR THE COMPLETION OF THE DRAINING.

Surplus Sluice at the mouth of the Oopenaur	2,000	0	0
Clearing the Mana Voykal	2,531	4	0
	Rupees	4,531	4 0

Completing the North bank of the Colleroon from the head of the Curpoor Channel	Rupees	17,000	0	0
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Grand Total Rupees 224,626 1 6

With respect to the irrigation of the lands formerly watered by the Ponairy, I have not materials even for a rough Estimate, but I have no doubt, that the expense will be so moderate, that the returns will be most ample.

In conclusion I would suggest, that if the Annicut is constructed, it should be followed up, in the course of a few years, by the construction of whatever minor works may be required to put these most valuable Talooks into the most complete state in respect of irrigation.

A. T. COTTON, Captain
Civil Engineer 3d Division.

MADRAS
June 2d 1835.

REPORT BY MAJOR A. ROSS.

Revenue Department.

To
The Chief Secretary to Government.

SIR,

I am directed by the Board of Revenue, to transmit to you, for the purpose of being laid before the Right Honorable the Governor in Council, the papers noted in the margin.

In Tanjore, notwithstanding the vast advantages it enjoys from artificial irrigation, it has been necessary, annually, in the villages in which a money settlement prevails, to make very considerable remissions for the failure of crops; and great losses have been sustained from the same cause in villages in which the settlement has been made on a division of the produce. The average of the annual remissions for lands left uncultivated, and failure of crops from Fusly 1235 to 1243 inclusive, in the villages on a money settlement is Rupees 109,697 and the average loss in Aumany villages, that is, the difference between the amount of revenue realized and the standard beriz, is still greater. Part of this loss is to be ascribed to inundation and other causes, but by much the greater part is ascribable to a deficient supply of water for irrigation.

The prevailing opinion, therefore, of the certain produce of Tanjore arising from the certain irrigation, must be received with some restrictions. It is not liable to such extensive failures, as the districts which are chiefly dependent on the periodical rains and Tanks are occasionally subject to. But in Tanjore no year passes without some failure, and the amount of loss on the whole is very serious.

It appears from the Registers of the state of the river, which are kept at the Grand Annicut, that the freshes are sometimes unseasonable, sometimes scanty, and at others in excess—and it often happens that, although a body of water much more than sufficient for the complete irrigation of all the present cultivation of Tanjore, passes down the Agunda Cauvery, the name which the river bears before its separation, yet, from a want of control over the mass, by far the largest portion forces its way into the "Colleroon," under which the cultivation is comparatively scanty, leaving a very inadequate supply for the cultivation that is under the "Cauvery" and its branches.

After much careful consideration of the subject, Captain Cotton has come to the conclusion, that the evil of this unequal distribution may be effectually remedied and great advantages gained, by constructing an annicut across the Colleroon at the head of the Island of Seringam, which will enable him to apportion the supply of water to the demand. Taking for example the year from June 1831 to May 1832 to illustrate the probable effect of the work, he observes, that in that year

there was sufficient water in the Agunda Cauvery for all the cultivation under both the Cauvery and Colleroon on 160 days, but that in fact, from the unequal distribution above exhibited, Tanjore received a full supply on 16 days only. Had there been an annicut, or any other means of distributing the water at pleasure, so that no more need have been left in the Colleroon than would have afforded the cultivation a full supply, Tanjore might have been fully supplied every day from the 15th June to the 15th December, with only the intervals of 3 or 4 days in one or two months; and in those also the deficiency would have been very inconsiderable. Again, in the months of September and October, the most critical time of the year, it appears that instead of a full supply on 9 days only, *as was the case*, there would have been no deficiency on any one day.

The general effect of the proposed work, Captain Cotton estimates, will be to render available for cultivation in Tanjore an increased supply of water on 100 days, amounting in all to $\frac{1}{3}$ of the total quantity that is available at present on an average. In 1831-32, he remarks, an addition of $\frac{1}{3}$ might have been saved from waste in the Colleroon, and made available for cultivation by an annicut. He calculates that an increase of revenue to the amount of Rupees 100,000 will result immediately from the projected work in Tanjore, from the lands at present cultivated and on the same crops, and he thinks that besides this much land may be converted from one crop to two crop land, and much Poonjah converted into Nunjah.

But the effects of the new Annicut upon Trichinopoly, in Captain Cotton's opinion, will be still more complete, not only by giving a certain abundant supply of water for all the land under the channels, whereby he reckons upon an increase of revenue to the amount of 15,000 Rupees, but by putting a stop to disputes of long standing between the Meerassidars of Tanjore and Trichinopoly, respecting the extension of the head of Seringam &c., and by rendering an annual expense of 2 or 3,000 Rupees for Corumboos unnecessary.

Another very important benefit to be derived from the projected work is, that it will advance the cultivation a whole month, diminishing thereby the risks from drought, and leaving a much more abundant supply for a 2nd crop. The Principal Collector of Tanjore and the Collector of Trichinopoly, with whom Captain Cotton has fully discussed the plan, concur in approving of it.

It may perhaps be a question, whether the immediate increase of revenue in Tanjore upon the lands usually cultivated (excluding of course those under the Colleroon), supposing the Annicut to have the full effect anticipated, in distributing the supply of water in proportion to the demand, would be quite so great as expected by Captain Cotton, whose estimate however, is support-

ed by the Principal Collector—but there can be no doubt that there would be a very considerable saving of revenue by a work calculated to render available for cultivation so large an additional quantity of water at times when it is most urgently required, whereby Government would be secured in a great degree from the necessity of giving remission in the villages under a money settlement, while in the Annany villages there would be a direct gain in proportion to the increase of produce: and if the increase or saving of revenue should be only half so much as the estimate, the work would be a most profitable one.

The cost of the Annicut is estimated at Rupees 82,952—11 including allowance for an Officer to superintend the execution of the work, which is of so much importance, that, if it is undertaken, the Board would strongly recommend the appointment of an Officer of Engineers for that particular duty, under the direction of the Civil Engineer, it being quite impossible for the Civil Engineer himself or his Assistant to give the necessary attention to it, without detriment to the service by neglecting other business of the Department, both Officers being already fully occupied.

A further charge will be necessary for making a new head to the Iyen Voykal which supplies the talook of Laulgoody in Trichinopoly, and constructing a new sluice to it, so as to give it the advantage of the Annicut. The estimate for these works is Rupees 13,381—10.

To keep a passage open for boats, by which there is a considerable traffic on the river, likely to be increased when the iron works of Porto Novo are in operation, Captain Cotton proposes to construct a single Canal lock in the north part of the Annicut, of sufficient capacity for the passage of two of the largest basket boats at a time. The estimate for this work is Rupees 2014. The total amount of the estimate for all these works is Rupees 93,353—3—7.

The Principal Collector of South Arcot was apprehensive that, however beneficial the projected annicut at the head of the Colleroon might be to Tanjore and Trichinopoly, it was likely to prove injurious to the cultivation of the two talooks of that district (Manargoody and Chellumbrum) which are chiefly irrigated from that river. Captain Cotton has answered the objections on this ground, in the most satisfactory manner. The Board think he has made it quite clear, that the irrigation of those talooks, instead of being obstructed, would rather be facilitated and improved by the annicut, by the water being brought more under control, so as to admit of the Corumboos, or embankments by which the water is forced into the channels, being constructed at an earlier period of the season. The advantage of this is manifest, when it is considered that the bed of the Vuddavaur, the principal channel, is 2½ feet above the level of the Colleroon, which must therefore rise above that height before any water can flow from it into the channel. When the depth of the Colleroon is 2½ feet, there may be about 200,000 cubic yards per hour passing down it, which is from 2 to 3 times more than the channel in its present state requires, but without a Co-

rumboo there would then be no water in the channel. With a Corumboo, as long as there is 1½ feet water in the river, there is a full supply for the Vuddavaur. It is only, however, when the water is low that a Corumboo can be constructed. Supposing there was 4 feet water in the Colleroon on the 15th December, as they could not construct a Corumboo in this stream there would be only 1½ feet in the channel. But, if there was an annicut at the head of the river, the stream might be lowered so as to enable them to construct a Corumboo, by which means the water in the channel might be made 2½ feet deep instead of 1½, while the water drawn off would double the supply to Tanjore.

The advantages of the projected work being so great and obvious, and there being, as far as the Board can see, no objection to it of any importance, they submit the estimates for the consideration of Government with a strong recommendation that they be sanctioned.

Captain Cotton has paid great attention to the irrigation of the talooks of Chellumbrum and Manargoody in South Arcot, already adverted to, and he has lately submitted a very full and able report on the subject, which is herewith forwarded for the consideration of the Right Honorable the Governor in Council.

In this report he has examined in detail the present mode of irrigation, and has explained very clearly and satisfactorily, the means by which it may be rendered sufficient for the full cultivation of nearly all the nunjah lands, of which a large proportion are now waste, apparently from want of water. The plan which he proposes, is to construct a second annicut on the Colleroon at the head of the Vuddavaur, the principal channel of supply to these talooks, and to open a Canal from the Vuddavaur to supply the channels which are now filled directly from the Colleroon.

This plan is intimately connected with that explained in the foregoing part of this letter, and is indeed supplementary to it, the common object being to obtain a complete command of the river in its course from the Agunda Cauvery to the sea, so as to make its waters as fully available as possible for the purpose of irrigation, in those talooks of Trichinopoly, Tanjore, and South Arcot, whose lands are dependent on it, and to distribute them in such a manner as to give to each a sufficient and seasonable supply.

The supply of water to the talooks of Chellumbrum and Manargoody is almost entirely drawn from the Colleroon by river channels, but these are supported by the Veeraunum Tank, the largest in the country. This tank is partly supplied from the Colleroon by the Vuddavaur channel, but the channel is not large enough to fill it. It always receives a considerable supply from the local rains in the N. E. monsoon, but with both these helps it is not filled every year. The most important object in Captain Cotton's plan, as regards the cultivation of these talooks, is to fill this tank from the Colleroon. There is abundance of water in the river for this purpose, and for the supply of all the channels, but the means now used for diverting the water into the channels, are so defective that by far the greater part is

lost. The only effectual plan for obtaining a complete command of the water, is the construction of an annicut. By means of an annicut, and by widening the channel of the Vuddavaur, a quantity of water could be conveyed from the river sufficient to fill the Tank by the freshes in July and August, and to fill it up by almost every succeeding fresh, and to supply all the subordinate channels. Of the whole quantity of water calculated by Captain Cotton to be required for these talooks, about $\frac{3}{4}$ rds, he states, is required for the cultivation under the Vuddavaur channel, and the Veeraunum tank supplied by it, and as the cultivation under the channel may be almost entirely supplied from the tank, as long as there is any moderate quantity of water in it, it is evident that the tank being once filled, by much the greatest part of the whole cultivation of the talooks would be secured, however low the river might afterwards fall. Captain Cotton is quite sure that an annicut with the subordinate works proposed would, in the common course of things, render the whole irrigation of these talooks secure; and he reckons that the increase of revenue by extended cultivation, in consequence of the improved means of irrigation, would not be less than 100,000 Rupees per annum above the average of the last six years.

The district of Tanjore, he observes, would also be immediately and materially benefited in two respects; "1st, by giving the complete command of the water in the lower Colleroon, it will enable us to divert the greatest possible quantity into Tanjore by the Cauvery. 2d, by throwing a larger supply into the Veeraunum tank in the high freshes, it will make these talooks more independent of the river in the latter part of the season, and so leave a larger proportion of the water in the Augunda Cauvery disposable for Tanjore." A further advantage, he thinks, may be obtained ultimately, by carrying a channel from the southern end of the annicut to improve the irrigation of the N. E. talooks of Tanjore, and to irrigate about 3,000 vaylies, at present waste in that part of the district.

The principal Collector of South Arcot, when this scheme was first proposed, was satisfied that the annicut would secure an abundant supply of water to the Vuddavaur, but entertained doubts whether the subsidiary channels could be supplied sufficiently from the Vuddavaur, on account of the narrowness of that channel. The Vuddavaur however, is to be widened from 18 yards to 30, and it appears to the Board, that Captain Cotton has provided effectually for the supply of the subsidiary channels, by a Rajah Voykal from the head of the Vuddavaur, to be carried "close on the north side of the river bank as far as the head of the Vayloor channel, and then along that channel to where its cultivation begins, after which, separately, still near the river bank, to the head of the Comaratchy canal." "In this way (Captain Cotton observes), in making the Rajah Voykal, the river bank would be made perfectly secure, and be converted into a good bandy road, which is very much required."

The principal Collector suggested that objections might be raised by the inhabitants, on account of land

being sacrificed in the construction of the new works, and the irrigation of lands already under cultivation from other channels being interfered with. But no doubt such objections may be easily obviated, and they are of little importance compared with the great object which the projected works are calculated to effect.

The principal Collector also expressed doubts whether so great an increase of cultivation and revenue as Captain Cotton then anticipated, could be effected by any improvement of the means of irrigation; he did not think the cultivation incapable of being increased by improved means of irrigation, but he was of opinion that it could never attain the height to which Captain Cotton expected it would arrive, nor even very far exceed the estimate for the current year.

The revenue of these talooks has fallen off very greatly of late years. The average of the 3 years from Fusly 1241 to 1243 (exclusive of the Jaghire included in the accounts since Fusly 1240) is about 60,000 Rupees below the average of the first 3 years after the assumption of the country, which exceeds the average of the last 6 years by about 50,000 Rupees. There can be no doubt that this decline is owing to deficient irrigation, and as it appears that there was a sufficiency of water in the Colleroon in those years, it may be inferred with certainty that, if the works now proposed for commanding the water had been in existence, the decline would not have occurred. Circumstances have been so favorable this year, that the estimate of revenue (excluding the Jaghire) is Rupees 231,000, exceeding the average of the last three years by Rupees 90,000 nearly, and the average of the last six years by about 78,000. If with the present impediments to irrigation the cultivation has been so greatly increased in one year, it is surely not too much to calculate (the extent of land cultivated this year, being less than $\frac{1}{4}$ of the whole fit for cultivation) that when those impediments are removed, a further increase to the amount of Rupees 22,000 may be obtained, by which the revenue would be raised one lac above the average of the last six years, as anticipated by Captain Cotton in the present report. But, if the proposed works should only serve to maintain the revenue at the standard of the current year, that is, to secure an increase of about 90,000 Rupees above the average of the last three years, they would be well worth the estimated cost of their construction in respect to South Arcot alone, without taking into consideration the advantages to Tanjore which are expected to result from the Annicut.

The proposed plan also provides for a great improvement in the water communication for the trade, arrangements being made for the boats passing by the channels, from the annicut to Porto Novo, in which line there will be a constant supply of water for about eight months, with the means of tracking and freedom from many of the disadvantages of river navigation.

Independently of the increase to the revenue from the annicut, there will be a saving of the expenses annually incurred in raising embankments, clearing the heads of the channels, &c.

The whole plan appears to the Board highly deserving of approbation, and they strongly recommend it for the sanction of Government. The estimate now submitted, amounting to Rupees 135,236-1-6 provides for the construction of the Annicut and the excavation of the Rajah Voykal channel, also for the construction of the requisite sluices and bridges, and a lock for the passage of trading boats, for which, if the general plan is approved, the Board request sanction. The remaining works included in the plan, of which the principal are widening the Vuddavaur channel, and raising the bank of the Veeraunum tank, are estimated roughly by Captain Cotton in his report at Rupees 89,390. The total expenditure for completing his plan for the improvement of the irrigation of these talooka, will therefore be about Rupees 224,626.

The sums for which sanction is requested are as follows :

For the Seringam Annicut, &c.	98,383 3 7
For the Vuddavaur do. Rajah	
Voykal, &c.	135,236 1 6
Total Rupees. . .	233,619 5 1

I have the honor to be, &c.

A. Rosa,

Inspr. Gen. of Civil Estimates.

MADRAS, 8th June 1835.

(Extract from the Fort St. George Gazette 28th November 1837.)

Result of the works on the public and private resources of the Country.

VUDDAVAUUR OR LOWER ANNICUT.

The results of the past year, as respects this work, are highly satisfactory to my mind, though there was but a small increase of cultivation. From about the 20th of May to the end of November, six months, the water in the Vuddavaur stood at the level of the top of the Annicut, or higher, that is—there was on no day less than about 4½ feet of water, or about 40,000 cubic yards an hour; from the 1st of December it gradually decreased. On the 1st of January there was a depth of 3½ feet, on the 1st of February 2½ feet, and it did not fall below 1½ feet; it has now begun again to increase. There has thus, without the expense and excessive inconvenience of constructing a Corumboo in the midst of the season of cultivation, been a perfectly regular and constant supply of water in a season in which the local rains entirely failed, and which was the worst season, as respects the supply of water in the river, of which the people have any recollection. It is particularly remarkable, that though the river was entirely shut up at Seringam about the end of October, and the whole of the water of the Agunda Cauvery distributed to Tanjore and Trichinopoly, yet the drainage water from the sands of the Colleroon kept the S. Arcot channels nearly full till the 1st of December, and it has not yet ceased to flow, though it is 6 months since the river

was shut up at Seringam; the end of the river between the two annicuts, forming a tank of about 40 square miles of surface, and capable of containing in its sands about as much water as the Veeraunum. We have hence an undoubted proof that the Vuddavaur will never be without water; in an ordinarily bad year even, it will be kept full from the beginning of June to the end of January, without intermission, being 8 months: a sufficient time for two crops, and excepting in such a year as the past, there will always be a large stock of water in the Veeraunum. We may judge of the effect of the Annicut by comparing the current year with the year 1832, when the local rains failed, but there was a very fair supply of water in the river. I have not been able to ascertain exactly what the revenue of this year will be, as the accounts were not made up; but I was informed that the Chellumbrum revenue will be rather less, and the Manargoody rather more than last year. The revenue from Fusly 41 is as follows :

	Manargoody.	Chellumbrum.	Bowanygherry.	Total
1241 Rs.	80,363	Ra. 81,844	162,207	123,004
2	111,583	93,151	204,734	124,798
3	127,383	105,323	232,706	126,646
4	166,914	143,125	310,039	173,060
5	168,140	144,246	312,386	165,181
6	about 175,000	about 140,000	315,000	

It appears from this, that the revenue of this year exceeds that of Fusly 41, by about 1½ lacs of Rupees; in both these years there was a failure of the North East Monsoon, but in the latter there was a failure of the river too, whereas there was a good supply in the river in 41; so that in the worst season ever known as respects the river, the revenue is very nearly double that of 41. I compare the past year with 41, because it is the only one in which there was a failure of the N. E. Monsoon. The whole of this increase of 1½ lacs of Rupees is not perhaps owing to the annicut, because something had been done before to improve the irrigation, but certainly almost all of it was produced by this work. I have put down the revenue of the neighbouring talook of Bowanygherry, which is chiefly dependent upon the local rains, to shew that the great improvement in the other Talooks in the years preceding the last, was only in a small degree owing to the difference in the N. E. Monsoon; and that it was not owing to the improved supply in the river, is certainly shewn by the Annicut returns, from which it appears that there was no deficiency in the river in 41. I understand that the revenue of Bowanygherry has this year fallen very low, but I have not yet received the accounts of it. At all events it is evident, that with a failure both of the N.E. Monsoon rains, and of the river, the revenue of these two small Talooks exceeds what it was 6 years ago, by 1½ lacs of Rupees, which is I believe nearly double the total expense of the Officers, Surveyors, &c. employed in the whole Tank Department of the Presidency.

The total cost of the Annicut and Rajah Voykal has been about 130,000 Ra. I think it probable, that had the Annicut not been constructed in the past year, the

revenue would not have much exceeded that of 1832, so that it seems nearly certain, that this work has by its direct effect upon these Talooks alone, (and without considering it in reference to the upper Annicut, as part of a general plan of works which enabled us to make use of every drop of the water of the Agunda Cauvery for Tanjore and Trichinopoly), that it has in this first year of its construction paid to the Government more than its whole cost, besides the incalculable benefit to the inhabitants of the Talooks, (the population probably 100,000), a great proportion of whom would have been literally in a starving state at this time, but for this work. The price of grain in Tanjore is about 70 per cent above the average, and had this Annicut not been constructed, the inhabitants of these Talooks must have been buyers at this high price, instead of selling at the same price; they will now be enabled to take advantage of the increased supply of water in the approaching season, as they will have some money to lay out in extending their Nunjay cultivation. Another proof of the effects of the Annicut is obtained from the state of the Veeraunum tank: hitherto this Tank has been mainly dependent upon the local rains to fill it; this year it got no supply in that way, but having been filled up quite full, before the end of September, by the freshes of the S. W. Monsoon thrown into it by the Annicut, it was quite independent of the N. E. Monsoon.

I think, however, enough has been effected in these Talooks (Chellumbrum and Manargoody), to give every encouragement to the Government to proceed with plans for their improvement. The increase of the revenue in the last 6 years has been beyond all expectation, and it has undoubtedly arisen from the improvement in the irrigation.

SERINGAM OR UPPER ANNICUT.

I now propose to endeavour to show what has been the effect of the Upper Annicut in the past year. It cannot be shown directly by figures, because there was so extraordinary a failure of water in the River, that the produce of Tanjore has been less in the past year than in many of the preceding ones; but I feel quite satisfied that the effect of the work has in fact been very great indeed, and far greater than it would have been had the supply of water been considerable. Indeed it is evident, that the value of such a work must be felt in proportion to the deficiency of the supply of water, because it is then that the loss of a portion of that supply will be most injurious.

As to the failure of the supply of water, I particularly inquired throughout the district, and all declared that such a failure had not been known for fifty years. The following table will show the truth of this, by the heights of water at the Grand Annicut:

	Average height of 20 years.	Worst season of 20 years.	Last year.
	c. f.	c. f.	c. f.
June	2 8 below crown	5 4 below crown	2 3 below.
July	0 1 above crown	1 7 below	0 6 above.
Augt.	0 10 above	0 10 below	0 9 above.

Average	0 11 below	2 7 below	0 8 below.
Sept.	0 4 below	1 10 below	0 6 above.
Oct.	0 1 below	1 10 below	1 12 below.
Novr.	0 11 below	2 5 below	2 1 below.
Decr.	1 12 below	3 2 below	(up to the
Jany.	2 13 below	3 14 below	22d.)

I take the liberty of requesting the Board's particular attention to the following remarks upon the above table, as I think they will shew unavoidably, that the effect of the Annicut must have been very great.

1st, Upon the supply in June, July, and August, of course, mainly depends the forwardness of the crop; if this supply is abundant, the whole of the main crop is thrown so forward, that it is little dependent upon the supply in the latter part of the season, when there is very little water. In June it will be seen, that the average was rather above the average of 20 years; all this month no water of any consequence escaped by the Colleroon, so that the supply must have been much more than double what it would have been had there been no annicut, or about 180 millions of cubic yards, instead of 80 millions; for hitherto more than half has always passed down the Colleroon. In July and August there is very generally a good supply; last year there was much more than the average of 20 years in July, and nearly the average in August. This was after the breach took place, and more water escaped by the Colleroon, which however was of no consequence, as there was a full supply throughout those two months; or at least very nearly as much as they could possibly make use of. It must be observed, that an average of 6 inches above the Annicut now, will generally show a much better supply than the same average height did before, because the supply is much more regular; formerly there would be at one time much more than could be of use, and at another not half enough; but that will not be nearly so much the case now that the Upper Annicut is constructed, in consequence of its throwing into the Cauvery nearly the whole of the water in low freshes, but not a much greater proportion in high freshes than it formerly received. The average of the months of June, July, and August, is rather greater than the average of 20 years; I should judge that, allowing for the loss by the breach, about one third of this was thrown in by the Annicut. Throughout July and August, the water stood on the upper side of the Upper Annicut at from 2 to 3 feet higher than on the lower side, showing that had it been removed the water would have fallen about 1 foot, which would have taken off about $\frac{1}{4}$ of the supply. Thus in June considerably more than half the water was thrown in by the Annicut, and in July and August, about $\frac{1}{4}$. The month of September is the most critical of the season; by the table it appears that there was on an average a full supply throughout the month; I can only find one such case in the returns of 20 years. The average for 20 years is about 1,500,000 cubic yards per hour, last year it was $\frac{1}{3}$ th more. From the Upper Annicut returns it appears, that the supply without that work would have been about 1,400,000 cubic yards, or only $\frac{1}{3}$ th of what it actually was. Thus it appears, that from near the end of

June up to the end of September there was generally a constant and abundant supply thrown into the district, and nearly $\frac{1}{3}$ rd more than it would have received. The supply was deficient in about ten days out of the 3 months, but this was not sufficient to have any serious effect upon the district. From the 20th of September the river began to fall rapidly, and there was no rise whatever during the north east Monsoon. I can only find one season in 20 that at all approaches this; in that year the average height of the Grand Annicut for October and November was nearly the same as this; but it appears from the returns at the Upper Annicut, that had it not been for that work, the average would have been, for October, about 2c. 3in.—or 7 in. below the worst year in the 20, and in November about 2c. 7in. or 5in. lower than the average of the same month of that year, viz, 1828; the average supply for October was about 400,000 cubic yards per hour, or $\frac{1}{3}$ th of a full supply, of which about $\frac{1}{3}$ ths or 160,000 were thrown in by the Annicut, without which there would only have been $\frac{1}{3}$ th of a full supply. In November up to the 22d (beyond which I have no returns, for there was scarcely any water in the river), the supply averaged 260,000 or about $\frac{1}{4}$ th of a full supply, of which about 60,000 or nearly $\frac{1}{4}$ th was thrown in by the Annicut, without which work there would have been only $\frac{1}{10}$ th of a full supply.

Now, in such a season when, as things were, perhaps $\frac{1}{3}$ ths of the whole crop of the district was extremely nearly lost, what would have been the state of the district, had the crop not been in a forward state from the steady and abundant supply in the early months, had it not had the unprecedented supply in September, and had it been deprived of $\frac{1}{3}$ ths of what it received in October, and $\frac{1}{4}$ th of what it got in November? The quantities of water it did get, and those it would have got without the Annicut, may be estimated as follows;

Quantity in an average year.		C. Yds. per hour actually supplied.	Quantity that would have been supplied.
220,000	June	240,000	110,000
1,600,000	July	1,850,000	1,400,000
1,700,000	August	1,900,000	1,450,000
1,500,000	September	1,850,000	1,400,000
1,600,000	October	400,000	240,000
1,300,000	November	200,000	200,000

making the total supply of the year about 4,800 millions, and the supply that would have been thrown in about 3,600 millions, the average supply being above 6,000 millions.

But let us also consider what the effect of this work must be at this moment upon the surrounding districts. The whole of the neighbouring districts have had a most disastrous season; the failure of the Monsoon was so complete, that drinking water was not procurable in many places; they are now sending carriage from all around into Tanjore to buy grain, where the price, as stated, is 70 per cent above the average. Suppose that out of about 114 lacs of Cullums, the computed produce this year, the inhabitants require 80 lacs for their own consumption, seed, &c.; there is a surplus of 34 lacs for

export. Had $\frac{1}{4}$ th of the crop been lost, there would have been a surplus of only 6 lacs of Cullums for exportation, and that of course at prices far greater than even the present, which yet is so high as to indicate very severe suffering in the neighbouring districts.

The principal Collector of Tanjore expected a deficiency upon last year, but the question as respects the Annicut is, not what this year produces compared with the preceding; but what it produces compared with what it would have done without the Annicut.

The calculations I have above made from the Annicut returns, perfectly agree with the opinions of the Tassildars and other natives with whom I spoke on the subject.

The two Talooks of Trichinopoly have also partaken of the advantages obtained from this work, though not, of course, in the proportion that Tanjore has, as they were not so liable to a want of water.

The results of this year have fully justified the Civil Engineer in making such an effort to get both the Annicuts finished in one season. The gain of a year under ordinary circumstances was well worth great exertion, but it appears now that the Annicuts were built at a most critical time, and that they have thus, providentially, been the means of preventing a very great extent of distress in the Southern districts, and a very great loss of revenue: and this saving of revenue extends even to the districts round Tanjore, for had the crop there failed to a greater extent than it has, the price of grain would have been much higher, and the surrounding districts would consequently have been still further impoverished, and less able to take advantage of a better season in the present year.

(Extracts from a Letter from the Principal Collector of Tanjore, to the President and Members of the Board of Revenue, under date the 1st July 1837.)

Para. 2. As for the condition of the Annicut, having lately undergone a thorough repair, it is perfect.

3. As to its value to the public and private resources of the Province, it is obvious that, as the instrument of turning into the Cauvery, at low freshes, a large body of water which formerly ran waste by the Colleroon into the Sea, and thereby increasing and rendering more regular the supply of water to about 500,000 acres of nunnay land, enabling the cultivation to be commenced earlier, and the crops to be watered later than before, it must be immense.

4. The object of the structure being, not to make water, but to direct its course, the extraordinary failure of the freshes subsequent to the 25th September is no more an argument against its efficiency than the ordinary dryshod passage of the River in March; and that it has answered its professed object, is proved by the notorious fact, that the Colleroon is now frequently forded with facility, when the Cauvery is impassable without a boat, the very reverse of their relative states before its construction. Unprecedented, however, as the failure of the freshes was, and scanty as the North East Monsoon proved to be, the decrease in the gross produce of

the wet lands paying full revenue to Government, which are watered by the Rivers, will be, as nearly as the present state of my accounts enable me to judge, but 723,777 Cullums or 6 $\frac{1}{8}$ per cent. below that of last year; and though it is impossible to shew, or perhaps to guess, within

1245..	1,23,65,864	
1246..	1,16,42,087	7,23,777

some lacs of Cullums, what it would have been but for the Annicut, one thing is certain, that it would have been, like the failure of the freshes in the parent stream, *unprecedented*; and my conviction is, that Tanjore, instead of largely supplying the wants of the adjacent districts, must have imported grain for her own consumption.

6. Another important advantage of the Upper Annicut is a great improvement in the navigation during low freshes, from the districts of Salem, Coimbatore, Trichinopoly, and Tanjore, to the Coast; from the whole stream of the *Agunda* Cauvery, by far the larger portion of which previously found its way to the Sea in a shallow stream diffused over the wide bed of the Coleroon, being now confined to the narrower branches of the Cauvery, and forming comparatively deep Canals.

Extracts from a Letter from the Collector of Trichinopoly, to the President and Members of the Board of Revenue, under date the 20th July 1837.

Para. 2. With respect to the condition of the Annicut, as far as I am competent to judge, I am of opinion that the alterations and additions that have been made to it in the present year have greatly increased the security of the work; and that there is little risk of any serious accident again occurring, except under some most unusual and unlooked for circumstance.

6. With regard to the results of the Annicut, as it affects this district, they have been most favorable.

7. The two channels which were expected to derive the chief advantage from the work, are the Peravully and the Iyen, which irrigate nearly the whole of the wet lands of the Lalgoody Talook, yielding a revenue of Rs. 205,326.

8. The head of the Peravully Voykal opens into the Iyaur river at its junction with the Cauvery, which as your Board are aware, is immediately above the Annicut. Hitherto it has been necessary, every year, to carry a Corumboo a considerable distance up the river,

when the water was low, to conduct a stream into the Peravully Channel, and in unfavorable seasons it has of course suffered equally with other Channels from scarcity of water.

9. During the last season, as unfavourable a one, probably, as regards the state of the River, as has ever been known, the Peravully Voykal, owing to the constant head of water which stood above the Annicut, had not only a sufficient supply of water in it to bring to perfection (with some slight exception) the whole of the cultivation depending upon it, but there was not a single day in the year in which a stream did not flow into the channel; and this without the labour and expense of constructing the usual Corumboo.

10. Besides the great advantage derived by the Merassidars from the abundance of water for their cultivation supplied by this channel, its constant running stream in a season of severe drought like the last, proved a real blessing to the Ryots of the dry Villages in many parts of the Talook, who, without this supply, would have been severely distressed for water for themselves and their cattle.

12. This new cut for supplying the Iyen Voykal has fully answered my expectations, and the lands depending on the Iyen Voykal will now be as favourably circumstanced, as regards a constant supply of water, as those lying under the Peravully. Both channels will in future be saved all the trouble and expense that has hitherto been annually incurred in constructing Corumboos, which must be considered a very great advantage to the Merassidars.

13. There is a third channel in the Lalgoody Talook, called the Nudookurry Naut Voykal, which irrigates the whole of the nunjay land on the Island of Seringam, comprising about 2,500 cawnies. This channel branches off the Cauvery a few miles below its head, and it has benefited very considerably by the increased body of water thrown into the river since the construction of the Annicut.

14. Besides these channels in the Lalgoody Talook, there are two, the Rom Voitally, and Yelanda Voitally, which water part of the land in the Conaud Talook, lying on the south bank of the Cauvery, which, from their head sluices being situated below the Annicut, have also participated, though in a less degree than the Nudookurray Channel, in the advantages derived from that work.

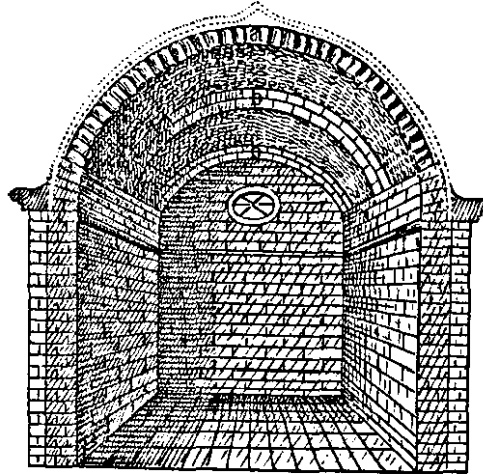
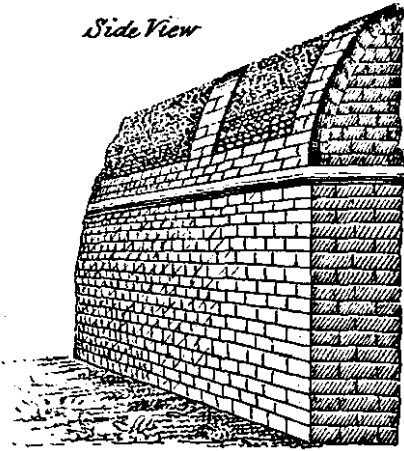
MEMORANDUM REGARDING SYRIAN OR CYLINDER ROOFS.—BY CAPTAIN GEOURGE UNDERWOOD.

This description of roof, without any wood-work, is composed entirely of hollow earthen-ware cylinders (formed on the wheel) which are about 9 inches long, 5, 5½, or 6 inches diameter at the larger end, and about 3 or 3½ inches diameter at the smaller. They much resemble in shape a quart bottle with the neck cut off, the bottom being flat. The smaller diameter of these cylinders must of course vary according to the nature of the curve, very large semi-circular spans, or segments of large circles requiring a less diminution than when the arcs are small. The centrings being prepared (and very common ones are sufficient), having commenced the intended arch with solid brick and chunam on the two side walls of the room, and having raised these portions to a height of about 3 feet, or about ¼th of the curve on either side, so as to form solid haunches, the hollow cylinders are laid side by side in chunam along the length of the room, with their small ends pointing inwards. On these, in the intervals between every two, well imbedded in chunam, another row is now laid, and so on, row on row (both sides of the arch rising equally), till the last course, forced in on the top, completes the whole. This last line of cylinders, of course, is vertical, and care must be taken during the construction to press every row well against the centring, and to beat into the interstices as much brick, jelly, and chunam as possible, to render the mass compact. Over the cylinders thus packed, chunam well diluted is plentifully spread; and on the summit of the arch in large curves, a sufficient quantity of jelly and chunam is laid to raise that part a little, and thus to prevent the lodgment of rain and moisture. Two coats of flat tiles in chunam are afterwards placed over the arch, and the exterior polished with fine chunam. The haunches being about 15 or 18 inches thick in circular spans, and more in others, the lower portion of the cylinder arches will need to be thickened with jelly, or brick and chunam, to produce an uniform slope in the extrados before the flat tiles are placed. The centrings should not in my opinion be removed before the arch is thoroughly dry, for the materials being slight, and fragile while *wet*, a sudden settlement at that time is very dangerous, and much more mischief is to be apprehended from it than from any slight improbable sinking of a well turned curve composed of light pottery, extremely strong when dry, and surrounded, as it will be then, by firm cement, and upheld as it were by the outer coatings of an equally powerful substance. The reasons which prompt the speedy removal of centrings to heavy stone and brick arches, do not here exist, and as with the common native centrings of mud, the gradual sinking of the various parts can, and does take place during the construction from the flexible nature of such supports, I certainly prefer them for cylinder roofs. The centrings used at Bangalore

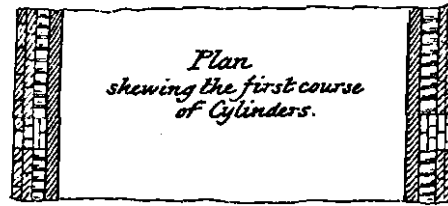
were of the roughest kind, and apparently very weak; indeed on one occasion during my absence, so careless were the workmen on this point, that a failure of one, before the work was dry, caused the ruin of a large arch, and the irreparable injury of the outer verandah. The centrings were principally composed of crooked old bamboos laid over and tied to jungle-wood Malabar trusses, supported on sun-burnt brick and mud pillars—sun-burnt bricks were packed closely together on the bamboos, earth strewed on these, and a plaster of wet mud applied over all, to render the curve smooth, which was further effected by a coating of dry sand. Strong posts of timber are preferable to the weak brick and mud pillars, and the trusses are about nine feet apart. When the centring is to be removed, the bricks and earth along the middle of it, that is, immediately under and near the key stone, should be carefully picked out first, and cleared away from between the bamboos; then equal portions on either side simultaneously, to a distance of about three feet, after which the whole may be rapidly taken down. As a proof of the vast strength of these cylinder roofs, I must record the fact, that, on two occasions, owing to heavy rains having completely saturated the mud and earth of the centrings before the arches could be completed, the former became when dry so caked to the interior of the roof, that, after the severe blows of a crow-bar proved ineffectual, a hammer and chisel were resorted to. Many of the cylinders were broken at the smaller end by this violent process; yet (notwithstanding several men were walking over head at the same time) not a crack occurred. It must be remarked that, at certain intervals along the roof, and at each end, arches of solid masonry, one and a half feet broad and nine inches deep, are turned from wall to wall, as aids and binders to the cylinders, which are built up between them, and at the same time: so that in a building sixty feet long, forty-two feet only are really composed of cylinders. The following memoranda, taken on the spot, may serve to facilitate calculations for various spans, but as the actual cost of material will vary much at different places, and the workmen will necessarily at first be rather slow in their operations, while such strict and constant surveillance may not be always attainable, the actual expenditure will be a little greater perhaps, though the quantities ought not much to exceed the estimate I have formed. The operations connected with the construction of these roofs are really so very simple throughout, and ordinary bricklayers so promptly comprehend them (those at Bangalore being now highly expert in the matter), that it is surprising such excellent permanent coverings to houses, godowns, and stabling have not become more general—one half the weight of a tiled roof (as subsequent statements will prove) one-third cheaper than the same formed of teak,

- a Section showing the
Cylinders in front.
- b Masonry Binders in
the middle & rear.

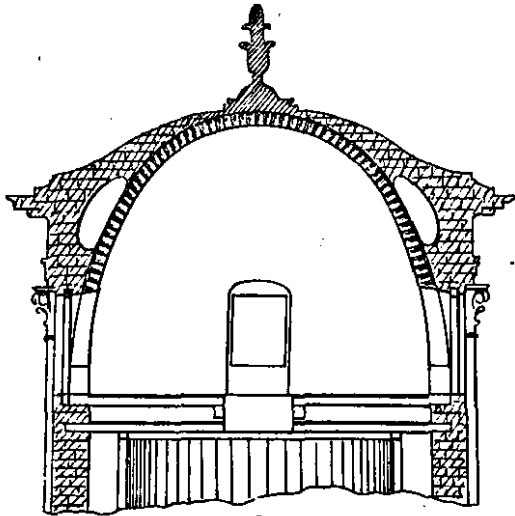
Side View



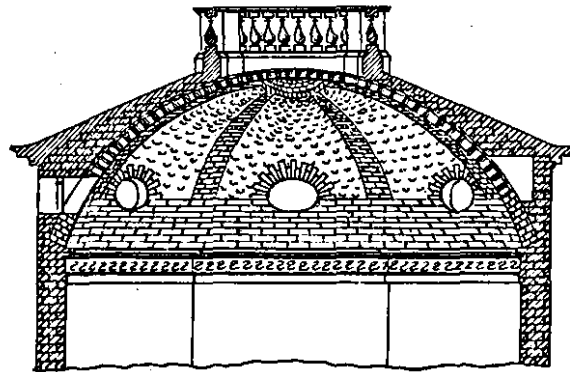
Plan
showing the first course
of Cylinders.



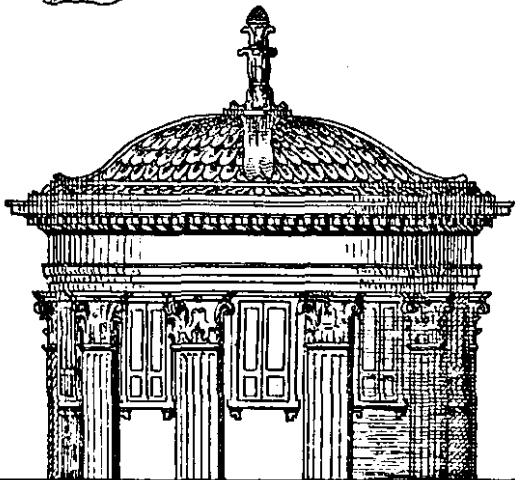
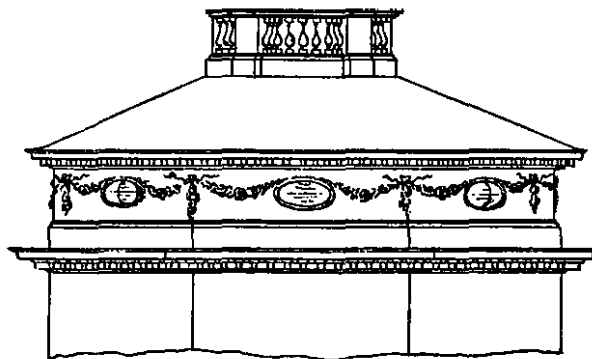
Section of the Ice House.



Section of the
Medical School.



Elevation of the
Medical School



wood rafters, reapers, &c. &c. one half the price and weight of a terrace roof, while in duration, cleanliness, coolness, and appearance, it far exceeds every other; the Syrian or cylinder roof on the score of comfort and economy deserves the highest patronage in India, where white ants, rats, and vermin, are destructive and annoying.

For a room 33 feet × 21 feet—semi-circular arch—1088 superficial square feet.

CYLINDERS—5 inches largest diameter, 4½ inches smallest diameter.

60 { (Now in the above curve there are 32,97 feet, or 395.64 inches, and it would require 70 cylinders (5 inches diameter) to go over; but with chunam, and deducting for solid brick and chunam curves at the haunches (about 3 feet on each side) 60 only were found to be necessary, (quarter less than the whole estimated.)

70 { Again, there are four brick and chunam binders, 1 foot broad each; and therefore 70 cylinders only were used in the length.

4200 at 6 rupees per 1000 = Rupees	25 0 0
CHUNAM, about 50 candies, at 1½ Rs. per Candy =	75 0 0
FLAT TILES 7000, at 12 As. per 1000 =	5 4 0
BRICKS—for binders and haunches 8000, at 2½ Rs. per 1000 =	20 0 0
Materials. Rs.	125 4 0

CENTRING to erect—8 men at 4 fanams per day, for fixing timbers.....	32 fanams.
Laying bricks, mud, &c. &c. and bamboos.	
16 men at 4 fanams.....	64 fanams.
40 women at 1 fanam.....	40 "
4 coolies for mud, at 2 fanams	8 "
	about 12 0 0
Taking down centring, 4 men 5 days, 80 fanams.....	about 6 8 0
BUILDING ARCH.—The same number of men and women as above, 1½ day, or Rups.	18 0 0
Laying flat tiles, &c. &c. and chunaming outside, 4 men 2 days, 32 fanams, about Rs.	2 8 0
Roof without ornament and in the rough though quite water tight.	Total Rs. 164 4 0
Fine chunam, inside and outside, and ropes, and timber for centring, and sundries not included, as these last were carried to account elsewhere.	

A TILED ROOF with teak rafters, reapers, &c. shorter by 3 feet would cost 230 Rupees in the rough..... 230 0 0

ROOM 20 feet × 17 feet span—actual observation. 1555 baskets of chunam were used for the cylinder roof—3 baskets contained 10 seers of chunam and 10 seers of sand—

Therefore 518 marcals of chunam were used—25 candies and 18 marcals.

Room 21 feet × 15 feet span—semi-circular—about 450 superficial square feet.

CYLINDERS—5 inches diameter larger end—52 were found to go over, and owing to two brick and chunam binders at the ends—45 were required for the length.

2340 required for the roof, at 6 Rs. per 1000 about	Rupees 14 0 0
CHUNAM,	12 0 0
FLAT TILES—5000 at 1 Rupee per 1000	5 0 0
Workmanship for this and chunam.	10 0 0
Workmanship for laying cylinders, erecting, centring, and removing do.	20 10 0
Total Rupees	<u>61 10 0</u>

Sundries not included.

Spans of 9 feet, 16, 18, and 20 were tried, the result of the whole is, that in large spans 4½ cylinders per square foot superficial seems to be a fair allowance; and 5½ cylinders in moderate spans of 10 and 15 feet, there being less of the arch composed of brick and chunam.

CHUNAM about 12 candies to 1000 chatties, a fair allowance, fine chunam and ornament not included.

FLAT TILES, twice as many as the cylinders used (for two coats).

AVERAGE COST of the roofs in the rough, without ornament, about 6 superficial square feet of roofing for 1 rupee.

The arch may be very highly ornamented inside by allowing the brick and chunam binders to project from the cylinders about 2 inches. These parts embellished as Grecian soffits with stars, flowers, wreaths, &c., and a device at the key stone for chandeliers, while the retired cylinder portions are formed into tablets, give the whole a pleasing and cool appearance; or ceiling cloths may be adopted at the cornice to avoid such expense. Windows can be placed above in the arched end walls of various rooms, or small circular perforations may be safely left at intervals along the length through the haunches above the drains; some openings above, whether windows or otherwise, are desirable certainly, as well for the coolness, as to destroy the echo which slightly exists in all arched rooms not much furnished. The walls which supported the large 21 feet arches were partly brick and mud, but mostly formed with chunam. They were about 13 feet high, with so many lofty and wide doors, that the solid parts were very slight, yet the thickness of these walls, 1½ feet, has been found to answer perfectly. They were strengthened, however, by the Ionic pilasters inside and out, and the 10 feet cylinder arch of the verandah abutted against the larger one, and thus added to the stability. In the smaller arches of 17, 16, and 15 feet, the walls were purposely tried of pisé, brick and mud, and a composition of both; they were of various heights, but generally about 10 feet and 1½ feet thick only, the upper foot, or foot and a half, being built with brick in chunam. The pisé at Bangalore was

found to be extremely hard, but situated as was my building close to water, I was enabled to build cheaper with brick, therefore that mode was relinquished.

The supporting iron hooks for chandeliers, &c. were fitted into blunt wedge-shaped blocks of wood, which were built into the solid brick and chunam binders as key stones, and perfectly surrounded with chunam and masonry.

MEMORANDUM OF THE COMPARATIVE WEIGHT OF THE CYLINDER AND TILED ROOFS.

(From actual observation and experiment.)

CYLINDERS.

4 cylinders about 10 inches long—larger diameter 5 inches—smaller diameter 4½—were found to cover 9½ inches × 9½ inches, when properly placed.

Weight of the same..... 7 lbs.

Now adding..... 5½ lbs.

For the weight of chunam between the cylinders and for the plastering on the top and bottom of the four cylinders, then the total weight for a space, 9½ inches by 9½ inches. 12½ lbs.

(The chunam is overrated.)

TILES.

For a corresponding space of 9½ inches × 9½ inches (according to the ordinary mode of laying tiles at Bangalore)—the following tiles and parts of tiles were found to cover it. These portions carefully cut off and weighed gave the following result:—

2 whole tiles	=	2
2 half tiles (longitudinally)	=	1
2 portions (¾ of a tile each)	=	1½
2 portions (⅓ of a tile each)	=	1¼
1 portion ⅘ of a tile	=	⅘
3 do. each ⅙ of do.	=	½
2 do. each ⅓	=	⅔
	}	1

Total equivalent to tiles 6½ the actual weight of all these was found to be 11lbs. *without* chunam.

The tiles were picked, and the lightest as well as the best that could be procured, while no selection was made for the cylinders. The flat tiles were not taken into calculation, as both roofs require an equal number, unless two and three coatings of these be given to the arched roof, in which case, as tiles are much increased in weight by rain, while the cylinder roof is not so affected, the ultimate strains will be even then much alike. The timber, nails, &c. of the tiled roof are all in excess, and a cylinder roof once properly laid presents much less resistance to the wind, and will seldom or never require repair.

N. B.—As 6½ tiles cover 9½ inches × 9½ or 95.0625 square inches, which is nearly ¼ of a square foot, about 10 tiles to the square foot is a fair allowance.

Since the foregoing was written, a Dome of 32 feet span composed of hollow Cylinders with solid brick and chunam Ribs has been constructed for the Medical School at Madras by Major J. J. Underwood Superintending Engineer. It has large openings all around some short distance above the spring, and with a view to improve the outward appearance of the Building, Masonry has been added which changes the exterior curve of the Dome into one apparently much more flat and resting on an Attic Story. This has a good effect, and tends to consolidate the superstructure, if judiciously managed, but of course the expense is enhanced.

A similar Syrian Roof of a parabolic shape is to be constructed over the new Ice House, and a section thereof is here given. A Chapel at Bangalore has also a Syrian Roof which has stood for some years very well; and indeed it is obvious that the longer a Roof of this description exists the stronger it becomes.

MADRAS, }
20th Dec. 1838. }

NOTES OF SOME EXPERIMENTS MADE BY CAPTAIN A. COTTON, UPON MR. AVERY'S STEAM ENGINE—BY CAPTAIN J. T. SMITH.

A great variety of highly interesting experiments have been lately made by Captain A. Cotton, on the subject of the efficiency of Mr. Avery's Steam Engine, and its fitness for locomotive, and other purposes in India, for which its beautiful simplicity so strikingly recommends it. A few notices of these experiments fell into my possession in the course of correspondence with the persevering and highly gifted author of them, and I am induced, imperfect as they must necessarily be, from my having only witnessed one out of many independent series, to unite them in the best form I can, for the information of others who have not had the same opportunity as myself, both because I feel sure that the subject is one well deserving of attention, and also because, from seeing the many perplexing disappointments and waste of expense which resulted in the early part of them, from too great reliance upon statements made by parties who were either incapable of correct judgment, or were interested to mislead, I have been strongly impressed with a feeling how very valuable more authentic accounts must be to all those, who may be led by necessity or choice to engage in a similar undertaking.

A good description of this Engine will be found in the *Mechanics' Magazine*, Vol. 24, No. 637, but for those who may not have immediate access to that publication it may be useful for me here to sketch briefly the principle of its action, in order that what follows may be more intelligible.

The general arrangement of the motive part of Mr. Avery's Engine, as well as the principle of its operation, bears a considerable resemblance to Mr. Barker's mill, the effect in the one being produced in the same manner by steam, that it is in the other by water; and the theory of the two machines, though the same perhaps when referred to general principles, may be treated quite differently, when the latter is confined within the practical limits to which we have reference at present.

From the subtle nature of the prime mover, also, in the one case, much greater nicety is rendered necessary in its construction and adjustment. The general arrangement may be described as follows.

A hollow axle closed at one extremity, is mounted between two supports, the first of which is a pivot on which the closed end turns, the second is a collar with a stuffing box, attached to a small steam chamber fixed on the top of the boiler, and in communication with it. Within the collar the open end of the axle fits as a gudgeon, so as to be capable of free rotary motion with very little friction, while the stuffing box renders the joint steam tight. In the middle of this hollow axle two hollow arms are fixed perpendicularly, in line with

one another, on opposite sides, having closed ends, but each pierced with an aperture near its extremity, pointing in the direction of the track described by the rotation of the arms, and intended for the escape of the steam; which, passing from the boiler through the steam chamber and the hollow axle before described, rushes through the arms and discharges itself from these apertures into the air, at the same time generating in the arms the circular motion which impels the whole machine.

In endeavouring to explain, or to submit to calculation, the efficiency of steam as a prime mover, when employed in this manner, it is necessary to premise, that as the communication is quite free from the boiler to the end of each arm, unless purposely interrupted by a throttle valve or stop cock, there is necessarily the same pressure upon every square inch of the arms, as upon the boiler itself, which pressures, however, balance one another in every part, excepting at that point opposite to which is the aperture whence the steam is liberated; hence the *reaction*, arising from the unbalanced pressure of the portion of the arm opposite the aperture, produces the motion; and it is obvious that the effect derived in this manner will be proportioned to the amount of this pressure, and the velocity at which its action is applied at the end of each arm.

In regard to the first point, it has been before observed, that as long as the communication is complete, the pressure in the arms ought to be exactly equal to that in the boiler; but this must be understood to refer only to the uniform pressure at which the boiler is capable of maintaining a constant velocity in the Engine, since it is evident, that unless a proper proportion be preserved between the evaporating power of the boiler, and the apertures of discharge, a maximum of effect cannot be obtained; an undue contraction of the apertures causing an accumulation of the steam, and loss by the safety valve, while an over-enlargement leads to a reduction of the pressure, and consequent diminution in the effect.

It is indispensable, therefore, to a proper estimate of the power of an engine to be constructed upon the above principle, that we should know—First, The quantity of steam per unit of time, (or in other words the evaporating power of a boiler) necessary to constantly supply an aperture of a given size, at a given pressure; and Second—The velocity at which the power thus obtained can be practically applied to useful purposes.

It is in reference to these points that the principal benefit is to be derived from the experiments which are here to be noticed, and as the main object to be aimed at is that of fixing a definite value to the effects of

known quantities of steam, acting by means of this new mechanical agent, it is unnecessary, in examining them for this purpose, to deduce the results from any comparison of the quantities of fuel consumed; as no improvement in the mode of evaporating water was attempted in any of them. I shall therefore refrain from paying any regard to that part of the experiments, unless in the way of incidental notice; and I am the more strongly urged to do this, because, not only is the statement of results more simple when referred to the cubic foot of water evaporated, but also because, in the trials which I refer to, the means of generating the steam were open to many objections, which could not be easily taken into account, and which would otherwise prejudice the examination of the results obtained.

Previous, however, to entering upon a detail of the practical results arrived at, it may be useful to anticipate an enquiry which naturally suggests itself, in the consideration of the theory of this machine; viz., whether the pressure which arises from the escape of steam in the manner above explained, while the engine is at rest, remains still unaltered after the point upon which it acts has been urged by it to a high velocity. In considering this question, the operation of the elastic fluid in the arms may be compared to that of inflamed gunpowder in a rocket, and a clearer insight into the mode of its agency may be attained by observing, that as the origin of the power and mode of its application in the latter case are both internal in the body moved by it, so no loss of effect can be produced by any change of position in that body in regard merely to external objects. It is thus that in the case of the rocket the motive force arising from the expulsion of the condensed gas or vapour has no relation to the velocity with which the projectile is moving; and were a similar instrument propelled by the issue of condensed air or steam, the force impelling it forwards would be *constant*, as long as the condensation was maintained unchanged.

The same considerations also apply to Mr. Avery's Engine, for although the generation of the steam and supply to the arms cannot be said to be internal as relates to *them*, still the effect is in no way diminished by whatever velocity may be attained by the orifice of discharge, as long as that velocity is not "relative" in regard to the source of supply; that is, in other words, as long as the motion which produces this velocity does not increase the distance between the aperture and the origin of the steam. For, should the principle of the explanation just given be correct, it cannot be denied that the impelling force must remain invariably the same, as long as the tension of the confined vapour is undiminished; and the only way in which this diminution of tension could be effected, whilst the supply from the boiler is exactly equivalent to the discharge, would be by some enlargement of the capacity of the boiler and other passages containing the steam; but as the utmost conceivable velocity

communicated to the arms would make no alteration in the capacity of the Engine, or the bulk of the confined vapour, it is impossible to attribute to it any change in the tension, or diminution of the impelling force; which must therefore be *constant* at all velocities.*

This consideration points out the very great importance of the attainment of a high speed in the rotatory arms, since every increase of velocity is attended by a corresponding augmentation of the effective power of the machine; and we have abundant evidence that every effort has been directed to this point by the ingenious inventor, in the fact of some of his machines being stated to work at a velocity of no less than 45,000 feet per minute. This high speed is however only attainable by a combination of favourable circumstances, and by a nicety of workmanship and adjustment, which it would be vain to expect from native workmen in India; and it will be therefore observed that in none of the experiments hereafter related does it amount to any thing like that above stated. This is not however entirely due to the want of skill in the execution of the work, but more to the absence of other necessary arrangements in the fitting up of the machines, none of which were ever so completely finished in all their parts, as to be incapable of further improvements to a great extent; and more particularly by the addition of an outer case to enclose the revolving arms, as a means of diminishing the resistance of the medium through which they have to force their way, which is one of the greatest difficulties to be overcome.

The first experiments which were made on this Engine were tried at the lower Annicut across the Coleroon, about 35 miles below Trichinopoly. A small machine was here made for pounding magnesia, and by it a hammer weighing 30 lbs. was tilted by the usual contrivance of a set of wipers fixed on the circumference of a cylinder, which was made to turn by a strap passing round a large band wheel fixed on it, and over a pulley on the same axle with the arms. The boiler which supplied this Engine was ascertained by experiments, to evaporate about $\frac{1}{2}$ of a cubic foot of water per hour, which was made use of in the condition of steam of 30 lbs. effective pressure. The arms were of $2\frac{1}{2}$ feet length, and each was pierced with an aperture of rather less than $\frac{1}{4}$ of an inch diameter, the two together amounting to about $\frac{1}{10}$ of a square inch in area. The sum of the pressures of the steam at the ends of the two arms was found by experiments to be between 5 and 6 oz., and the useful effect produced was thirty lifts of the hammer to the height of one foot per minute, equal to 900 lbs. 1 foot high per minute, or about $\frac{1}{4}$ th of a horse power.

The greatest velocity which was obtained in this small machine was 25,000 feet per minute, when the arms were allowed to revolve without any load. The working velocity was 10,000 feet per minute. The friction of the axle of the arms was ascertained to be about $\frac{1}{2}$ oz. as

* In these and the following remarks, no attention is paid to the "vis inertia" of the steam, and the loss of effect which takes place by its passing from a state of rest into the arms which are moving with a high velocity; neither is any notice taken of the additional pressure which may be caused at the end of the arms by the centrifugal force of the steam contained in them; both these considerations appearing to be too refined, to be of any practical importance in the manner in which the subject is here considered.

measured at the place of the aperture, and Captain Cotton estimated that the whole steam power was thus disposed of.

Resistance of the air to the arms.....	0.8 oz.
Friction of the axle.....	0.33 do.
Friction of the Fly wheel, wipers, &c.	2.75 do.
Useful effect.....	1.5 do.
Total..	5.38 oz.

In the above results it will be observed, that the amount of pressure obtained by experiment at the end of the arms does not precisely bear the same ratio to the pressure of the steam in the boiler that the area of the apertures does to the unit of surface, for the $\frac{1}{3}$ of 30lbs. would give 6 oz. as the pressure at the end of the arms, while that actually measured could not be stated on the average at above $5\frac{1}{2}$ oz. This difference was explained by subsequent experiments, and found to be due to the contraction of the vein commonly observed in all discharges of fluids through small apertures.

On increasing the area of the orifices supplied, as well as the amount of pressure realized, in the ratio of 4 to 3, it appears that a cubic foot of water per hour expended in the condition of steam of 30lbs. effective pressure, ought to supply an aperture of $\frac{1}{3}$ of a square inch (or two of half that area each) producing by this means a pressure of $7\frac{1}{2}$ oz. The results, however, of the experiments made on this occasion, being derived from an apparatus on so small a scale, cannot be considered worthy of so much confidence as those which will be hereafter given.

The next trial of which I have any notes, was made at Porto Novo. Here a pair of arms was fitted to a common boiler, the evaporating power of which was not measured, but which was estimated by the Engineer, (Mr. Brunton) to be sufficient to supply a five Horse engine in the common way, that is, evaporating about 7 or 8 cubic feet of water per hour. At an effective pressure of 50 lbs. the arms, which were each 30 inches long, and of a circular form $1\frac{1}{2}$ inches diameter, attained a speed of 1,000 revolutions per minute, indicating a velocity at their extremities of 15,708 feet, without any load.

The next memorandum which I come to, gives a valuable experiment on the issue of steam. It is contained in the following Extract dated 5th May 1838.

“By a very careful experiment continued for an hour and thirty minutes, I obtained a constant pressure at the end of the arms of $2\frac{1}{2}$ lbs. at 40 lbs. (effective) pressure per square inch—Diameter of orifices $\frac{1}{8}$ inch each, or area of both $\frac{1}{8}$ square inch. This continued without a perceptible change of pressure in the safety valve or at the end of the arms for 1 hour 30 minutes, when we put out the fire and let the water cool, without opening the safety valve, and the quantity evaporated proved to be 12 cubic feet, or 7 cubic feet per hour, allowing $\frac{1}{4}$ hour for the time that the escape of the steam was stopped.” “I tried the evaporation of the boiler two or three times, and found it about 7 cubic feet per hour each time. This gives 5 oz. per cubic foot.”

On the 31st May another pair of arms was attached to a large boiler, whose evaporating power was estimated to be equal to about 41 cubic feet per hour. At the time the experiment was made, the boiler was also supplying steam to a common (high pressure) engine, which was supposed to take away 31 cubic feet per hour; there was therefore calculated to remain 10 cubic feet per hour for the supply of the arms. The effective pressure in the boiler was 30lbs. per square inch, and that at the end of the arms was found by experiment to be 12lbs; the size of the apertures is not stated. The greatest velocity obtained with this engine was from 15 to 18,000 feet per minute; and by way of trial, an iron lathe was attached to it, which “it worked very well.” The working of the lathe was stated not to make the least perceptible alteration in the velocity.

While these experiments were being made, another small engine was in progress at the Red Hills. It was originally constructed as a locomotive, to run on the Rail way between that point and Madras, but its power was found insufficient for that purpose. The boiler was of a capacity sufficient to evaporate a cubic foot, or a foot and a half, of water per hour, being cylindrical, and of 8 inches internal diameter, and 6 feet length, and having a large fire box and grate; and it was expected, from the statements made in the Mechanics' Magazine and other publications, referring to experiments made in America, that this would have given an available force of from 3 to 5 lbs. at the end of the arms. This however was soon discovered to be an over-statement, the pressure at the end of the arms being in no case equal to 1 lb.: but the individual experiments themselves cannot be exhibited in a form capable of comparison with other results, owing to the anomalies they contain, and to the difficulty, in so small a boiler, of maintaining an uniform rate of evaporation, or indeed of keeping up any experiment for a sufficient length of time; no means having been provided for replenishing it as the water became low. Sufficient knowledge was however derived from the results obtained with this engine to show, that the evaporating power of a boiler capable of keeping up the required force at the end of the arms must be much greater than the one tried; and it also seemed to be a fair conclusion from the whole of the trials made, that from 8 to 10 oz. per cubic foot of water evaporated per hour, was the utmost that could be safely calculated on.

A new locomotive engine was now constructed from the above data; and, as it was considered that a force of 3 lbs. at the end of the arms would be amply sufficient for the purposes required, such a capacity was given to the boiler as to ensure an evaporating power of about 4 or 5 cubic feet per hour. This was completed in the latter end of August 1838, and after a few preliminary trials gave the following results.

RED HILLS, Aug. 28th, 1838.

Experiment No. 1 with Locomotive.

Arms 3 feet long, thickness $\frac{1}{2}$ th Inch.

Steam passage at end of Arms $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ square Inch.

Velocity of Carriage $\frac{1}{4}$ of the end of the Arm.

Avery's Steam Engine.

1st Experiment.

Weight of Engine and Carriage	2,600 lbs.
3 other Carriages	3,000 "
21 Persons	2,500 "
Coal, Water, &c.	500 "
	8,600 lbs or 4 Tons.

Orifices; 3 in each Arm of $\frac{1}{8}$ Inch Diameter
 = $6 \times \frac{1}{8} \times \frac{1}{8} = \frac{3}{8}$ Square Inch. or $\frac{3}{8}$ of ditto (to allow for the contracted vein) $\frac{1}{8}$.

By trial, with pressure 35 lbs. per square inch, force at end of Arms 17 oz.; Friction very trifling. Total pressure 17 $\frac{1}{2}$ oz. = $\frac{1}{8}$ square inch; $\frac{1}{4}$ of which is $\frac{1}{8}$ inch.

Do. at 40 lbs. 20 oz.
 Fall average 1 in 1,000
 Force of Gravity 9 lbs. $\frac{1}{8}$ of 9 lbs. = 2 oz.
 Total Force of Gravity and Steam 22 oz.
 Friction of Engine by after Experiment about 7 oz.
 Train exclusive of Engine 6,000 lbs.
 Friction of do. by former trials about 40 lbs. or 1 in 150.

$\frac{1}{8}$ of do. = 8 oz.
 Then

Friction of Engine	7 oz.
do. of Train	8 "
	15
	22

Resistance of air 7

Velocity of Train about 2 $\frac{1}{2}$ miles per hour.
 do. of Arms . . . 200 do.
 or 1,056,000 feet
 or 17,600 " per minute.

2d Experiment.

Velocity 3 $\frac{1}{2}$ miles per hour.	
Fall 1 in 1,000.	
Force of Gravity 6 $\frac{1}{2}$ lbs. or 1 $\frac{1}{2}$ oz.	
Weight of Engine	2,800 lbs.
2 Carriages	2,000 "
10 Persons	1,200 "
Sundry things	500 "
	6,500 lbs. or 3 tons.

Orifices 8 Diameter: as above
 6 : 20 :: 8 : 27 oz.
 Gravity 1 $\frac{1}{2}$

Total force 28 $\frac{1}{2}$

Resistance of Engine as above 7 oz.
 do. of Train 3,700 lbs. 5

12
28 $\frac{1}{2}$

Resistance of air 16 $\frac{1}{2}$

Miles. Oz. Miles. Oz.
 (2 $\frac{1}{2}$)² : 7 :: (3 $\frac{1}{2}$)² : 14, Error 2 $\frac{1}{2}$ oz.
 Velocity of Arms 280 miles per hour.
 or 1,480,000 feet do.
 or 24,700 do. minute.

3d Experiment.

Engine above just ascended inclination of 1 in 60, with Steam at 30 lbs.

Weight of Engine 2,800 lbs.
 2 Men, &c. 450 "

60 | 3,250

Gravity 80 | 64 lbs.
 .7 do.
 16
11.2 oz.

lbs. oz. lbs.
 40: 27 :: 30: 20 oz.
 Total force 20 "
 Gravity 11
 Friction of Engine 7

18 — 18

Error 2 but this probably

will not be more than the additional Friction of the Engine, owing to one strap being reversed.

In these experiments it will be observed, that the total force exerted at the end of the arm was much less than what was calculated upon, being only in the most favorable case (Experiment 2d) 1 lb. 11 oz. instead of 3 lbs. This was owing to defects in the furnace and chimney, producing an insufficiency in the draught; so that it was impossible to keep up a proper fire. These defects were soon remedied, and the power was then found to be much increased, the evaporation having been augmented to very nearly 4 cubic feet per hour, and the pressure at the end of the arms (when the apertures were of a size sufficient to expend nearly all the steam) being raised to 2 lbs. 6 oz. This being sufficient to propel the engine at an increased speed, the mechanical arrangement by which the relative velocities of the arms and the carriage were regulated, was altered, and the following was the result obtained.

Experiment with Locomotive Engine, 12th Sept. 1838.

Weight of the Engine with its } 3,000 lbs.
 boiler and Carriage, &c. }
 Tender and Coals 1,600 "
 Carriage and 8 passengers 2,400 "

Total 7,000 lbs. = 3.12 tons.

The pressure in the boiler was fully 50 lbs.; and there were six apertures in the Arms of $\frac{1}{8}$ inch diameter each, making in all $\frac{1}{8}$ of a square inch in area. The force at the end of the Arms was found by experiment to be 38

oz. the evaporation being about $3\frac{1}{2}$ cubic feet per hour, (being at 10 oz. per cubic foot per hour) and with the above load of $3\frac{1}{2}$ tons the Arms acquired a velocity of 16,000 feet per minute, the whole train being carried forwards at the rate of about $4\frac{1}{2}$ miles per hour.

The contrivance by which the motion of the Arms was conveyed to the carriage, was that of a pulley fixed on the axle of the Arms round which a strap passed over a band wheel fixed underneath the carriage frame, and carrying on its axle a pinion which drove a large cog wheel fixed on the axle of the carriage wheels; the velocity of the end of the arms was thus reduced, so that the circumference of the wheel moved with only the $\frac{1}{4}$ th part of that of the apertures.

Weight of the Engine & Carriage	3,000 lbs.
Tender and Coals	1,600 „
Tappal Carriage	1,400 „
8 Persons	1,000 „
Total	7,000 lbs. or $3\frac{1}{2}$ tons.

Friction of Engine	35 lbs.
Tender	10 „
Carriage and People	15 „
Gravity 1 in 1000	7 „
Total	67 lbs.

The road was not perfectly level where this experiment was made; but there was an ascent of about 1 foot in a thousand, and from various experiments it was judged, that the following was the distribution of the power derived from the above mentioned pressure of 38 oz. at the end of the arm.

Friction of the Engine and Traction of the load	} $\frac{1}{4}$ of 60 lbs. = 24 oz.
Gravity $\frac{1}{4}$ of 7 lbs.	
Resistance of the Air to the Arms	11
Total	38

On this occasion the length of the arms was 30 inches each, their breadth $1\frac{1}{2}$ inch, and their thickness (being that side opposed to the air) $\frac{1}{2}$ inch. The total useful effect obtained may be calculated at rather more than $\frac{1}{2}$ a horse power, since, from the bad state of the road, the traction of the load was ascertained to be not far from 15 lbs. per ton; whence the resistance overcome in hauling the train, and in propelling the engine, may be estimated at $3\frac{1}{2} \times 15$, or 47 lbs. nearly, moved through 196 feet in a minute, equal to 18612 lbs. through 1 foot per minute; and this result from an evaporation of $3\frac{1}{2}$ cubic feet of water, is about $\frac{1}{3}$ th of the usual effects of steam in a condensing engine, calculating the latter at the rate of 33 cubic feet steam of low pressure per horse power per minute. The above is the most favorable result which was arrived at from any of the experiments hitherto made, and it is much to be regretted that their abrupt termination by the sudden departure of their indefatigable author, owing to ill health, has deprived us

of the opportunity of becoming acquainted with the results of a further prosecution of the enquiry in the capabilities of this machine.

This is the more unfortunate, since the most important question relative to it, viz. its comparative efficiency as a mechanical agent with the other means of applying steam now in use, rests upon the determination of a point still left undecided. The results derived from the various experiments which have been given, seem to point to the truth of the important peculiarity in the theory of this engine before noticed, viz. that the same powers which are measured at the end of the arms, when in a state of rest, are also exerted by them when moving at high velocities; whence it might be inferred upon theoretical grounds, that by an indefinite increase of the velocity, the mechanical effect might be multiplied in an almost unlimited ratio; to this the chief obstacle opposed is evidently the term fixed by the resistance of the air to the acceleration of any body through it, and the danger of the destruction of the machine by the mere centrifugal force of its parts. The latter difficulty is to be met by careful and sound workmanship and substantial proportions, and with regard to the former, since it may perhaps be impossible wholly to escape the difficulty, no pains should be spared to extend the limit of the terminal velocity as far as possible, by all the aids which ingenuity may suggest; and as the measure of the mechanical efficiency of the engine must entirely depend upon the success with which this improvement is prosecuted, it would have been highly satisfactory could some practical answer have been given to a question which must finally depend for its solution upon mechanical resource, as some criterion whereby to judge of its future capabilities.

In the last and most favorable experiment above recorded it will be observed, that the highest velocity attained with a load, is stated at about 16,000 feet per minute, but in other trials, of which I have unfortunately no data, the speed was occasionally augmented (with a lighter load) to more than 20,000 feet. Nor does it appear unreasonable to suppose, that with better workmanship and in a larger engine, in which the same *proportionate* loss of effect from atmospheric resistance would correspond to higher velocity, since the thickness of the arms need not be much increased, this velocity might be very much improved; more especially by the adoption of the outer case for the revolving arms used in all the Patentee's engines, which by substituting steam for the atmospheric air, changes the medium to one of less than half the specific gravity, and diminishes the resistance accordingly.

In the absence of any certain information on so material a point, it is perhaps in vain to speculate upon the results which may be anticipated from a fuller trial of this machine upon a more extended scale; but as this notice of what has already been done would be practically incomplete without some kind of clue for the guidance of future expectation, it may be mentioned, that the highest velocity which has been yet announced by the inventor, as that under which the machine has worked, has not exceeded 45,000 feet per minute, and

although the other statements which have been made (probably through ignorance) by other parties, have been found extravagant, there seems to be no reason, from the results already recorded, to suppose that there is the same error in this, which refers to a point on which it is more easy to obtain decisive results. Indeed it seems quite reasonable to infer, that in a medium of less than half the density of that in which these experiments were made, the residual force (left after accounting for the friction and work of the machine) should impel the arms with a double velocity; and as in large engines the working power will approach the term expressed by the pressure at the end of the Arms drawn into the velocity attained, it is fair to conclude, that under favorable circumstances, a much greater effect than that above realised may be calculated upon.

To render this opinion more intelligible, it may be remarked, that as the experiments show that a constant pressure of at least 8 oz. may be maintained by the evaporation of each cubic foot of water, it may be calculated that if the velocity of 45,000 feet per minute be realised, the power will be equal to 22,500 lbs. raised one foot high per minute. The same quantity of steam made use of in the common condensing engine, not worked expansively, is calculated to raise 27,500 lbs. through the same space, which is only about $\frac{1}{4}$ th more; but it must not be omitted, that this latter estimate exhibits the effective power remaining after the deductions on account of leakage, friction, waste, and condensation &c. have been made, which is not done on the other side of the comparison.

Upon the whole, therefore, there appears to be encouragement to hope, that the further improvement of this invention, which though one of the oldest in its first discovery, has only of very late days possessed any practical interest, may perhaps reach the limits of a fair comparison with the usual effects of the condensing engine, as hitherto applied. The extraordinary results which have been obtained in the Cornish machines, by means of an extreme application of the principle of expansion, and a minute attention to every refinement in the economy of heat, ought not perhaps to be brought into comparison with an invention at so early a stage of its improvement, and these are accordingly not here referred to.

The remarks which I have ventured to make upon

the great improvement to be expected from the application of an outer case, by which the Arms are made to revolve in a rarer medium, naturally lead to a suggestion which would appear to promise the advancement of a further step towards rendering this invention more perfect. I here allude to the consequences which would result from condensing the steam led off from such an enclosure, and thus causing the Arms to revolve in vacuo. As the quantity of steam expended in this kind of engine with the increased velocity thus obtained, would not, as appears from the calculation given above, much exceed what is condensed in common engines, no practical difficulty in obtaining a partial vacuum by the same means need be apprehended, and it seems an almost inevitable consequence, that by thus removing the grand obstacle, the velocity of the revolving arms might be very much further augmented. It may perhaps, indeed, be thought questionable, whether the further increase of a velocity already more than half that of a cannon shot would be a safe, or at least an advantageous experiment; but, when we refer to the accounts of the extreme ease and quietness of motion with which that high velocity is maintained in the engines already worked, there seems to be much less ground for apprehension than would at first be entertained; and the immediate and inseparable connection in this machine between the velocity and useful effect encourages every effort to overcome whatever practical difficulties may be met with in its accomplishment.

The removal of the resisting medium would in one respect so modify the character of the engine, as to give a facility to the attainment of the above desirable object in a way not before practicable; since it would under such circumstances be advantageous to use arms of a greater length, and thus increase the velocity without adding to the number of the revolutions; nor ought it to be forgotten, that an addition of an atmosphere to the pressures, also, would be gained by this improvement, independently of the benefit to be derived from the removal of the resistance; which, as it would at once augment the power of an engine worked at a pressure of 60 lbs. by one fourth, seems to put a seal to the assurance of those advantages, which offer a recompence for the cost and trouble of submitting this interesting experiment to the test of actual trial.

MADRAS, }
January 25th, 1839. }

POSTSCRIPT.

In the foregoing observations no reference was made to the consideration of the effects of the vis inertiae of the steam, and the centrifugal force generated by the revolution of the arms, as was specially mentioned in the note to page 96. These forces, which appeared to be of too small amount to be worthy of notice during the existence of the more sensible causes of retardation before referred to, become however of the highest interest when those resistances are removed; and although it is perhaps impossible to obtain an entire fulfilment of the conditions aimed at, by the creation of a perfect vacuum in the way pointed out above, still the following investigation of the limit which would *then* be opposed to the velocity of the steam, for which I am indebted to the kindness of a friend, cannot fail to be highly interesting to the scientific reader, and is moreover especially deserving of attention, as exhibiting a more precise view of the extreme limit to which the utmost success in improvement may be expected to extend the powers of the machine.

Let ω be the angular velocity of the arms; then the velocity in the direction of the tangent, which has been communicated to a point P at the distance r from the axis is ωr . And if v be the velocity of the steam down the tube at that point, it appears that the pressure of a section at P, perpendicular to the arm, will be represented by $2 \omega v$. If the centrifugal force be neglected, v will be constant, call it V. then the moment of the section at P whose length is represented by δr , round the axis will be $2 \omega V \delta r$; and taking the integral, observing that the moment vanishes when $r=0$, the sum of all these moments $= \omega V R^2$, if R be the length of the whole arm; or if $\omega R = V' =$ the linear velocity of the end of the arm, the sum of these moments $= V V' \times R$.

But if the centrifugal force be taken into consideration, it is evident that v will be a function of r , and it may easily be shown to be $= \sqrt{V^2 + \omega^2 r^2}$ where V = velocity of steam entering the tube. In this case the moment of the section at P $= 2 \omega r \sqrt{V^2 + \omega^2 r^2} \delta r$ and the integral will be found to be

$$\frac{2}{3\omega} \left\{ (V^2 + V'^2)^{\frac{3}{2}} - V^3 \right\} \text{ which } = \frac{2}{3V'} \left\{ (V^2 + V'^2)^{\frac{3}{2}} - V^3 \right\} \times R$$

The motion of the section at P has here been investigated as though it were a separate particle—The lateral pressure will not be materially altered by the circumstance of its being part of an elastic fluid mass, though the velocity would be much more affected by it; but it seems certain that the true result would lie between the two before stated.

The pressure of the issuing steam, which causes the arm to revolve, will be represented by the square of the velocity of the steam there (supposing the aperture to equal the section of the tube, and the density to be unaltered by any change in the constitution of the steam.) In the case therefore in which the centrifugal force is neglected, the moment of all the forces acting on the arm will be $R (V^2 - V V')$ which vanishes when $V' = V$. But if the centrifugal force be considered, then the velocity of the issuing steam $= \sqrt{V^2 + V'^2}$ and the moment of all the forces $= (V^2 + V'^2 - \frac{2}{3V'} \{ (V^2 + V'^2)^{\frac{3}{2}} - V^3 \}) R$.

The limit which might be indicated by the expression here arrived at, however, is applicable only to the revolution of the arms without any load, and must therefore, when applied to a practical consideration of the power of the engine, be modified by taking into consideration the value of the resistance caused by the work to be performed.

From the circumstance already hinted at above, viz. the possibility of a change in the constitution of the steam at high velocities, as well as from the retardation by friction along the inner surface of the tube, which has not been taken into account, it seems probable that the effect of the centrifugal force, included in the expression last given, ought not to be fully calculated upon; and that the truth will be more nearly exhibited by the first equation, in which the accelerating force acting at the end of the arm $= (V^2 - V V') R$.

If this then be taken as correct, the work done will be a maximum, when $(V^2 - V V')$ V' is one; that is, when $V' = \frac{V}{2}$. In this case, if F be the load acting at the end of the arm, (including the friction of the machine), F must equal $V^2 - \frac{V^2}{2} = \frac{V^2}{2}$ that is, the load should be equal to half the pressure at the end of the arm—and the maximum effect will be attained when the linear velocity of the aperture is equal to half that of the issuing steam. This result gives a much more unfavorable view of the prospects of the machine than that conveyed by the opinion expressed in the latter part of the foregoing paper; but it must be observed, that it is founded upon the supposition that the centrifugal force has no effect whatever, being neutralized by other circumstances, as above stated; and it may be right to take into consideration, that to whatsoever extent that hypothesis may be untrue, to that extent may the powers of the engine be enlarged by the agency of the centrifugal force, within the limits comprehended by the equation $P = (V^2 + V'^2 - \frac{2}{3V'} \{ (V^2 + V'^2)^{\frac{3}{2}} - V^3 \}) R$.

**NOTICES, ON THE PAST AND PRESENT CONDITION OF THE PORT
AND STATION OF MASULIPATAM, AND ON THE WORKS
RECENTLY UNDERTAKEN FOR ITS IMPROVEMENT—
BY LIEUT. E. BUCKLE ENGINEERS.—CIVIL ENGINEER
IN THE SECOND DIVISION.**

1. The attention of Government having been directed to the present condition of the Port and station of Masulipatam, the Civil Engineer of the Division was in the year 1836, called upon to report on the same, which in substance he did as follows. But such additional information is also here given as has since been collected.

2. This station, at the close of the last century, was a place of considerable importance, both in a military and in a commercial point of view, and it was, at that time, an object of interest to the state. The fortress is the only work of the kind between Fort St. George and the Hoogley, but the works have long been in a state of great decay, the revetments split from top to bottom, the wet ditch filled up, and the Embrasures of the different bastions in ruins.

3. It is well known that, within the present century, the trade conducted between Masulipatam and Persia alone was of a very extensive character, the Chintzes of the former place constituting its staple export; while, prior to this date, English, as well as Moghul and Armenian Merchants, were settled there; the whole now may be said to have disappeared; on the trade being thrown open in 1813, the cheap goods of England drove the Indian manufactures out of the market; but the inferiority of the former having been discovered, a demand for the better dyed Masulipatam cloths has revived, and is the cause of an increase in the Exports of 1835. Cloth and grain, as exports and imports, constitute the trade, it may be said, of Masulipatam. It would have been satisfactory to have supplied, to some extent, a table of the Port charges and duties, during a series of years; but this has not been possible, such information not appearing procurable. Latterly, Masulipatam has been the seat of a considerable trade in grain, conducted with Aracan and Calcutta, and with Ports along the Coast of the Northern Circars;—its amount, during the years 1833, 1834 and 1835, was from four to twelve lacs of Rupees per annum; the quantity imported has been from 2700, to 3500 Madras Garce and upwards, each year; with the returns of the last three years the writer is unacquainted.

4. The recently published survey has failed of its general accuracy, in the delineation given of Masulipatam, and its precincts. The river represented as flowing past Masulipatam, no longer exists in this form, though there are traces of it, and at some period, perhaps not very remote, it was a monsoon water-course of magnitude, fed in those days by the Kistna overflow.

5. Masulipatam stands on the North border of an insignificant inlet or sound; which, at a distance of 7 miles from the sea, is joined by the Chinnapore Canal; a small cut, $5\frac{1}{2}$ miles in length; which, running up to the North arm of the Kistna, is the Channel of a river trade of some importance.

6. In the year 1794, the astronomer of the Presidency, Mr. Topping, who appears to have been a person of general scientific attainments, was engaged in the Masulipatam District, in investigating the resources of the Kistna, as regards irrigation; and at that time also, he appears to have submitted a project, for the improvement of the Port and Station of Masulipatam, which was immediately put in course of execution, under his own superintendence.

7. Of his report, suggesting the operations which were undertaken, no copy can be found, nor could a single document throwing light on the subject, be obtained from any of the public offices, beyond one or two maps and plans.

8. Mr. Topping appears to have had two principal objects in view, the reclaiming the Masulipatam marshes for cultivation, and the improving the Navigation of the inlet, to carry which into effect a large expenditure was incurred, with every prospect of success.

9. To reclaim the marshes, it was necessary to embank out the tides, which overflowed them daily, and to dam up a large arm of the inlet, extending across the marsh on the east of the Fort; with very great labour, a dyke 1450 yards in length was established, from the counterscarp of the ditch to the sand hills on the sea shore; a similar dyke was carried out to the west for 3000 yards, in each of these dykes was a triple drain à clapet, or self acting sluice, to afford vent to the land flood as soon as its level rose higher than the water in the inlet, which would of course be at every low tide, these works were completed in a most durable and workman like manner; the dykes were to have been planted out with Cocoanut trees, and land drains dug on the face of the swamp; at this period matters looked so well, that a person of enterprise offered to assume the cultivation of the ground, with a view to rearing there the cochineal insect then supposed practicable, however his terms not being considered advantageous by the Government, were rejected, and while the works were yet in progress Mr. Topping died, on which the whole of what had been attempted was lost to the state, no efforts being

ever made to bring the reclaimed land under the plough; In a short time the Copper sheeted shutters of one of the sluices were stolen, and no endeavour being made at remedying this injury, the salt water again returned to its old bed. Both sluices have long lain open, and the dykes for 40 years allowed to fall into gradual decay. A third dyke there was towards the sea, a little way up the coast, which has totally failed more than once, and been restored.

10. It appears evident that Mr. Topping's opinion was, that while constructing these dykes he was also tending to improve the inlet, on the well known general principle, that to narrow the channel of a stream is to deepen it, but it was apparently overlooked, that diminishing the quantity of running water is impairing a channel. Formerly through the inlet a sufficient supply of water daily entered, for the overflow of several square miles on its banks, which at ebb tide again running off, produced by its ingress and regress a greater effect on the sides and bottom, than when only half the quantity was admitted, as of course became the case when shut out from half its old bed. It is an admitted fact, proved by abundant experience, that all inlets have a constant tendency to fill up, and that no natural harbours can be maintained for a long series of years unless a river or land scour of some description runs out at it. Consequently, had Mr. Topping embanked both sides, instead of one only, of the inlet, he would merely have the sooner occasioned its being silted up, unless he had contrived at the same time to introduce a head of water along its course by the restoration of a drainage channel, which at one time must have been constantly fed by the Kistna inundation—the loss of the latter appears to be the one great cause of the inlet having become so shallow; it has failed, owing partly to the lamentable neglect of the great river channel with which it was connected, and partly to the river inundation not overflowing the same lands as formerly.

11. Mr. Topping was probably deterred, even at that day, by the expense which would attend the operation of embanking both sides of the inlet for a distance, it may be said, of 12 miles, since to be effective, it would be necessary to complete the work along both sides of the Chinnapore canal to the Kistna. It has also been suggested that the inlet would have been improved at a very moderate cost by planting the Mungrove, or some marine shrub, on each side, as is done in the Sunderbunds; but this seems extremely problematical; through the Sunderbunds a powerful land scour periodically takes place, which of course must deepen the bed when the sides are secured by the roots of these shrubs; and moreover the backwater of the Sunderbunds are most extensive, so that there would be no difficulty in modifying any particular channel, precisely as might be done for a few yards along the Masulipatam inlet; indeed the experiment has been attempted, but the shrubs were soon destroyed by the people who fed their buffaloes on them.

12. That the Masulipatam inlet, or sound as is sometimes called, forms no exception to the ordinary condition of harbours deprived of a land scour, may be deduced

from the subjoined statement, which gives the depth and breadth of various sections of the sound, as laid down by Mr. Topping in 1796, and as observed in 1836, both depth and breadth are taken at low water spring tides, and the depth in mid channel, as the water shoals immediately towards the sides.

Places of Observation.	Breadth.		Depth.	
	1796	1836	1796	1836
	Ft.	Ft.	Ft.	Ft.
Bar off the entrance of Inlet	0	0	5	1 9
Entrance	450	300	9	3 5
Off the Polurthippu Creek	1000	280	5	5 0
A little higher up	1020	270	7	3 6
Below the village of Gilkadindy	930	260	8	3 6
Off Gilkadindy	1050	230	7	4 0
Above Do	500	200	6	3 6
Do. Do	450	170	6	3 0
Do. Do	320	200	6	3 0
Opposite Pier Head or wharf	270	120	5	3 6
Do. S. W. Bastion	300	130	not stated	3 0
Off the village of Garuldebba ..	420	130	0	3 0
Half a mile above Do.	360	150	0	2 9

13. From information derived from Mr. Alexander the present Master Attendant, and who not only has been resident at the station for almost half a century, but who is also of still older commercial connection with the Port, it may be presumed, that the minimum depth of water on the bar within the memory of the last generation, was about 10 feet; large craft then coming up to the Fort, whereas now empty cargo boats may frequently be observed both within and without the bar waiting for a tide to float them over.

14. Some other local particulars remain to be stated, for presenting a full outline of the character of Masulipatam; it has been mentioned that the Fort is situated on the edge of an inlet, but between the inlet and the Fort a mud bank intervened, which prevented the free approach of boats for discharging or loading at the Fort. To remedy this an attempt was made by diverting the course of the inlet towards the Fort; a Dam was thrown across it above the Fort by which it was intended to oppose the Kistna freshes descending through the Chinnapore canal, and turn the flood on to the Fort, but the channel that had been cut for the purpose was probably inadequate, as the dam which had been constructed at considerable cost, was swept away, and no beneficial effect produced, nor was the experiment ever repeated.

15. Mr. Topping, conscious of this failure, proceeded to erect two double sluices opposite the sea Gate, and connected by channels to the Fort Ditch, these in his own words, "serving to pen up the water of the Fort Ditch, and afterwards to discharge it upon the mud bank when the tide is low, in order to scour that impediment to commerce quite away, or at least to deepen a sufficient channel for vessels, quite up to the wharf. This mud bank is dry at half Ebb, and has not two feet water upon it at high tide, small vessels with cargoes of grain

&c. have therefore been obliged hitherto to anchor on the opposite side of the river, not being able to approach within 250 yards of the landing place." The operation of these sluices was at first aided by drawing up boats in a line with them, so as to direct the full force of the scour on the bank opposite, but the expedient not being persevered in, no direct passage was ever either maintained or effected through the mud bank, but only an oblique one, and that very contracted and shallow; indeed in 1836 it had become only half the depth of the adjoining part of the inlet, and was proportionably narrow, so that the state of things seemed fast recurring, which Mr. Topping had undertaken to remedy.

16. These observations, however, do not include all the difficulties of Masulipatam as a harbour, to them is to be added the disadvantage of a shifting mouth to the inlet, the winds and currents constantly altering the channel out, while it seemed probable that at no distant period this would be closed altogether, as has been the case with an opening at Pedda Gollapollum, a few miles higher up the coast, or like the bar of the Coum at Madras, such an occurrence would indeed be a serious evil—In 1821 Major Cleghorn, Superintending Engineer of the Division projected the establishment of stone Piers at the mouth of the creek, with a view to its preservation, suggesting at the same time the advantages of throwing a supply from the Kistna into the inlet; nothing of the kind however was ever attempted; the expense that would attend the construction of any such works could not be otherwise than very great, and a Pier at the mouth of the inlet would most probably prove inefficacious, since the waters might easily force a passage round it, or the sand drift, being arrested by the pier, would defeat its object; it is not necessary however in this place to discuss the subject farther.

17. The above remarks exhibit, perhaps with sufficient precision, the peculiarities of Masulipatam as a Port, but it should also be mentioned that the Fortress is divided from the Pettah by a marsh $1\frac{1}{2}$ miles long, so that after grain and goods are landed at the Pier, they still have eventually to be conveyed across the intervening swamp to the Pettah, which is the most populous and important town in the Northern Circars, and the residence of a large number of traders and Merchants. It is obvious that to consumers, this piece of land carriage is of material consideration, for taxed by it must come not only the finer description goods, but their grain, firewood, building materials, &c. In an old plan professing to shew Mr. Topping's works, a canal is introduced, as communicating across the swamp with the back-water skirting the south face of the Fort; the best information available however, contradicts the supposition of any such work having been undertaken, while it is stated that at one time by a natural passage across the swamp, boats were enabled to approach the Pettah, this however, if it ever existed, must have been cut off by the Western dyke, and decidedly no such means of transport has been in use during the present century.

18. To complete the sketch of Masulipatam it remains to be added, that the only permanent communi-

cation between the Fort itself and the Pettah, has for ages been by a causeway across the mile and a quarter of swamp that separates them; this in former times consisted of an earthen Mound or bank with wooden bridges in it, to give the inundation free passage from side to side; while along its crest a pipe made of Cylinders of pottery, cased in coir, &c., was laid for the supply of the Fort with fresh water, which was propelled through it from wells in the pettah about $1\frac{1}{2}$ miles distant. This work, evidently not composed of the most durable materials, was superseded some years since by a regularly constructed causeway, formed by two retaining walls, placed 12 yards apart, rising to a height above the level of floods, having the space between filled with Earth, over which was laid a coating of brick jelly, to form a road, while along the top of one of the walls a conduit pipe of burnt clay was passed, in lieu of the old expedient; however in a short time the water led through it to the Fort proved to be brackish, and the conduit consequently fell into disuse; the road way soon became impassable to conveyances, from the large pieces of brick which covered the surface; and a breach being effected through the causeway by some storm, the whole undertaking lay for a time abandoned, till finally in 1835 a gale and inundation combined, destroyed the drains, made further breaches in the causeway, and in short, for a time cut off all communication between the Fort and Pettah.

19. Finally it should be pointed out, that the great efficacy of the Fort Ditch sluices is eminently dependent on the ditch being preserved clear of mud, whereas now it scarcely averages a depth of 3 feet water at high tide even, instead of being fully double this throughout.

20. The very deteriorated condition of the Port and station of Masulipatam has now been shown, its natural deficiencies have been stated, and the efforts pointed out that were at a former period made to remedy them; also the neglect and injury sustained by these works, and the difficulties under which the place laboured at the period herein referred to;—it now remains only to show what measures have been proposed to meet this state of things, and how far they have been carried into execution, and with what success.

21. The first great object proposed, was to endeavour to restore a land scour to the inlet, the loss of which it will generally be conceded has occasioned the silting up of the latter—this was feasible by taking advantage of certain inland Nullahs, connecting them with the surplus waters of a large river channel from the Kistna, which, for the sake of its irrigating powers, was under any circumstances to be renewed; and then, by a system of damming and draining, bringing the waters so collected into the inlet, this has been done, and in a manner to benefit at the same time the general cultivation of the country: on proceeding to execute the scheme, it was discovered, that a dam had actually at one period been constructed, for turning the course of a Nullah to supply a tank, at the very spot where with a different object this was to be undertaken in the present instance, the former dam being unskilfully attempted by the natives,

had failed for sufficiently obvious reasons. To render the details of the scheme clearly comprehensible, would demand a map for the purpose; it may be thought sufficient here to state, that during 1836, these operations were accomplished, at an expense of about 2,500 Rupees, and the Monsoon being favorable, and the river fresher more than usually abundant, a large flood was by these means diverted through the Masulipatam Inlet.

22. Another expedient, having the same object as that detailed in the last paragraph, was improving the Chinnapore Canal, this connecting cut between the Kistna and the Inlet, had become so sadly choked up, that boats drawing less than 3 feet required four tides to carry them through it, a distance of about 5 miles, besides which the head was so disadvantageously led from the Kistna, that the tendency of the channel was to run into the river, not from it. Under any circumstances it was indispensable to clear the Canal, this had been done in the year 1807, and again in 1821, and fully requiring it in 1836, it was during the following year effected, at a cost of about Rupees 4,000; the work was performed by putting a number of small dams across the channel, with strong ones at its two extremities, and gradually running off the water at every low tide, through small openings left for the purpose; what afterwards remained was speedily evaporated in the hot weather, nor was there any difficulty in making the requisite excavation, beyond what was occasioned by the character of the workmen. A new head was at the same time given to the Canal, its length 2,700 yards, and its cost, including a large dam on the old line, about 2,500 Rupees; this has answered perfectly, a strong flood passing through it during the freshes, which indeed reached an undesirable height, as regarded the old canal, since the flood out topped its banks, sweeping in again much of the recently excavated soil, notwithstanding care having been taken to lodge it on the seaward bank.

23. After these endeavours to recover a land flood for the inlet, the next point to be attended to was the boat passage up to the Fort, that steps might be taken to prevent a recurrence of the former difficulties, when no boats could approach within 250 yards of the landing place. It was therefore proposed to throw out a Pier

or Wharf at right angles with the boat passage, and by removing to the head of the new Pier, one of the original ditch sluices, to turn in this manner a strong stream along the passage, the Fort ditch being the Reservoir for the purpose, and a covered gallery connecting it to the head of the Pier; this has accordingly been undertaken, the accompanying plan (Pl. 13) will explain its nature, and the following details regarding its execution may be acceptable.

24. The sole difficulty in executing the work lay in the nature of its site, accompanied by the absence of efficient superintendence. The work was to be constructed on a mud bank, and without any European Officer to direct the operations, nor was even a Maistry*, or any workmen procurable, who were acquainted with the common process of Well sinking required for the foundations; accordingly the Civil Engineer, before quitting the district, had to instruct his workmen in this branch of Indian building, while the fact of their ignorance was the more singular, from a large portion of the Fort itself being built on wells.

25. In erecting the New Pier, the convicts of the station were extensively employed, but not under so perfect a system of discipline, as to ensure regular labour on their part. When put to beat chunam, they did it so badly, that it was found necessary to disuse them altogether, while on the other hand in the much more disagreeable operation of working in mud and water, they behaved well. The convicts were also employed in preparing tile dust, which was used in the cement, and usually there were about a hundred of these men assisting at the work.

26. After the materials had been collected, the first operation was, to enclose the required space for the Pier, by a strong bund; this was effected by establishing a double line of Palmirah stakes, or piles, at short distances, which were driven by fishermen; mats were then interwoven with these piles, and the intervening part filled in with mud by the hand; this was principally performed by the convicts. The dam was in this manner raised about 2 feet above the highest tides, having its upper surface 2 yards wide, the water from within was then bailed out by Picottahs, which were kept at work night and day.

* The Engineer Officer no longer possesses any establishment for the execution of the works he may project, and is consequently often compelled to entrust his undertakings to persons in whom he can have little confidence, and who also, as they know but little of their employer, feel more disposed to act upon their own views, than upon the instructions they receive. To persons unacquainted with the character of Native Maistries, their indomitable self-conceit would appear incredible; it rarely happens, that if an officer is not in immediate superintendence of his own buildings, he can command their being carried on in conformity with his orders, while the native builder is often as uninformed as he is self-opinated. On one occasion the writer of these remarks left a plan of a large light drain with a native to execute, but the man thinking probably the crown of the arch too thin, actually made it thicker than the haunches, and when the natural consequence began to disclose itself, he immediately, by way of an effectual remedy, ran a wall under the centre of the arch, to preserve it from actual demolition, and this monument of art continues to adorn the high northern road through the Madras presidency. This is rather a ludicrous than important instance of the disappointments to which the executive officer is liable, and there are few Engineers who have not at different periods to undergo very serious embarrassment from the acts of these people. The native maistry thinks little of making alterations in the details of a building, its form, or materials, occasionally substituting some new clumsy work of his own altogether. Their cupidity also is frequently an obstacle to the adoption of any new description of materials, since they are sure to have systematised a plan for obtaining a profit on the customary contracts.

With no education, freed from immediate control, deriving their greatest emolument from fraud, employed temporarily merely, the result is only what might be expected, and the evil is irremediable, until some regular provision be made for better ordering this department; to maintain maistries otherwise than wholly dependent on the Engineer Superintendent, is to encourage them in a disregard of his instructions, and to disengage them from the only check that can be effective.

27. The wells for the foundations were principally sunk by the convicts, and, as might be supposed in such hands, they occasionally descended obliquely, some of which consequently it was necessary to take up and relay a second time; the superstructure fortunately being one of comparatively little weight, no evil consequences have followed the defective workmanship in the foundation; some cracks did make their appearance as the brickwork settled, but principally in the blank revetment wall, and not to an extent of the slightest importance.

28. The Cement used throughout the work, was composed of one part lime, one of tile dust, and two of river sand; these proportions were determined upon after making some experiments with cubes of brickwork, cemented variously, and then immersed in salt water. The lime is that yielded by shells, native maistries having a prejudice against the use of the stone chunam found in the Kistna, excellent as it is considered; the sand was brought from the bed of that river, and the bricks also were manufactured on its banks of the fine clay found there; the earth of which the latter material is made at Masulipatam, being quite unfit for the purpose, such bricks rapidly corrode away, being devoid of all tenacity. A quantity of climker bricks were also ordered, that they might be employed in the facing of the work, especially the part below high water mark, this object though was not sufficiently appreciated by the native builder, and the turn out of the material was bad, much of it having run to slag, into vitrified masses that is. A species of diversified coloured sand stone was obtained from Ellore, a distance of 40 miles, for applying at the sluice gates, and for the sills and cheeks of the smaller discharge apertures, while slabs of lithographic limestone were likewise brought from Juggiahpett on the Hyderabad road, 90 miles distant, it being proposed to adopt them instead of wooden shutters for the small sluices; this was an ingenious proposition on the part of the Maistry, who conceived they would wear better than mere pieces of wood, while they would be cheaper than the same copper sheathed; no difficulty was experienced in cutting them into any shape required, nor in boring them, but in securing the fastenings they always split, the expedient was therefore abandoned, though not so much on account of the failures just noted, which might have been remedied, as from an apprehension that they would always be liable to fracture from even any moderate concussion.

29. In taking up the old large sluices, with a view to replacing them in the New Pier, much careful labour was requisite; it was with difficulty that so large a frame of timber could be disengaged from the masonry in which it had lain so long imbedded, especially as the principal uprights, and some of the ground timbers were quite rotten, the copper having been partially displaced;—the wood was found worm eaten, and full of shells. A small detachment of Sappers at that time quartered at Masulipatam, afforded useful assistance in raising and removing the old sluice, and the same party likewise aided in dressing the stones, and in establishing the sluice in its new position, after the damaged wood work had been replaced; with such untutored

workmen as were alone obtainable in the bazar, the task would have been a very troublesome one, it was, though with the Sappers' assistance, successfully accomplished, and the sluice is now in constant use.

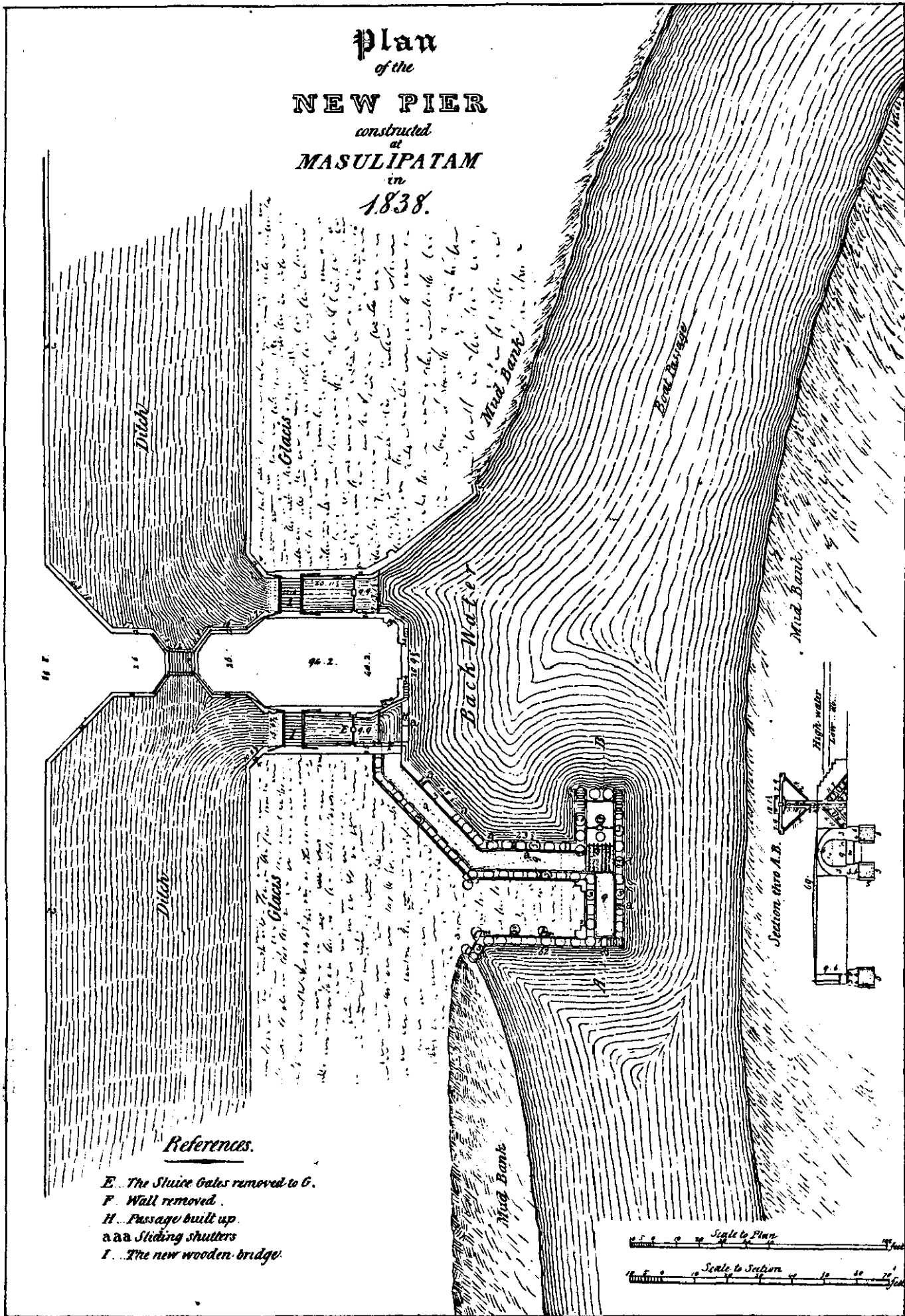
30. Of the Ellore sand stone, it may be observed, that it appears almost as perishable as brick, the material is distinguishable by its coloured veins, and it works up easily, it has been used in various parts of the works of the Fort, but is now generally found to be in a decayed state.

31. The cement adopted, which was likewise mixed with jagghery in the proportion of about 1 lb. to a parrah, remains very hard and adhesive; an experimental block of brickwork cemented with 2 of sand, 1 of Tile dust, and 1 of lime, no jagghery, and salt water instead of fresh, remains very firm.

32. The Pier now stands completed, with the exception of the plastering, the application of which was deferred until after the Monsoon of 1834; the work should also be furnished with a cast iron traversing crane, which might easily be supplied from the Porto Novo Foundry. The Pier has cost, altogether, about 5600 Rupees. Of its effect, it would be premature yet to attempt to speak, beyond stating, that boats are constantly unloading at it, and that the latest soundings along the boat passage gave an increase of 6 inches in depth, indeed it now appears singular only, that the work should not have existed long ago.

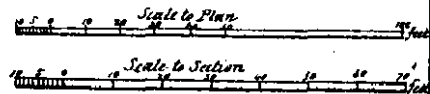
33. To give full efficiency to the Pier it evidently would be requisite to clear out the Fort ditch, this indeed on other accounts, has long been ordered, but upon the understanding only, that it should be performed by convicts, the expense of executing it in any other way being too formidable. The labour indeed would be very considerable, but beyond that, it might be supposed to present no extraordinary difficulties, the ditch being most likely choked by mere sand-drift off the adjoining marshes, which during the hot weather present the appearance of a continued cloud of dust. By some it has been supposed, that the ditch is principally filled by mud from the backwater entering through the sluices, this though would account only for the ditch being on the same level as the bottom of the inlet, whereas it is very much higher, which appears nearly fatal to this view of the subject; from the interior of the Fort no filth is allowed to pass into the ditch, the drains into it are solely for rain water; were the ditch really a deep one, it would have been best to have altered the form of the sluices, so as to exclude the mud held in suspension by the lower section of the current, but the bottom of the ditch being only fixed on the level of the present bottom of the inlet, the sluice gates, as single shutters, are unobjectionable; still the ditch could only be cleared to the depth of a foot or two by unaided manual labour, as below that level the springs would put a stop to the operation. During 1838 an effort was made to see what could be done by a limited number of convicts, towards making an impression on the work, and with some trouble the ditch was drained and partially dried, but the day's work of 100 men in raising the mud was very trifling indeed;

Plan
of the
NEW PIER
constructed
at
MASULIPATAM
in
1838.



References.

- E. The Sluice Gates removed to G.*
- F. Wall removed.*
- H. Passage built up.*
- aaa Sliding shutters*
- I. The new wooden bridge.*



some complaint was made of stench arising from the stagnant pools in the ditch, and the newly exposed mud, the latter though is a questionable cause for such an effect, as the mud can differ so little from that of the marshes around. It has however been recently ascertained, that in the year 1804 the Fort ditch was cleared out by a dredging machine under Colonel Morris, then the superintending Engineer of the Division, the mud so excavated being spread on the glacis; and the effect of the operation was, to render the Fort unhealthy to such a degree, that the natives left the place; while the Europeans who remained suffered much from fever, this is a material drawback on renewing the attempt.

34. Having thus provided for the scour of the inlet and boat passage, as well as for establishing a landing place, and wharf of embarkation for troops and stores, and commercial purposes, a commencement was made at excavating a Canal from the inlet across the swamp for the benefit of the Pettah, furnishing the same with entrance gates and a basin; this is now in course of progress, the convicts advancing satisfactorily with the excavation of the Canal. The expenditure on this branch of the improvements will probably be about 5000 Rupees.

35. The last mentioned work will not interfere with the Western Dyke and sluice, should the cultivation of that part of the marshes ever be undertaken.

36. The Eastern Dyke has been repaired at a small outlay by convicts, it forms the road from the Fort towards the Sea. The Currameda, or Sea Dyke, likewise, is now complete, and these, with the sand hills, the Causeway, and the bound hedge embankment, enclose some square miles, which at any time may be brought under the plough.

37. A boring experiment was conducted in the Fort of Masulipatam during the year 1837, but without suc-

cess, no fresh water being obtained; all the springs in the Fort are more or less brackish, which is the case also at the village between it and the sea, the inhabitants of both are compelled to bring this necessary of life from considerable distances; the conduit pipe along the causeway with its various cisterns is no longer serviceable, and all views of restoring this mode of supplying the Fort have been abandoned; should a large force ever again be lodged within its walls, it may be necessary to lay down a cast iron pipe to supply it with water from the pettah.

38. The last point to be noticed in connection with these observations upon the past and present condition of Masulipatam, is the re-establishment of a road between the Fort and the Pettah, this it was determined to effect by converting the Causeway into a solid bund, bricking up its drains, as well as closing the breaches, and extending its retaining walls till they joined the the sally Port of the Fort. All this has been done, and the surface coated with a species of sandstone which was discovered on the swamp, and which, being hard rammed, has formed an economical substitute for the more costly gravel from the Kistna. By adopting it, and by the employment of convicts, the actual cost of restoring the road, has amounted to Rupees 2,050 only, instead of Rupees 7,182—8 as estimated; the road was completed in 1837, and stood the monsoon and floods of that year, without being in the slightest degree impaired by them.

40. It may be trusted that the execution of this series of improvements will be effectual as far as mere physical efforts can be, in arresting the progress of decay in the value and prosperity of Masulipatam, regarded both under a military and under a commercial point of view.

REPORT UPON A WALL BUILT OF PISÉ AT GUNTOOR.

In 1835 I was called upon to furnish a plan for a Jail at Guntoor, on the model of one built many years ago at Cuddapah, by the unassisted labour of the prisoners, and described by one of the Circuit Judges as an assemblage of open sheds enclosed by a mud wall 18 feet high. Economy was of course the sole reason for adopting such a plan, which in the eyes of many public officers, and especially of medical men, is replete with defects—but it is I am informed, notwithstanding all objections, likely to generally copied, even in the Bengal Presidency.

Upon consideration of the great expense of time necessary to build a mud wall of the height of 18 feet, upon the ordinary native method, on account of the broad base required to give it a good chance of standing, and further of the indifferent security such a wall, the sloping sides and rough surface of which would offer strong temptation to attempt to escape from a jail possessing no other means of confining the prisoners, I turned my attention to the practicability of constructing a pisé wall, which I knew would stand with an insignificant diminution of the breadth from the base upwards, and the exterior of which would be hard and comparatively smooth.

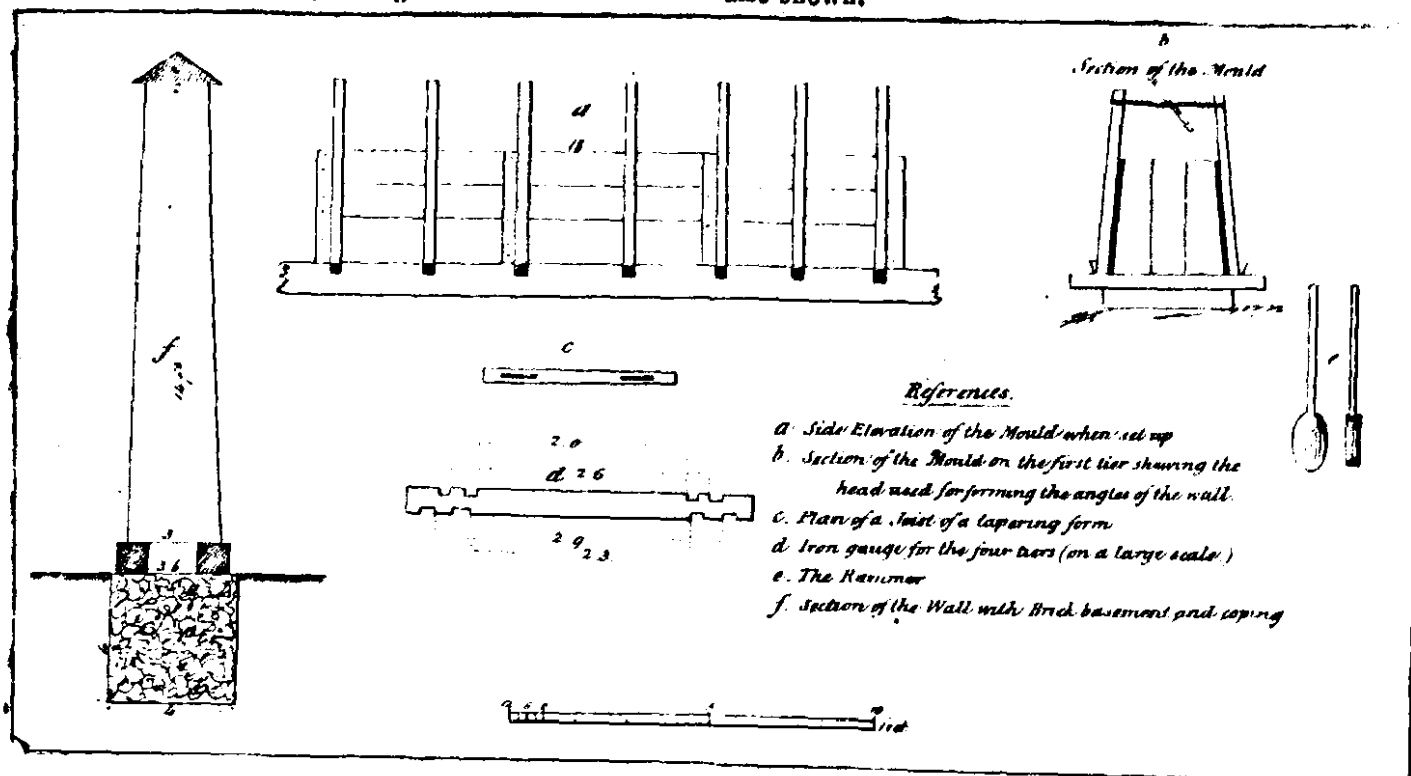
It should be here observed, that as the prisoners were to perform almost all the work of the jail, it was very important to economize their labour as much as possible, as the great length of time occupied in the preparation of materials only, fully proved.

Immediately after the estimate for the jail was sanctioned, I left the Division on leave of absence, and did not return for 19 months, during which interval the ma-

ior part of the jail buildings had been erected, but nothing done towards the construction of the pisé, except the making of two sets of moulds, with which a small experiment had been made at Masulipatam. The cause of this was, that the Acting Superintending Engineer had been too fully occupied in the Northern section of the Division, to be able to commence a work, the novelty of which would have made his personal superintendence necessary for some time. The necessity for his absence in the north continuing, he wrote to the Military Board desiring sanction for a revised Estimate of a wall to be built of brick, which however was refused on the ground of economy, and I afterwards had occasion to observe that the execution of this work would have cost a very great deal of time, owing to the incurable slowness of the prisoners in making bricks, added to the difficulty of procuring fuel at or near Guntoor.

We were thus in a manner compelled to adhere to the original plan, but it was not till the latter end of May 1837 that I returned to the Division, so that I had an unfavourable period to commence operations with the pisé, the south west monsoon being close at hand, to be followed not long after by the north east. Besides this, as no experiments had been made upon the soil, which as the nearest at hand it was proposed to use, I was obliged to commence work in much uncertainty as to its probable tenacity, which mainly contributed to the failure of the first part of the construction.

The moulds were formed of the several parts described in the subjoined sketch, in which a section of the wall is also shown.



The brick coping shown in the section was not erected, as will appear afterwards.

The mould was intended originally to have only three uprights on each side, and three joists, but these were found quite insufficient, and the thickness of the planks forming the sides ought to have been fully two inches, instead of little more than one. The dimensions given in the sketch were perhaps somewhat different in the apparatus, but certainly not materially so.

The work was performed as follows—the soil being very hard at a trifling depth, the foundation was formed with kunkur and rubbish rammed into the excavation, and above this was built a brick basement of two parallel walls connected by cross-walls at intervals, which were filled with earth. The base of the *pisé* being 3 feet, the two sides of the mould (consisting simply of planks 18 feet long jointed and battened together, on being first placed, rested on the borders of the basement, in which grooves were cut to receive the joists. The uprights being fixed in the joists by wedges in the mortices (which were purposely made much longer than the tenons) at a distance regulated by a 3 feet gage at the bottom of the mould inside, the top of the mould was fixed at the diminished distance of 2.9, by means of the iron gages, of which 3 were used for each mould. The uprights were then connected above with strong cords, and racked together, the racking pins being used as the increasing pressure of the earth rendered necessary. The mould being thus prepared, four men were placed in it, each with a rammer, and a few inches of very slightly moistened earth being thrown in, was levelled over every part, and then beaten down into a compact mass. This was succeeded by another similar layer, and so on till the mould was filled. The mould was then dismantled. The uprights being unracked were of course easily removed, and the sides of the mould followed, but to shift the joists now imbedded in the wall several heavy blows of a mallet were required on the narrow end, after which their tapering form made it easy to withdraw them. The wall was then prolonged by again setting up the mould, so that it should embrace the broken termination of the first division of the work, to which the second was joined by an irregular diagonal line. The whole of the first tier was thus constructed in successive divisions, the angles being formed by means of the head pieces shown in the section, of which four were required for each mould, to suit the different thickness of the wall; they were bolted into the sides and so made fast.

The lower tier being thus completed, the second was commenced by cutting grooves, as before, in the basement, but it was afterwards found better before completing the tier to lay short joists of the same scantling as the others, and beat in the earth in the intervals between them, so that the others might afterwards fit exactly in their places. The work then proceeded as before. Various improvements in the mode of working were no doubt made by the intelligent overseer in charge, as I was able to see only a very small portion of the wall completed, and found that the rate of progression latterly much exceeded what was attained at the beginning.

In the Month of June 1837 as I have above said, the wall was commenced, the foundations and basement having been previously laid. From the first it was interrupted by heavy showers from the south west, and very soon exposed to the violence of an uncommonly heavy north east monsoon. The wall was of course suspended, and covered, *pro tempore*, with tiles. At the close of the wet season I received from the Joint Criminal Judge of Guntoor information of the injuries the wall had received, which he stated to be extensive, and likely to prove fatal to its stability. It was subsequently, in the month of December, examined by Lieut. Buckle the Civil Engineer, and shortly after by myself, and we found that by the force of the rain the sides were in many parts loosened and crumbled off to the depth of some inches. I thus had an opportunity of proving the unfitness of the soil for the construction of such a wall, owing to the quantity of sand it contained, but Lieut. Buckle and myself agreed that the wall had not had a fair trial, owing to the little time allowed for it to dry, and I therefore determined to proceed with it. But the Joint Criminal Judge offering to bring potter's earth to mix with the soil on the spot, a great improvement was made upon the composition of the former work, for which I am indebted to that gentleman, as well as for the expedition with which the wall was completed, through his exertions. Instead of the brick coping designed by me, a tiled roof was constructed by the Judge. It had been executed to some extent before I was made aware of the change, which, with its cheapness and other reasons induced me not to oppose it, although I did not deem it preferable either for security against escapes, or for stability; and the protection it will afford to the sides of the wall is very trifling. The Judge also built a revetment of sun burnt bricks of potter's earth to the part constructed in 1837, which I think a judicious measure. My next visit to Guntoor was in September 1838, when the whole jail was completed and occupied. The wall I am informed has received no injury this year, the monsoon having been very moderate, which, while the durability of the work is still not proved, is a considerable advantage gained to its hardening well, before being subjected to a severe attack.

As the result of this experiment remains to be seen, it would be premature to recommend any similar construction in the open air in this climate, but enough has been above detailed to show, that a wall on an economical plan may be built of great height, nearly perpendicular, and with a moderate consumption of time and material, with at least as good a chance of stability as the common native walls which are wanting in some of its conditions. A coat of rough cast has been recommended as a finish, but it is doubtful whether any kind of plaster will stick to mud work in the open air.

The method of building was copied in the first instance from Nicholson's Architectural Dictionary, but many alterations were made as circumstances, particularly the number of available hands, rendered expedient.

J. H. BELL, Lieut. *Engrs.*

To

The Adjutant of Engineers,
FORT ST. GEORGE.

Sir,

I have the honor to enclose a report of an experiment lately made by us, on the applicability of the percussion cap to the explosion of charges lodged under water.

The result, which appears to favor the adoption of the fulminating powder in such cases, will I hope be considered by the Chief Engineer sufficiently interesting, to justify me in submitting this brief account of it.

I have the honor to be,
Sir,
Your most obedient servant,
THOS. PEARS, Captain,
Commanding Sappers and Miners.

BANGALORE, }
April 18th. 1859. }

REPORT.

Much interest has lately been excited by Colonel Pasley's published account of his success in destroying, by the application of Gunpowder, the hull of a vessel which had been sunk in the Thames, and impeded the navigation of the river. Few, however, can be expected to feel the same degree of pleasure in the success of this almost novel experiment, as those who derive improvement from it, as a matter of professional experience; and many of whom, from old associations, feel a degree of personal interest in all Colonel Pasley's undertakings in pursuit of practical science. The following experiment connected with the same subject has been lately made at this establishment, and is recorded, as likely to offer at least a clue to the application of very simple means of explosion, in the case of charges of gunpowder lodged under water.

We are indebted to 2nd Lieut. R. B. Smith for the suggestion of the common copper cap as a substitute for all fuzes, hoses, tubes &c. &c. which have hitherto been used, and the application of which appears to have been the chief, and indeed only source of doubt or difficulty to Colonel Pasley, in the performance of his late interesting duty. Anxious to put to the test what appeared to me such a simple and judicious expedient, I caused a small charge of powder, about one pound, to be lodged in a water proof case, with the intention of fixing it to a copper cap, and firing it under water by means of a spring made roughly like that of a gun lock.

With this simple apparatus we made several attempts to fire the charge under water, but met with repeated failures, in consequence of the apparent impossibility of keeping out the water, which seemed to force its way in between the cap and the nipple. This difficulty, by lengthening the screw of the latter, was obviated, and we made a very successful attempt in the following manner.

The Charge

consisted of 1 lb of Powder in a water-tight tin case, being a cube of rather more than 3 inches, into which (being necessarily first soldered up), the powder was

poured through a small hole in one side, the hole being afterwards closed with a wooden peg, and covered over with a piece of dammered cloth.

From a small hole at the top of this case, and near one end, a strong iron tube $3\frac{1}{4}$ inches long, and $\frac{3}{8}$ th inch in diameter, passed down the inside of the case, and while it rested on the bottom thereof, projected about $\frac{1}{2}$ of an inch at top. This projecting part consisted of a fine female screw for the reception of the nipple, and the whole tube was charged with powder, having 2 or 3 holes bored within, to communicate with the charge in the box. The sole object of this tube was to offer a resistance to the spring striking on the cap, but it might probably be dispensed with, if the top of the box was made of stronger material than that used in the present instance.

The Spring

was 4 inches long, and at the end of the lower portion, which it was necessary to fix firmly on the case, a hole was made to permit the projecting tube to pass through. The upper active part of the spring was lifted up and cacked, as it were, by means of a small iron prop, an inch high or thereabouts, having a pivot at bottom to move on, by which it could be raised to a vertical or lowered to a horizontal position, and having at its top a small friction roller, to obviate the difficulty in pulling it down, which arose from the force with which the spring pressed upon it. To the middle of this prop a trigger was attached, and a line by which it was to be fired.

As the sole object of the experiment was connected with the application of the cap, and that only, I adopted that mode of disposing of the charge which offered the least difficulty; I therefore selected a block of hard stone, (granite) being a cube of 15 inches, and having cut on the top of this a hole of 4 inches cube, placed the charge in this, fixing it with small wedges. The whole was then let down into 3 feet of water, with a line of about 58 feet long attached to the trigger.

Result.

After allowing it to remain about 5 minutes, the string was pulled, and the charge exploded. The effect presented a very remarkable appearance; The water was thrown up in a column which assumed the form of a paraboloid, having a base of about 30 feet, and a height of 50. The stone was found broken in several small pieces, some of which, and of those which lay in its vicinity, were thrown out a distance of 14 and 15 feet.

Although this was a very interesting experiment, and leads us, I think clearly, to the conclusion, that this simple mode of firing charges under water is capable of extensive and useful application, it will readily be seen that our apparatus was of the rudest description, and doubtless, experience will suggest many safer and better methods of applying the detonating powder in the explosion of Mines: as for instance, to secure the charge at a great depth from the danger of water being forced in between the nipple and cap, the use of this latter might be dispensed with, and for this express purpose a sort of

Report by Captain Pears.

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detonating nipple might be found, which should be simply screwed into the case containing the charge.

I shall not however enlarge upon the varieties which suggest themselves, or the mode of applying the percussion principle to the explosion of mines. I will only express a hope, that those whose duties lead them to the frequent and practical application of the various modes of firing subaqueous charges, will put the method here proposed to further test; circumstances, unfortunately, are likely to prevent our making further experiments at this place.

It may be as well to mention, that the cost of the

whole of this simple apparatus, spring &c. will be about 3 annas. They were made on this occasion in our stores, under the able superintendance of Conductor Almond, and I am glad to avail myself of this opportunity of acknowledging the zeal and intelligence displayed by him in the conduct of all his professional duties.

THOS. PEARS, Captain,
Commanding Sappers and Miners.

BANGALORE, }
April 18th. 1839. }



To
The Adjutant of Engineers,
 FORT ST. GEORGE.

SIR,

Having had lately many opportunities of observing the great uncertainty which attends the operation of blasting rock, from the want of definite rules by which to regulate the charges, and the consequent expense incurred in an unnecessary outlay of powder, I availed myself of the means placed at my disposal by the establishment of the Head Quarters of Sappers and Miners at Bangalore, to make a series of experiments on the subject, the result of which, although perhaps yielding no fixed principles for the regulation of charges in all cases, and under every variety of circumstances, might yet prove a useful addition to similar experiments which may have been made elsewhere; and indeed it can only be from a large collection of facts connected with the subject, and drawn from repeated experiments, that we can hope to find any guide in the practice of blasting rock, since it is certain that no general rule can be laid down, that shall be applicable to blasts in every description of rock.

The attention of the Officer appointed to conduct these experiments was directed to three points in particular. 1st, The best description of tamping. 2ndly, The charge required with reference to the line of least resistance; and 3rdly, The effect of mixing other material, as sawdust, with the powder, for the purpose of increasing its effect.

It is evident, that before any satisfactory conclusion on the two latter points could be obtained, it will be necessary to come to some determination on the former. The least possible charge of powder required for blasting rock in a given position can only be ascertained after the best material for tamping has been brought into use, and our first experiments, therefore, were directed to the trial of various descriptions of tamping.

The most common description of tamping consists of a sort of jelly, made by mixing the chips of the rock itself with common earth, and ramming them into a compact mass. This from its appearance and character would promise the best effect, but being attended with some risk when iron needles are used, and moreover requiring some little time, other material has been sought which should be attended with less risk, and applied with greater expedition.

Among others, common sand has been used, and strongly recommended, and a statement appears in Captain

Straith's work on fortification, in the chapter on Mines, which has been extracted from the *Encyclopædia Britannica*, wherein the writer asserts that in certain quarries sand has been used as tamping with good effect, and appears to render the fact indubitable, by adding that with nothing but sand for tamping very large charges have been fired. It must however be observed, that no mention is made of the strength of the charges, as relating to the effect desired to be produced. It is simply asserted that the effect of the charge when wadded with sand was great. We know from experience, that when the object is mere destruction, simple tearing and blasting, the simplest mode of ensuring success is to use plenty of powder; and in fact I suspect, that in practice, mines in rock are almost always very considerably surcharged, and from the effect of such charges no satisfactory conclusion regarding the tamping can possibly be obtained.

Whenever the tamping is blown out while the rock is blasted, no evidence is found that other tamping would not have answered as well. The mine was surcharged. Although it is expedient in cases of simple demolition thus in some degree to ensure success, yet it is not the less desirable that some idea should be given of the quantity of powder required to produce a certain effect, and also of the mode of distributing the powder so as to produce the effect at the least expense of time and labour. We commence the enquiry by putting to the test the tamping, as a necessary preliminary.

I had hoped to have been enabled to submit a complete report of these experiments, for the information of the Chief Engineer, but I regret much that these have been interrupted by the unexpected removal of the corps from Bangalore; and as I do not consider myself justified in employing any of the men in work unconnected with the road, on the repair of which they are now occupied, I am unwillingly compelled to close these experiments for the present, submitting the results as far as we have gone, by which it will be seen the question of tamping is set at rest.

I have the honor to be,
 Sir,

Your most obedient servant,
 THOS. PEARS, Captain,
Commanding Sappers and Miners.

CAMP CHINNAPATAM, }
 May 8th. 1839. }

REPORT BY LIEUTENANT R. B. SMITH.

Report of the Experiments on Blasting Rocks, instituted at the Head Quarters of the Madras Sappers and Miners, under orders from Captain PEARS Commanding; by Lieutenant RICHARD BAIRD SMITH,

In charge of the Experiments.

1st. Of the General Project of the Experiments.

Before entering on a detailed report of the blasting experiments lately in progress here, under orders from the Officer commanding, it may perhaps be of advantage to submit first a general outline of the series, as thus those points on which information is desired will be brought into view, and deficiencies in our experiments may be supplied by any, who at a future time may have it in their power to attend experimentally to this subject. Our acquaintance with the best methods of blasting rocks, either above or under water, is exceedingly limited, and indeed the only trust worthy observations which have been made relative to the details of these, are due to Colonel Pasley, and have been embodied by him in a small pamphlet intended for the use of the Engineer establishment at Chatham. While, however, these are duly appreciated, the avowedly limited experience on which they are based, with the inadequate means employed in the experiments, renders it of importance that the rules should either be verified, or such modifications made in them as the results of extended enquiry might demand. It was therefore resolved to deduce independent rules from the experiments here, without having any reference whatever to those laid down by Colonel Pasley, and thus to make the ultimate comparison of the two sets more fair.

In the arrangement of the experiments it was further determined, that classes should be formed, by marking the peculiar circumstances under which the rocks are found in nature, relative to their localities, the position of the blasts &c. &c. So that thus each class being formed independently of the others, all observations could be made upon the experiments included under it, with more ease, and attention could be fixed with less distraction upon them. For example, a rock with a perpendicular face would be a type of one class, one bulging out where it met the surface of the ground would mark another, and so on.

The determination of the comparative merits of different tamping materials, the setting at rest the much disputed question as to the efficiency of sand as a material for this purpose, the effects of mixing certain substances with the powder employed, the comparative efficiency of masses of powder, and of the same quantity distributed in a series of smaller charges, how far it is advisable to

use in the first instance a charge only sufficient to produce a crack, into which powder is subsequently to be put, were among the most important points to which attention was directed. On minor points information was also to be obtained, a general sketch of the operations need not however embrace these.

In reference to blasting under water, the inefficiency of the present methods, their complicated arrangements, their uncertainty, and withal their expense, render the substitution of some new plan in their stead perhaps the greatest desideratum in blasting operations. Such a method, of a construction so simple that the merest mechanic can make the requisite apparatus, of a cost not more than a few annas, and judging from our experiments here, certain in its operation, was proposed and adopted in our under water blasts. The details of this are given in a separate report.

2nd. Of the nature of the Rock in which the blasts were prepared.

Passing on, now, to the details of the experiments, the first to be noticed is the nature of the rock. The component parts of this were Felspar, Quartz, and Hornblende, forming together the rock commonly known by the name of Sienite. As members of the series to which Sienite belongs frequently pass insensibly into each other, in some parts the Hornblende was replaced by Mica arranged in parallel streaks, and thus Gneiss was formed. No regular lines of strata were however observed in the latter, if they existed at all their thickness was greater than the depth to which our blast holes were sunk. The structure of the Sienite in which the greater number of experiments were made was hard and compact, the grain of the Rock varying according to the size of the materials composing it, but generally close and small veins of pure Quartz of different dimensions traversed the whole, without however materially affecting its tenacity, save where cracks rose from them, when the rock was found to become softer in the immediate vicinity of these, and the holes are apt to become crooked in consequence. One material advantage may be referred to, as resulting from a hard tenacious rock having been experimented upon, and that is the certain efficiency of charges which could detach masses of it to have equal effect on rocks of a softer kind. Rules therefore determined for Sienite, which yields in tenacity to few known rocks, may with safety be applied to sandstones, limestones, &c.

3rd. Of the Tools employed.

(a) *Of the Jumpers.* The Jumper is an Iron bar of variable length, according to the depth required for the blast. Its two ends are tipped with steel, formed like knife edges, their length across depending on the diam-

ter of the hole for which they are to be used. The Jumpers employed in our experiments were originally $5\frac{1}{2}$ feet in length, and about 18 lbs in weight. From wear and tear, however, they soon lost both length and weight, and ultimately were perhaps not more than 4 $\frac{1}{2}$ feet in length, and 12 lbs in weight. When obtained from the Arsenal here they had a large swell of metal in the centre, for the purpose of enabling the men working them to have a firm hold, and perhaps also from an idea that a weight there would tell with a greater force on the Jumper being driven home, no such advantages however were found to accompany this construction, and indeed it was found very inconvenient, since after the hole had been driven about 1 ft. 9 or 2 ft. the swell caught against its sides, and prevented the bit striking on the bottom. On these accounts the swell was beaten out, and the Jumpers made of uniform diameter throughout, when they were found fully as effective as before, and could be used to greater depths. The knife edge bits were $1\frac{1}{4}$ inches across when the Jumpers were new, on them however, as well as on the Jumpers themselves, the great hardness of the rock had a most sensible effect, the steel being worn down very soon, and the necessity for re-steeling them being of frequent recurrence. The intervals between these repairs were sometimes not more than an hour, and the repeated demands for the latter were found most serious impediments to the work. It was however impossible to remedy this, because from having only four Jumpers in use, we could not allow two to each hole, which it would be advisable always to do on actual service, as thus, while one was being repaired the other would be available to continue the work with. It is also impossible to state how long the men ought to work after their Jumpers have been repaired, in consequence of the variety both in the rock and in the steel employed to repair the bits. In regard to the latter, however, it may be remarked, that country steel is always to be preferred to that from Europe, both because it is much harder, and also because the native Artificers know much better how to work with it.

Colonel Pasley remarks, that Jumpers always make a hole somewhat larger than their own bits, and cautions the workmen to make a proportional allowance for the charge &c. The above remark is true of the Jumper at any one point in the blast hole, but not when the whole depth is taken into consideration, and our practice here would lead to a caution relative to the charge quite the converse of that given by Colonel Pasley, for in consequence of the great hardness of the rock we used, it invariably happened that the bottom part of the hole was less in diameter than the upper, and that therefore in measuring lines of least resistance &c., the centre of the charge would require to be taken higher instead of lower. The difference between these remarks finds a ready explanation, when the degrees of hardness of the rocks are taken into account, most probably Portland stone or a material like it was employed by Colonel Pasley, in which, from the steel being so much harder than the stone, the effect he mentions would follow, but in

the Sienite, the steel yielded so much, as to make it impossible to get on with the work if we waited to renew it each time, the original dimensions therefore became reduced. Our holes thus ultimately became like frustra of cones, with the greater end uppermost, instead of being perfect cylinders, as in soft rocks they would have been.

(b) *Of the Spoon.* In using the Jumper, one man sits down on the rock in a convenient posture, and holding the lower part near the bit, he guides it so that it may strike fair in the hole. Another man stands upright, and raising the Jumper perhaps a foot above the surface of the rock, he drives it forcibly home. At intervals a little water is poured in, by which the rock is to a certain extent softened, and the dust formed by the Jumper is made of a pasty consistency, and thus more easily removed. For the purpose of doing this, a metal spoon is used consisting of an iron rod having one of its extremities beat out and curved, so as to form a groove like half of an hollow cylinder. The under part of this is closed by a semicircular disc on which the mud filling the groove rests. In sinking a blast hole the Jumper and Spoon are the only tools necessary; every thing however depends on the former being efficient, and it would be a point worthy of attention, to determine whether varieties in the shape of the steel bits might not be advantageously employed. All we used were straight lined, but experiments, which we had it not in our power to make, can alone determine whether this form is the best.

4th. Of the Task and Time.

In allotting the daily work to the men, it was early found necessary to resort to the system of Tasking, and the quantity usually given as the Task, was from 1 ft. 6 inch to 2 ft. per day. This depth was generally excavated by men willing to work, having before them the prospect of the remainder of the day to themselves, in 3 or 4 hours. On an emergency, therefore, by having reliefs every three hours, from 6 to 8 feet might be prepared in the course of a day, in one blast, if it were necessary to carry it to that depth. The above dimensions are given for holes $1\frac{1}{4}$ " in diameter, if the diameter were increased of course the work would progress more slowly. The greatest delays usually arose from the men requiring to get their Jumpers re-steeled; on service, as we before remarked, this would be guarded against by furnishing two Jumpers for each blast. Much difference was also observable in the time that the different parties made their Jumpers last, after having had them renewed. Those who were anxious to finish their task, worked with care, and guarded against the Jumpers striking on the sides of the hole, by directing them fairly for the centre, while others neglected to take the same care, and thus increased their own labour. Some also managed frequently to break the Jumpers in the holes, so as to render it impossible to proceed. Such an accident may of course occasionally happen even to the best workmen; but its frequent recurrence was ever found to be due to the carelessness of those employed in the work. There is but one remedy, and that is to insist on the task being

finished, either in the hole originally commenced, or if something occurs to prevent this, then the remaining portion must be concluded in a second, whatever interruptions may occur.

5th. Of the Tamping.

On the holes being sunk to the proper depth, and the charge deposited in them, we next tamped or filled them in again, so that a due resistance might be offered to the explosive force of the powder, and that this force might be directed through the line of least resistance, which is measured from the centre of the charge to the nearest surface of the rock. Much uncertainty prevails as to the best material for tamping, but before detailing the experiments made here to remove this, it will be proper to describe the tools employed in the process.

6th. Of the Tools employed in Tamping.

(a) *Of the Tamping bar.* The tamping bar is a heavy brass rod, of a diameter a little less than that of the hole in which it is to be used, and slightly tapering at the extremities. At each end an open groove is formed along the side, to admit of the bar being used with facility, while the needle, to be described immediately, is placed in the hole. Brass is selected for tamping bars, to avoid the risk of accidents from the charge being ignited by sparks, which would be struck were iron or steel to be employed. In using the bar, the tamping material is put into the hole in small quantities sufficient to fill from an inch to an inch and half at a time, and each is well and firmly rammed home by successive blows. The Time required varies with the material used, and the quality of the tamping depends much on the dexterity of those employed.

6th. Of the Needle.

Through the tamping it is necessary that a communication with the charge for the purpose of priming should be made. This is done by means of the priming needle, which is a thin metal rod having a loop handle at one extremity, and being pointed at the other. In our first experiments brass and copper priming needles were employed, of about $\frac{1}{4}$ inch in diameter. The former metal answered very well, but the dimensions were too great, and to reduce these in brass was inadvisable, from its liability to twist and break, in consequence of the very great friction between it and the hard tamping. The copper is a bad material for priming needles, as its softness, we found, was such, that rock tamping cut regular grooves in it while it was being drawn out, and from the friction it sometimes presented an appearance similar to that of a twisted cable. We were therefore under the necessity of fixing on some different material which should obviate these difficulties, a thin iron rod cut to the requisite length was tried. The great objection to the employment of iron in any way in connection with powder is the constant liability to accident from sparks being struck by it. When however we consider that the priming needle has no other motion communicated to it beyond that of simple rotation, and that the tamping it-

self early acts as a preservative against a spark reaching the powder, the risk in using iron needles cannot be considered otherwise than merely nominal. To guard against even the shadow of danger, however, our needles were tipped with brass. It must however be remarked that doing this very materially reduced their value, as not unfrequently the needle broke in the hole, and the fracture invariably took place at the point where the brass and iron were brazed together. The iron was about $\frac{1}{8}$ th inch in diameter, and on the whole answered admirably. In using the needle it is necessary to grease it well before the Tamping is commenced, and to turn it frequently during the process, since the friction ultimately becomes so great, as to cause nearly half the time required for tamping to be consumed in withdrawing the Priming needle.

7th. Of the best materials for Tamping.

In order that a comparison instituted between different tamping materials may be unobjectionable, it is necessary that each kind should be tried under circumstances precisely similar to those of the others. Now the nature and local forms of the rock at this place rendered it quite impossible to select positions for the different blasts in which each individual point, as depth, line of least resistance &c. should be alike in all. It was at first attempted to give *proportional* dimensions throughout, but the few experiments made on this plan afforded no satisfactory results. It was necessary that there should be some fixed standard of comparison to which all might be reduced. It therefore became necessary wholly to change the principle on which we had been proceeding, and I determined to derive this standard from the resistance offered by each kind of tamping to the explosive force of the powder directed solely against it. To this end it was necessary that the line of least resistance should be through the tamping, and I therefore prepared four holes in the body of the rock, having equal depths, diameters, and all with the line of least resistance thus directed: it will readily be perceived that under these circumstances the explosive force of the charge and the cohesion of the tamping were antagonist forces, and an equilibrium between the two may be considered as established, when the force of the powder was just sufficient to blow all the tamping out of the hole. Such is the simple principle on which the experiments now to be detailed proceed, and within very unimportant limits there can be little doubt of its correctness.

(a) Of Rock Tamping.

This tamping consists of small fragments of the same rock in which the blasts are being prepared. It is advisable that the size of the fragments should be from $\frac{1}{4}$ to $\frac{1}{2}$ inch in linear dimensions, and on a sufficient quantity being prepared, a little water should be added, so that the whole may be damped. About a handful is put into the hole at a time, and well rammed home by the tamping bar. There being no experiments on record, by which an estimate could be formed of the quantity of powder required to overcome the adhesion of tamping of

any kind, it was necessary to begin with small charges, and by successive additions thus ultimately to arrive at the desired information. After the last and decisive experiment, the hole was always left just as it was before any tamping was put in.

The annexed table exhibits the series by which the value of rock tamping was determined.

Table of Experiments for determining the value of Rock Tamping.

No. I.

No. of Experiments.	Depth of Hole.	Diameter of Hole.	Charge in oz.	Time of Tamping.	Quantity of Tamping blown out.	General Remarks.
1	2' 0"	0' 1 1/2"	1 1/2	13 m.	0	
2	2' 0"	0' 1 1/2"	1 1/2	"	0	
3	2' 0"	0' 1 1/2"	1 1/2	9 1/2 m.	0	The little mud placed round the
4	2' 0"	0' 1 1/2"	1 1/2	"	0	Priming blown off,
5	2' 0"	0' 1 1/2"	1 1/2	14 m.	0	Tamping untouched.
6	2' 0"	0' 1 1/2"	1 1/2	11 "	0	
7	2' 0"	0' 1 1/2"	1 1/2	14 "	0	
8	2' 0"	0' 1 1/2"	1 1/2	10 1/2 "	0	
9	2' 0"	0' 1 1/2"	2	9	1' 6"	
10	2' 0"	0' 1 1/2"	2 1/2	7	1' 4"	
11	2' 0"	0' 1 1/2"	3	5	1' 8"	
12	2' 0"	0' 1 1/2"	3 1/2	4 1/2	2' 0"	Wholly blown out.

The foregoing table thus gives the force generated by the explosion of 3 oz. of powder as the equivalent to the adhesion of Rock Tamping. It is scarcely necessary to remark, that this result will not remain invariably constant, since it must be affected both by the quality of the powder employed, and the dexterity of the men by whom the Tamping is made. In these respects however all our experiments were alike, as the same powder and workmen were, with scarce an exception, continued throughout.

It will be observed how rapidly the time required for Tamping decreased after a little practice, the rapidity however did not at all vitiate the Tamping itself, as that made in 4 or 5 minutes was fully as good as that prepared in 12 or 14.

Rock Tamping possesses several most material advantages, which may be briefly enumerated.

1. It is always to be obtained, without leaving the spot where the blasting is in progress.
2. It never adheres to or clogs the Tamping bar, and is pleasant to work with, so that the men prefer it.
3. The Priming needle is easily withdrawn from it.

Though the friction is considerable even in Rock, it is trifling compared with that of some other materials, which when used require fully as much time to be expended in withdrawing the needle, as in completing the Tamping of the blast.

These points will be referred to again in discussing the comparative merits of all the kinds experimented upon. We now pass on to

(b) Clay Tamping.

This consists of a close compact tenacious clay used by potters, and found in great abundance in the immediate vicinity of Bangalore. In using it, the clay is beat up with a little water, till it becomes plastic and adhesive. It is then put into the blast hole by successive portions sufficient to fill about an inch each time, and with the brass Tamping bar is rammed well home.

The determination of its value is given in the subjoined table.

Table of Experiments to determine the value of Clay Tamping.

No. II.

No. of Experiments.	Depth of Hole.	Diameter of Hole.	Charge in oz.	Time of Tamping.	Quantity of Tamping blown out.	General Remarks.
1	2' 0"	0' 1 1/2"	1 1/2	13m.	0' 10"	[be indifferent. Tamping found to
2	2' 0"	0' 1 1/2"	1 1/2	"	0' 4"	Hard and Good.
3	2' 0"	0' 1 1/2"	1 1/2	15m.	0' 9"	do.
4	2' 0"	0' 1 1/2"	1 1/2	18m.	0' 9"	do.
5	2' 0"	0' 1 1/2"	1 1/2	11m.	1' 0"	do.
6	2' 0"	0' 1 1/2"	1 1/2	11m.	1' 8"	do.
7	2' 0"	0' 1 1/2"	1 1/2	1 1/2 m.	2' 0"	Wholly blown out.

Hence the value of Clay Tamping is found to be equivalent to the explosive force of 1 1/2 oz. of powder. Its adhesion is therefore only half that of Rock. The first hole was Tamped carelessly, and hence the greater effect due to a reduced charge, but in the subsequent experiments the steady progressive increase of the quantity of Tamping blown out at each increase of the charge, proves both that the balance is a fair one, and also that the Tamping throughout was nearly equal in quality.

It will be seen farther, how much greater is the time required for clay than for Rock Tamping. This difference is due solely to the enormous friction exerted between the clay and the needle, half the time required being consumed in withdrawing the latter. In addition to this disadvantage, clay may not always be obtainable, and it is also found to adhere to and form a paste around the Tamping bar, thus making it a most unpleasant material to work with.

(c) Of Ant Hill Earth Tamping.

The earth of which ant hills are composed is rendered adhesive and tenacious by a glutinous excretion from the bodies of the ants. It was therefore thought it would make a good Tamping material, and since it abounds in the neighbourhood of Bangalore, a supply of it was obtained; and its comparative value determined as shewn in the annexed Table.

Table of Experiments to determine the value of Ant Hill Earth Tamping.
No. III.

No. of Experiments.	Depth of Hole.	Diameter of Hole.	Charge in oz.	Time of Tamping.	Quantity of Tamping blown out.	General Remarks.
1	2' 0"	0' 1 1/2"	1 1/2	6 m.	0' 11"	
2	2' 0"	0' 1 1/2"	1 1/2	7 m.	0' 9"	
3	2' 0"	0' 1 1/2"	2	10 m.	1' 4 1/2"	
4	2' 0"	0' 1 1/2"	2 1/2	10 m.	2' 0"	Wholly blown out.

2 1/2 oz. is therefore sufficient to dislodge the Ant-Hill Earth Tamping, thus placing it next in value to Rock. It works pleasantly with the Tamping bar, having no tendency to adhere to it, and it admits of the needle being withdrawn with much more facility than the clay. In common with the latter, however, it labours under the disadvantage of not being always at hand. Its colour varies, being sometimes white, sometimes red, and it is nothing more than the common soil held together by the natural cement above mentioned.

(d) *Of Dry Sand Tamping.* Much interest was lately excited by the supposed improvement in blasting, due to the introduction of common dry sand as a Tamping material. The facility and rapidity with which it might be used, the total exemption from the risk of accident that its use insured, were powerful arguments in its favour, and were duly insisted upon by several authors who stood forward to establish its claims. A few experiments due, in common with our other information on this subject, to the indefatigable zeal of Colonel Pasley, tended to cast some doubt on its supposed merits, and indeed his opinion is directly opposed to it; knowing however that Colonel Pasley's experiments were few in number, and that no direct comparison had been instituted between dry sand and other materials, it was determined to make this here, and to try the sand by the same standard which had been applied to the others.

The sand used was sharp, small grained, and clean, obtained from some Nullah beds, it was simply poured in over the charge, the priming being contained in a thin bamboo tube. From its high character a considerable quantity of powder was used at first, and hence it is that the annexed table exhibits a descending, instead of an ascending scale of charges.

Table of Experiments to determine the value of Dry Sand Tamping.

No. IV.

No. of experiments.	Depth of Hole.	Diameter of Hole.	Charge in oz.	Time of Tamping.	Quantity of Tamping blown out.	General Remarks.
1	2' 0"	0' 1 1/2"	2 1/2	2 m.	2' 0"	} Wholly blown out.
2	2' 0"	0' 1 1/2"	2 1/2	2 m.	2' 0"	
3	2' 0"	0' 1 1/2"	2 1/2	2 m.	2' 0"	

There can now be but little doubt as to the real value of sand as a Tamping material, and indeed when we consider the principles on which Tamping acts, it seems extraordinary that a fictitious one so high should ever have been assigned to it. The great object of Tamping being to oppose a resistance to the explosive force of the powder as nearly equal as possible to that offered by a like depth of Rock, it is self evident that cohesion among its own particles, and a tendency to adhere to the material with which it is in contact are absolute essentials to its proper action; now in dry sand both of these are wanting, its particles being loosely aggregated, and having no tendency to adhere, even without experiments, it is therefore scarcely possible to avoid condemning it, as such a material could not oppose any serious resistance to a force acting directly against it. These views are however confirmed by satisfactory experiments, from which the value of sand is shewn to be 12 times less than that of Rock, and 7 or 8 times inferior to clay, when all are tried under like circumstances. The question may hence be considered as settled, and it is impossible to recommend dry sand when any other material more adhesive and tenacious can be obtained. It would be out of place here to enquire how eminent practical Engineers have been led to advocate the use of dry sand, but the question is one of no very difficult solution, and those who are acquainted with the relation obtaining between the magnitude of the charge and the quantity of Tamping necessary, will have little difficulty in discovering the origin of the fallacy.

(e) *Of Wet Sand Tamping.* It being a well known fact that the intervals between the grains of dry sand, together make up a space nearly equal to that occupied by the sand itself, it was inferred, that if these were by any means to be filled up, the Tamping would be more compact, and of course more efficient. It was therefore determined to try the effects of completing saturating sand Tamping with water, and to protect the charge from the effects of the damp, the following plan was adopted. A thin circular piece of wood was made as nearly as possible to fit the blast hole. Through it a small aperture was made for the priming tube, a thin bamboo, to pass down to the charge. The disc rested on the surface of the powder, and above it a little clay was rammed down by the Tamping bar, which served to fill up any little interstices between the wood and the Rock. The dry sand was then poured in till the hole was full, and afterwards water was added till the sand ceased to absorb it. The following table exhibits the results.

Table of Experiments to determine the value of wet Sand Tamping.

No. V.

No. of Experiments.	Depth of Hole.	Diameter of Hole.	Charge in oz.	Time of Tamping.	Quantity of Tamping blown out.	General Remarks.
1	2' 0"	0' 1 1/2"	2 1/2	5 m.	failed	from bad bamboo.
2	2' 0"	0' 1 1/2"	2 1/2	5 m.	1' 10 1/2"	
3	2' 0"	0' 1 1/2"	2 1/2	5 m.	2' 0"	wholly blown out.

It thus appears that saturating the sand with water does adapt it better for a Tamping material, but the improvement is by no means so great as to justify its recommendation, when more adhesive substances are to be found.

7th. General Conclusions from the Preceding Experiments.

From our Experiments it therefore appears, that a Tamping material composed of fragments of the rock in which the blasts are being prepared is decidedly superior to any of the other kinds tried. Its absolute adhesive power is greater, the conveniences attending its use are also greater, and the time required, when it is employed, is the least of all, with the exception of sand, the inapplicability of which, in other respects, has been proved.

Rock Tamping possesses all the requisites for answering its purpose well. The small fragments of which it is composed, when firmly rammed home, act like so many wedges on each other, and each horizontal layer may be looked upon as being a series of minute groined arches, and consequently well adapted for offering a powerful resistance to a force acting directly against it.

The subjoined table exhibits in a condensed form the results of all our experiments on the comparative merits of different tamping materials. The value of rock tamping is taken as unity.

Table of the Comparative Values of different Tamping Materials.
No. VI.

Kind of Tamping.	Comparative value.	Quantity of powder in oz. required	General Remarks.
Rock Tamping.	1.0	3'	
Ant Hill Earth do.	0.75	2' 25	
Clay do.	0.5	1' 5	
Wet Sand do.	0.25	0' 75	
Dry Sand do.	0.833	0' 25	

It only remains on this branch of our enquiry to remark, that where the charges are large, of course a great-

er depth of hole is occupied by the powder, and consequently a less quantity of tamping has to be displaced by the explosive force of the latter. This in a very strict determination would require to be allowed for, it is not however considered necessary to render our results complicated by attending to it in the present case; it may suffice thus to notice the point, and to leave its numerical determination unattempted, at least under existing circumstances. In conclusion, I may add, that in Rock Tamping the large charge required to overcome its adhesion, and the space occupied by this, involving a diminution of the quantity to be dislodged, constitutes an additional argument for its superiority over the other kinds tried.

*8th. Of Firing Blasts.**

The most convenient method of firing blasts is by means of a match which burns at about the rate of 2 feet in a minute. This rate allows of time sufficient for the men employed to get beyond the reach of danger from Splinters, and is under all circumstances perfectly safe.

By a reference to the original project of our experiments it will be seen, that one principal section of it, that relative to the tamping, is here completed: the succeeding one, including the determination of definite rules for the charges, ought now to have occupied our attention; circumstances, however, over which we had no control, force me now to conclude this report, though I cannot but express my hope, that some future opportunity may be afforded to the commanding Officer for eliciting the information these experiments were designed to furnish, the value of which, viewed both practically and economically, admits not of a moment's doubt. It only further remains for me to acknowledge the zeal and activity displayed by Serjeant G. BRADBURN, the non-commissioned officer in charge of the party employed in the details of the preceding experiments.

(Signed) RICHARD BAIRD SMITH,
2nd Lieutenant,
In charge of Experiments.

CHINNAPATAM, }
May, 7th, 1839. }

* Although we were not able to try any other method of firing Blasts than the above mentioned, there has been lately introduced a plan which, as affording an exceedingly elegant application of science to practical art, may perhaps merit a short, and necessarily only a passing notice. I refer to the application of Galvanism as an igniting agent. The efficiency of the method has been put beyond a doubt by the Americans, who for many years have been in the habit of firing Blasts in Quarries by means of Galvanic Batteries. I am not acquainted with the details of these experiments, but under Colonel Pasley's direction I made some trials at Chatham, which perfectly satisfied me of the possibility of an extensive and easy employment of this Agent. I perceive, by reference to the published account of Colonel Pasley's successful demolition of the Brig William, that a Galvanic Battery on Professor Daniel's plan has been ordered by the Master General of the Ordnance for the use of the Engineer establishment at Chatham. We may therefore hope to have detailed experiments, by which a true estimate of the method may be formed, furnished to us by Colonel Pasley.

The great advantage of Daniel's Battery, by far the best as yet proposed, is, that a constant supply of the Galvanic fluid is kept up, and this adapts it peculiarly for being employed in mining operations, where some time is usually expended in preparations of different kinds. It is however a well known principle that, when, what may be styled calorific effects alone are required from a battery, which is the case here, the intensity of these depends on the extent of metallic surface exposed to the action of the dilute acid. On this principle, an Instrument called the calorimotor, consisting of coils of copper and zinc, the methods best adapted for Galvanic circuits, has been constructed, and it seems to me there would be but little difficulty in combining the advantages of Professor Daniel's plan, by which a constant supply of Galvanic energy

MEMORANDUM OF EXPERIMENTS UPON THE INFLUENCE OF JAGHERY IN CHUNAM—BY CAPTAIN J. T. SMITH.

A great deal of uncertainty has prevailed regarding the use of jaghery in chunam, its efficacy in improving such mixtures having been so little appreciated, that its application in the public buildings has in some cases become more nominal than real. This very circumstance indeed, may perhaps account for the want of confidence which has occasioned its neglect; For it is not improbable, that in the desire for reduction which accompanied the economical system introduced some years ago, the claims of an expensive ingredient whose beneficial effects were but doubtfully recognised, were first subject to retrenchment, and that the disappointment which the results of its too partial employment may have given rise to, have further tended to strip it of the little prepossession which remained.

Accordingly, it has happened in more than one instance, that its use has been entirely prohibited in new constructions, and though it still retains a place in the data for Public works, very little care seems to have been usually taken, even by those who have been favorable to its employment, to secure the full quantity which the reduced estimates allowed; the conditions of its efficacy being supposed to be fulfilled, provided it formed a part of the composition at all; This indifference of itself argues but an obscure perception of the relations of cause and effect, and a doubtful acknowledgement of the beneficial results of a practice sanctioned by long usage; and indeed the propriety of using jaghery at all has so long been a "vexata questio" in the Corps of Engineers, that the subject has become one whereon each considered himself entitled to adopt the results of his own experience, no certain rule being acknowledged.

This is the more remarkable in regard to a question which is so easily capable of being decided by mere practical observation, and were it not for the causes which I have above hinted at, aided by the very strong influence of a high authority, I have no doubt but that

a right determination would long since have been arrived at, and that this useful auxiliary, which has lately been so much discountenanced, would long ere this have re-established itself as securely in the favor of the Architect, as it is in that of the maistry and common workman.

My own opinion on this subject had long since been made up in favor of the use of jaghery, and I have elsewhere expressed my conviction of the practical benefits derived from its use in common mortars. This deduction from the results of my common observation, in the ordinary routine of inspection, seemed to me to be sufficiently plain to be given without any special comment, as it was not till afterwards that I met with the following passage in Colonel DeHavilland's account of the principal public edifices near Madras, and became acquainted with the circumstance, that that distinguished Officer had subjected the matter to the test of experimental enquiry, or had expressed any decisive opinion regarding it.

"To ascertain whether any advantage is derived from the use of jaghery (coarse sugar) in mortar, so prevalent throughout India, small pillars were carefully built in mortar mixed up, some with sugared water, and some with lime water, and allowed to set for nearly a month, when it was found that the tenacity of the former was about seventy-four pounds per superficial foot, while that of the latter was about eighty-one pounds on the same area. Several experiments had before been made, and have since been repeated to the same effect; and there is no reason to believe that, in the end, any advantage is derived to the mortar by the use of saccharine matter. The mortar, from the gluten or gum the sugar contains, appears more plastic with it, and the masons find it *works* better; but in reality, it is an useless expence in the first instance, and is probably prejudicial to the final endurance of the

would be kept up, with those of the calorimeter, by which we would be enabled to combine quantity with constancy. It would be irrelevant to enter at length on this point, as experiments are still a desideratum. It is however well worthy of attention, more especially as the means by which it could be settled involve neither difficulty, nor expense. A small quantity of sheet copper and zinc, some common vitriol, conducting copper wires of about one-fifth inch or one-sixth inch in diameter, and a few inches of iron wire of about one-hundredth inch diameter are all the materials requisite. The iron wire being so thin is used to ignite the powder, for, on the conducting wires being put into the Battery and the circuit completed, the quantity of fluid passing along the copper wire being much greater than can freely traverse the thin iron, the latter becomes intensely red hot, and having been originally placed in contact with the charge, instantaneous explosion follows. On many points, as the proper dimensions for conducting wires, the necessity for their being insulated by some non-conducting substance while passing through the earth to the charge, the minimum strength of the exciting acid solution &c. information is still required, and till this is furnished, but a very indifferent idea can be formed of the economical value of the Galvanic Battery.

“cement; first, because there is a considerable quantity of gummy and earthy matter which may not combine so well; and secondly, because, as it is found that quick-lime is with difficulty slaked in sugared water, when this is used many particles of lime may remain unslaked, or may be slaked *so late* as to disturb the crystallization after it has commenced; the use therefore of this ingredient was discontinued in this edifice, and the disuse of it generally has since been recommended for large and extensive works.”

Such a statement as the above coming from an authority so eminent as Colonel DeHavilland, affords an ample explanation of the doubts which have ever since prevailed against a practice, the advocates for which, though numerous, are for the most part to be numbered amongst a class who on many other points are guided by strong prejudices, and therefore on this liable to the accusation of similar mistaken views, since in this case their supposed experience is above stated to be contradicted, not merely by a single experiment, but many, repeated under various circumstances, by an Officer of acknowledged skill, and established scientific reputation.

But were it not for the above counter evidence, there would be, I think, a strong presumption in favor of a practice which has been established for time immemorial, in a nation so habitually thrifty and even parsimonious in all their arrangements as the natives of India must be allowed to be, amongst whom the constant use of an expensive ingredient like jaghery, would, unless there were some positive benefits really derived from it, be an enigma in their character very difficult of solution.

Upon a more strict examination of Col. DeHavilland's account, however, it will be found, that there is quite room for the supposition, either that some previous bias in his own mind has led him to interpret the results of his experiments in a way contrary to what a further investigation would have proved, or that the accuracy of his results has been interfered with, by the many accidental causes which may intervene to give a wrong direction to results—and thus defeat the correctness of the conclusion arrived at. The former probability is suggested by his indefinite reference to a number of experiments made elsewhere, and the general absence of all the details in the description of those upon which he grounds his opinion, as also a want of precision in the reasoning upon them; but the latter is sufficient of itself to account for the error into which Colonel DeHavilland appears to have been led, as it is far from unlikely that he should have overlooked some one or other of the various causes of discrepancy, which, had they been guarded against, would no doubt have been pointed out and particularised in his statement of results.

Independently indeed of the positive evidence contributed by the record of the experiments, there is but little corroborative assurance to be derived from the reasoning which accompanies them, for passing over the apparent confusion of the two substances gum and glu-

ten, neither of which are contained by sugar, nor is it probable, are to be met with in the commonest jaghery in any appreciable quantity, it does not appear that the operation of the jaghery, in respect to the first mixture of the ingredients, could have been very attentively studied, since the undoubted superiority of the composition formed with it is attributed to the mere *viscidty* of the fluid solution of the jaghery, owing to the supposed presence of gum; an explanation which would lead us to conclude that a solution of gum alone would possess the same virtues in a still higher degree; and that the smoothness and facility of working remarked by Colonel DeHavilland would be attainable to a much greater extent by the use of any other mucilaginous or adhesive solutions. The truth of these suppositions is well known to be quite opposed by experience, independently of its being discountenanced by the obvious absurdity of the general employment of an expensive article, for the beneficial effects of an adventitious impurity in it, when the ingredients whose aid is thus expensively sought, could be obtained unadulterated at so much cheaper a rate.

Nor do Colonel DeHavilland's further explanations of the agency of this substance give a more satisfactory confirmation to the proof which he considers himself to have established, as to its prejudicial effect upon the final induration of cements.

He says that it is probably prejudicial, first, because there is a quantity of gummy and earthy matter which may not combine so well, and secondly, because as quick lime does not slake so readily in sugared water, its use may cause particles to remain unslaked till so late a period, as to disturb the crystallization of the mortar after it has commenced. The first of these considerations can retain very little force, when we reflect how very small a proportion the whole quantity of jaghery used bears to the whole mass of the compound. According to the present custom, one pound of jaghery is added to about 180 lbs. of lime and sand; the *impurities* of which single pound of a material like sugar, can hardly be supposed to effect much in the constitution of a compound of one hundred and eighty times its weight, more particularly the earthy part of these impurities, which it seems almost absurd to speak of in presence of so vast a comparative bulk of sand. The second argument is also of little efficacy, when we consider that it is to *slaked* lime that the application of jaghery water is required, the un-reduced particles of which, if the previous preparation have been at all carefully attended to, could have but a very trifling effect upon the whole compound. The explanation too rests upon a statement, whose verification it would have been satisfactory to have had attested by distinct trials, before admitting it as the basis of reasoning towards the establishment of a truth not capable of practical demonstration.

There is a further circumstance which tends to throw a doubt upon the accuracy of the results arrived at by Colonel DeHavilland, and this is the very inferior nature of the compositions which he manufactured. If it

be true, as he states, that the adhesive power of the best of the two cements manufactured by him for trial, amounted to only eighty-one pounds per square foot, it cannot be doubted, but that, from some cause or other, the cement was of very inferior quality. It will be seen from the experiments hereafter quoted, that the average cohesion of the worst kinds of common mortar therein subjected to trial, amounted to 216 lbs. per square foot, and that the best exhibited a cohesive power of not less than 697 lbs. for the same area, taking an average of the whole of the experiments, while individual specimens gave 8 and 900 and 1,000 lbs. one even 1,136 lbs. This comparison seems to me to afford strong grounds for the conjecture, that the many circumstances and precautions requisite to obtain full success and perfect uniformity in trials of this nature, cannot have been attended to on this occasion, and that some unheeded cause has vitiated the correctness of the results.

I was led to consider this subject more attentively last year, in consequence of my desire to satisfy myself as to the certainty of an opinion which I had long considered to be universally received, and then for the first time heard questioned. I was interested in the enquiry also, it being important to me to ascertain the value, if any, of the benefit derived from the practice, in connection with the expense incurred, and I accordingly set about a series of experiments, whereby a determination upon both points might be arrived at.

Having by a few preliminary trials soon discovered that the use of jaghery was no doubt beneficial, my next step was to arrange a series of experiments to exhibit the effects of various proportions of admixture, and by multiplying the numbers in each series, according to the importance of the results to be obtained, to thus draw my average data from a sufficient number of distinct facts, to obviate any probability of error.

It must have been observed by all who have paid much attention to the humble art of the bricklayer, that there are great differences between the cohesive strength of different works, or even different parts of the same work. In a large edifice the enquiry into the cause of this is complicated with the questions of the different kinds of bond, and various inequalities of connection between the separate materials bound together, but if the subject be more closely investigated, it will be seen, that even adjacent pairs of bricks may be caused to adhere very differently to those above or below them, if there be slight differences in the way in which contact takes place. My own observation leads me to believe, that a considerable difference exists between the cohesion of two bricks cemented with the same mortar, when applied under various apparently unimportant circumstances.

Thus it has appeared to me, that if a brick in a soaking state, and with a film of water on its surface, be cased with a stiff mortar, the adhesion is not so com-

plete as if, with a more absorbent brick, the cement be also less tenacious.

Again, if with a tolerably stiff mortar it be attempted to join together a couple of bricks, the surfaces of which are covered with a thick coating of dust, or the fine powder which usually adheres to them, the adhesion is not only diminished, but is sometimes entirely prevented, the mortar leaving the surface of the brick after it has dried, and bringing with it the film of powder, with which alone it was in contact. This difficulty is aptly illustrated by homely comparison with the art by which the cook prevents her paste from adhering to the table, and I found it had frequently occurred, when I came to the demolition of small pillars built up for experiment; I was thus satisfied, that that mode of trial would, from that circumstance, be quite objectionable, as it is evident, that in order to a fair deduction drawn from a test of that kind, it is essential that the cohesion of every joint should be equal, since a single faulty one causes the fracture of the pillar at that part, whatever be the nature of the trial, it be subjected to.

Another cause of difference or disagreement between the results arises from the differences of asperity in the surfaces joined together, some cements deriving the principal part of their adhesive power from the roughness of the material to which they are applied.

But the chief difficulty seems to me to be the differences of fluidity in the cement applied, and the danger of an intervening film, of either water, or loose particles of dust, both of these causes being difficult to guard against in a numerous series of Experiments, without more personal watchfulness than can be usually spared; and both seeming to have extensive influences on the results.

In the trials made by me the above causes were, as far as lay in my power, carefully guarded against. To avoid as much as possible any difference in the manipulation of the compounds, the same workman was employed throughout; and to escape the multiplied difficulties occasioned by the use of many joints, each separate experiment was made upon a single pair of bricks only. The surfaces of these were first ground, so as to become quite smooth, and pairs were then joined together, a couple of wires being introduced at the time, but so as not to interfere with the cement, being let into grooves cut transversely across the centre of each brick. These wires had loops at both their extremities, and the two looped ends of either being turned back, so as to be opposite to one another behind each brick, were hooked together afterwards by a small iron cross bar to each, one above the pair of bricks, and one below. The upper one of these served to suspend the pair to a beam overhead, and the lower one to support the scale board and the weights of trial. Thus the test to which each pair was subjected was the absolute rupture of surface from surface, by the direct application of weight, which was in

all cases applied gradually, and by small additions, until a separation of the bricks was effected.

It was in order to ensure equality in the consistency of the compositions, that the same individual was, as before stated, employed throughout in applying the cements, and his attention was carefully directed to that point. It should be observed that the grinding of the surfaces of all the bricks together, was not done with any view to increase the cohesion in any case, but merely to insure *uniformity* in all the experiments, as to the advantage each might derive from the asperities of surface with which it might be in contact. In the same way, in order that there might be no kind of difference between the degrees of moisture or dryness of the bricks operated upon, I determined upon having them all saturated with the fluid to be used, previous to the application of the cement. After the above enumeration, it is hardly necessary to add, that as the differences whose effects were to be observed were merely in the fluid used for compounding the cement, this latter itself was the same throughout. The whole of the experiments were in fact made with beaten mortar taken from the same heap, which had been prepared for use in the public works; the proportions were two of sand by measure, to one of chunam, and the latter was by no means superior to what is in common use; in fact, as the mixture had been made some time, it is possible that its cohesive power might have suffered in some slight degree, by exposure; but whether this be the case or not, is evidently immaterial as to the value of the results viewed comparatively, although it affords fair grounds for the supposition, that as regards the abstract numerical value of cohesion exhibited for each class, more favourable data would have been obtained, had the quality and proportions of the principal ingredients been more scrupulously attended to.

The different classes of Experiments were composed as follows. 1st. Of mortars prepared with plain water. 2nd. The same prepared with fresh lime water. 3rd. The same made with jagherly lime water, in the proportion of $\frac{1}{4}$ lb. of jagherly to one gallon of water. 4th. The same made with jagherly lime water containing $\frac{1}{2}$ lb. jagherly to one gallon of water. 5th. The same made with jagherly lime water, containing 1 lb. of jagherly to 1 gallon of water. 6th. The same made with jagherly lime water containing 2 lbs. jagherly to one gallon of water.

In preparing the jagherly lime water, the above mentioned proportions of jagherly and water were first mixed, and a large quantity in excess of quick lime afterwards added, in order that as much might be taken into solution as possible. The jagherly was of the ordinary kind usually sold in the bazar, and very similar in

appearance to the very commonest kinds of brown sugar met with in Europe.

The following tables exhibit the results obtained by the Experiments in the different classes; previous to the consideration of which it ought to be mentioned, that the whole of the specimens were dried side by side, in precisely the same manner, for three days in the house first, and afterwards for a month in the open air, exposed to the sun by day, and under cover at night.

TABLE I.

Experiments upon the cohesive force of bricks cemented together with common shell lime mortar, worked up with plain water.

Number of Experiments.	Area of surface of the two bricks cemented together.	Total weight* which caused separation.	Average breadth of the margin which had been carbonated by the air.
1	40 Sq. inch.	82 lbs.	$\frac{1}{2}$ Inch.
2	36 " "	57 "	
3	39 " "	69 "	
4	39 " "	77 "	$\frac{1}{2}$ Inch.
5	37 " "	59 "	$\frac{1}{2}$ do.
6	38 " "	49 "	$\frac{1}{2}$ do.
7	37 " "	73 "	
8	38 " "	29 "	
9	37 " "	5 "	
10	37 " "	65 "	1 Inch.
11	38 " "	37 "	$\frac{1}{2}$ do.
12	36 " "	13 "	
13	37 " "	25 "	$\frac{1}{2}$ do.
14	37 " "	5 "	
15	39 " "	65 "	$\frac{1}{2}$ Inc. adhesion gave way
16	38 " "	41 "	$\frac{1}{2}$ do. do. do. do.
17	36 " "	53 "	$\frac{1}{2}$ do. do. do. do.
18	34 " "	77 "	$\frac{1}{2}$ do. $\frac{1}{2}$ A. $\frac{1}{2}$ C. gave way
19	36 " "	93 "	$\frac{1}{2}$ do. $\frac{1}{2}$ C. $\frac{1}{2}$ A. gave way

The first column in the preceding table represents the number of the Experiments; the second, the area of surface of the bricks cemented together, in square inches; the third, the total weight by which fracture was produced, and the fourth represents, first, the average breadth of the surrounding band, which on testing the newly fractured surfaces by means of a solution of proto-sulphate of iron, showed the depth to which the carbonic acid of the atmosphere had penetrated; and in

* Including the scale board, &c.

the last few numbers also a memorandum is added, showing when the bricks separated by the fracture of the mortar (or within the joints) in which case the cohesion is said to have failed, or when the mortar separated from the brick in which its adhesion is said to have failed; or thirdly, when it in some cases partly separated from the brick, and partly gave way within its own mass, in which case the proportions of both are stated. This particular was not thought of in the first trials, and is therefore only adverted to in the few later ones.

Before summing up the results of this class, there are three of the experiments which must be rejected, as giving results so very different from the mean, that it is quite plain some accidental cause had prejudiced the accuracy of the trial. These are numbers 9, 12 and 14, which I have accordingly struck out of the list in calculating the averages deduced. From the remaining sixteen it appears, that the mean cohesion of every pair of bricks was about 60 lbs. (59.4) and that the average cohesion per square inch was about 1½ lbs. (1.56.) The average depth of the induration caused by combination with carbonic acid was ⅜th of an inch, all round; and the great majority of the few last experiments, in which that point was attended to, exhibited a deficiency of adhesion rather than of cohesive strength.

The next series of experiments is a very small one, consisting of four trials which were made with fresh lime water; the object was merely to determine whether any very considerable difference could be occasioned by its use; for though it has numerous advocates, this is rendered improbable, by the very sparing solubility of lime in water, and by the great ease with which this small quantity is taken up by it. It is known by experiment, that under the most favorable circumstances the quantity of lime which dissolves in pure water, at ordinary temperatures, does not exceed ⅓th of the weight of the latter, and it has been stated by a late writer on this subject, that the combination is effected with so much ease, to that extent, that a mere contact is sufficient; so that a vessel of water standing over quick lime, and after dissolving a small portion of it, if it become successively robbed again by the precipitation of carbonate of lime by the action of the atmosphere, yet always continues saturated, making up for its loss by an immediate combination with an additional equivalent of caustic lime.*

If this be true, it is not to be thought possible, when quick lime and water are so violently brought in contact and with such an excess of lime as takes place in the formation of mortar, that a single particle of the fluid could escape saturation with the caustic earth,

and if such be the invariable consequence of the necessary processes of admixture, the pains and trouble bestowed in the preparation of lime water must be labour thrown away; and from these considerations, I cannot avoid being of opinion, myself, that that precaution is quite without effect.

Accordingly, the few trials which follow exhibit no marked superiority over the experiments made with plain water, and rather show a deficiency, which however must be attributed to accidental causes, and to the small number of the specimens operated upon, rendering the influence of any prejudicial cause upon the mean results more sensible.

TABLE II.

Experiments upon the cohesive force of bricks cemented together with common shell lime mortar, worked up with fresh lime water.

Number of the Experiment.	Area of surface of the two bricks cemented.	Total weight† which caused separation.	Average breadth of the carbonated band.	Whether the cohesion or adhesion failed.
1	38 inches.	45 lbs.	inch.	Cohesion gave way
2	39 "	75 "	"	½ Coh. ½ Adhesion
3	37 "	61 "	"	½ Coh. ½ do.
4	39 "	49 "	"	Adhesion gave way

The above columns represent the same particulars as in the preceding table, and in all respects the experiments were precisely similar.

On summing up these results it appears, that the mean cohesion of each pair of bricks was 57½ lbs, and the mean cohesion per square inch was 1.50 lbs. these numbers are somewhat short of the results obtained by the more extensive series with the plain water compositions, for which allowance must be made, as before explained: but as the experiments themselves, though few in number, show very tolerable agreement, their evidence is quite satisfactory as to the negative conclusion to be drawn from them. We now come to the jaghery solutions, on which it is necessary to premise a few remarks.

Although I have above contended against the probability of any benefit being derived by the troublesome practice of preparing lime water, and have, I conceive, established the conclusion I advanced by the result of the experiments, yet it must be recollected that my reason for objecting to the process was not that lime water

* Journal of the Franklin Institute Vol. 17—p. 237.

† Including the scale board, &c.

is in itself of no effect or assistance in the composition, but simply because the previous preparation of the lime water cannot effect the solution of a single particle of lime which would not of necessity be taken up by the water during the processes of manipulation, by which the materials are brought into such continual and intimate contact.

It must not therefore be looked upon as an inconsistency, if I now refer to the use of jaghery, as a means of preparing a solution of lime of a much stronger quality than could otherwise be effected, and leave the reader to form his own judgment as to the probability of the different explanations which may be advanced as to the causes of the improved cohesion induced by it, and which will be hereafter treated separately: for it is the object of this paper more to record the actual results of experiment, than to profess any theory to account for them; and in a subject which still contains so many doubtful and obscure points, as does the theory of solidification of cements, it would be unfair to give an undue preponderance to any reasoning, which cannot be established upon the surest grounds. It is certain, then, that the addition of jaghery enables water to take up a much larger quantity of lime than it could otherwise hold in solution, and this takes place in proportion to the quantity of jaghery used, every pound of which causes the union of one half of its weight of lime*. If therefore, as in the third series of experiments now about to be given, a quarter of a pound of jaghery be allowed to every gallon of water, this enables it to dissolve 2 oz. of lime, instead of $\frac{1}{10}$ th of an ounce, which is all that could have been taken into solution by the pure water. We see then, that by adding even so small a quantity of jaghery as $\frac{1}{4}$ lb. to each gallon of water, we in fact cause the preparation of a "lime water" of 80 times the strength of that which is so strongly advocated; and in practice it is desirable to add the quick lime to the jaghery in making the solution, or even to keep them before solution in a mixed state, for we not only by that means ensure a more complete saturation with the caustic ingredient, but the latter precaution also provides a remedy against what in this country might be a troublesome annoyance, the liability to frauds and theft, to which the unmixed jaghery offers a very trying temptation.

The solution which was used in this and the next two series, therefore, was a jaghery lime water, prepared by mixing the determined proportions of jaghery and water first, and then adding a large quantity of quick lime, which was violently agitated with the water until it was supposed that a maximum solution had been effected.

The bricks were soaked in this solution previous to being cemented together, as before, and in all respects the processes of manipulation were the same.

TABLE III.

Experiments upon the cohesive strength of bricks united by common shell lime mortar, worked up with jaghery lime water, containing $\frac{1}{4}$ lb. of jaghery to each gallon of water.

Number of Experiments.	Area of surface of the two bricks cemented together.	Total weight† which caused separation.	Average breadth of the carbonated band.	Whether the cohesion or adhesion failed.
1	37 Inches	101 lbs.	$\frac{1}{2}$ Inch.	Cohesion failed.
2	39 do.	81 do.	$\frac{1}{2}$ do.	do. do.
3	40 do.	77 do.	$\frac{1}{2}$ do.	do. do.
4	40 do.	123 do.	$\frac{1}{2}$ do.	do. do.
5	36 do.	65 do.	$\frac{1}{2}$ do.	do. do.

Upon summing up these results we are at once struck with the very sensible improvement which is shown even by these few experiments. The average cohesion of each pair of bricks is here found to be 89 $\frac{1}{2}$ lbs.; nearly one half greater than that of the first series, the cohesion per square inch being very nearly 2 $\frac{1}{2}$ lbs. (2.328.)

The average penetration of the atmosphere, as shown by the depth to which the lime was found to be neutralized by it, was $\frac{3}{8}$ ths or 0.363 of an inch; and it will be remarked, that great as was the improvement in the cohesion of the mortar, its adhesion to the bricks was still more increased, the failures which before took place in the latter, being now invariably confined to the former, showing now a decided superiority in the latter quality.

These observations are also confirmed by the remaining trials.

In the fourth and fifth series, the experiments are precisely similar to those last given, the only difference made being in the proportion of jaghery used. I shall therefore enter these tables together.

TABLE IV.

Experiments upon the cohesive strength of bricks cemented together with common shell lime mortar, worked up with jaghery lime water, containing $\frac{1}{4}$ lb. of jaghery to each gallon of water.

No. of Expts.	Area of surface of the bricks cemented.	Total weight† which caused separation.	Average breadth of the band of carbonate of lime caused by the action of the air	Whether the cohesion or the adhesion gave way
1	37 Inches	301 lbs.	$\frac{1}{2}$ Inch.	Cohesion gave way
2	38 do.	185 do.	$\frac{1}{2}$ do.	do. do.
3	38 do.	113 do.	$\frac{1}{2}$ do.	do. do.
4	40 do.	125 do.	$\frac{7}{8}$ do.	do. do.
5	36 do.	136 do.	$\frac{1}{2}$ do.	do. do.

* Ure's Chemical Dictionary, Article Sugar.

† Including scale board, &c.

These Experiments give the average cohesion of each pair of bricks at 131½ lbs. and the resistances per square inch nearly 3½ lbs. (3.48,) the average penetration of the indurating effect of the atmosphere is ⅔ths or 0.362 of an inch.

TABLE V.

Experiments upon the cohesion of bricks united together by common shell lime mortar worked up with jaghery lime water, containing one pound of jaghery to each gallon of water.

No. of Expts.	Area of surface of the joint.	Total weight* which caused separation.	Average breadth of the band of carbonate of lime, by the action of the air.	Whether the cohesion or adhesion failed.
1	38 Inches	125 lbs	½ Inch.	Adhesion, ½ cohesion failed.
2	37 do.	157 do.	½ do.	Cohesion failed.
3	36 do.	169 do.	⅞ do.	do. do.
4	40 do.	141 do.	⅞ do.	Ad. ½ Co. failed.
5	38 do.	157 do.	⅞ do.	½ do. ¾ do. do.
6	37 do.	117 do.	½ do.	Cohesion failed.
7	38 do.	117 do.	½ do.	do. do.
8	36 do.	121 do.	½ do.	do. do.
9	38 do.	113 do.	½ do.	do. do.
10	39 do.	135 do.	½ do.	do. do.

These experiments give an average cohesion per pair of bricks of 136 lbs. and per square inch of 3.62 lbs.; the penetration of the atmosphere seems to be more regular, and to be diminished, the mean being only ⅓ths or 0.23 inch.

In the next and last series of these experiments the number was augmented, in order that the comparison between the two extremes might be subject to as little chance of error as possible. The object of the whole series being in fact the determination of the answer to the question whether any benefit could be obtained from the use of jaghery, at all, it seemed to be most important to take the greatest pains in measuring the values of cohesion, first of the cement made up with plain water, and lastly with the largest quantity of jaghery ever likely to be used, in order that the difference, if any, might be exhibited in the strongest light, and be determined with the utmost certainty; with this intention this last series consists of 14, one of the pairs having been injured after preparation. The results are shown in table 6th.

TABLE VI.

Of the cohesive strength of a pair of bricks united together by common shell lime mortar, worked up with jaghery lime water, containing two pounds to each gallon of water.

No. of Expts.	Area of surface of the bricks cemented together.	Total weight* which caused separation.	Average breadth of the band of carbonate of lime.	Whether the cohesion or adhesion gave way.
1	36 Inches	289 lbs.	½ Inch.	Cohesion failed.
2	36 do.	117 do.	½ do.	Co. ½ Ad. failed.
3	37 do.	117 do.	⅞ do.	Wires not opposite.
4	36 do.	117 do.	⅞ do.	do. do.
5	Not msrd.	221 do.	Not measured.	Cohesion failed.
6	do.	117 do.	do.	do. do.
7	do.	137 do.	do.	do. do.
8	do.	121 do.	do.	do. do.
9	do.	209 do.	do.	Part Co. part Adn.
10	do.	149 do.	do.	Cohesion failed.
11	do.	181 do.	do.	do. do.
12	do.	153 do.	do.	do. do.
13	do.	241 do.	do.	do. do.
14	do.	209 do.	do.	do. do.

Of the above trials two were failures, in consequence of its being found, on proceeding to adjust the specimens, that in consequence of the bricks not being correctly fitted, the wires of suspension above and below were not in exact opposition to one another, the wire passing round the lower brick being, for instance ¼ or ½ an inch to the right or left of that which supported the upper one. On proceeding therefore to apply weights, the line joining the points of application of the two wires became vertical, and the bricks were twisted side ways, one end being raised above the other; and it was found impossible to keep them horizontal during the experiment, as all the rest were. This no doubt interfered with the fairness of the test, and in fact neither of them bore any thing approaching the mean load, in calculating which, however, I have deducted them from the list; and there are others also which ought perhaps to be omitted in summing up the results, their great departure from the mean rendering it almost certain that some accident interfered with the precision of the trial, but in regard to them, as there was no evident cause of failure, I have not thought it necessary to interfere.

From the twelve examples which remain to be examined, the mean cohesion per pair of bricks amounts to 178½ lbs., that per square inch to about 4.84 lbs. (counting the unmeasured surfaces at 37 inches each.) The mean penetration of the carbonizing influence of the air is ⅓ds or 0.156 of an inch; and it will be remarked, that in almost all cases the fracture was within the joint, the adhesion to the surfaces of the bricks proving to be superior to the cohesion of the mortar itself; the opposite

* Including scale board, &c.

to which result was deduced from the experiments upon mortars mixed up with plain water.

After a comparison of tables Number 1 and 6, and more particularly on consideration of the simple nature of the experiments, and the care which was taken to avoid the disturbance of accidental influences, there can I conceive, be no hesitation whatever in admitting the conclusion, that the use of jaghery in mortar is highly advantageous to its cohesion upon first setting, and that the improvement effected by it bears a proportion to the quantity allowed. It is proper to observe the distinction between the first set and the ulterior hardness acquired by the cement, because the experiments which constitute the above series, being confined to mortars only a month old, do not touch upon the question of the influence which jaghery may exert upon the ultimate induration of cements; and it appears to me, that for want of a just appreciation of this distinction, an erroneous view has been taken of the evidence which former experiments may have exhibited.

It is well known, in fact, that the cohesion of common mortars when *indurated* by the action of the air is vastly superior to any cohesion they may have on first setting, and this fact, which is erroneously attributed by the masons to the mere drying, or desiccation, is too well established by universal observation to be further remarked upon; but very great misapprehension prevails generally as to the time required for this induration, and the nature of its progress. Many well informed persons on other architectural points labour under the mistaken apprehension that a large mass of masonry dries and becomes indurated at the same time throughout its whole substance, and I have myself known very intelligent Engineers calculating upon the complete induration *throughout* of large masses of masonry, of upwards of 3 feet thickness in their smallest dimension, within a week or ten days after completion. A very slight attention to the nature of this action, and a few observations of its progress will suffice to show the fallacy of such expectations, and prove, that the change which slowly takes place in every cement exposed to the air, and which is entirely owing to combination of part of its ingredients with a principle derived from the atmosphere, is at first entirely superficial, and extends itself inward, towards the interior of its mass, as the parts more advantageously situated for the access of the indurating principle become saturated and allow it to pass. Indeed, by dipping the fresh broken surface of a cement undergoing this change, from week to week, in a solution of green vitriol, the gradual advance of this induration may be most distinctly seen and submitted to measurement, and I have elsewhere more particularly described the methods of making such examinations, and given the results of measurements under ordinary circumstances.

By the processes which I here refer to, the truth of the proposition which is advanced is most easily verified, but there are perhaps few experimental data whose numerical verification is attended with so much difficulty, and the results of which vary so much from one another,

owing to the impossibility of taking an exact account of the chief cause affecting the progress of this induration, namely, the mechanical closeness and impermeability of structure communicated to the mortar by the manipulation, either in preparing the cement or in laying it on. A mere stroke of the trowel in flushing up the joints of a piece of masonry may condense its outer surface so much as to enable it to resist the entrance of the indurating principle, which in other parts may penetrate with ease; and moreover, different mortars vary so much in their nature, as to the adhesive tenacity and closeness of union of their particles, that in these respects only, to lay down even approximate rules, experiments should be made for each independently.

In order to show the truth of these remarks I may observe, that by a mean of many hundred experiments I ascertained that the average progress of induration of plastering of common mortar, (similar to that used in these experiments, only containing more lime) which had been floated after completion, amounted to less than half an inch in twelve months.

In the experiments contained in table 1, it will be seen that the mean penetration was $\frac{1}{8}$ ths of an inch in one month. This is doubtless attributable to the greater porosity of structure in the latter, from the larger admixture of sand, and to the absence of the superficial condensation given to plastering by the process of rubbing with wooden floats. But with such remarkable differences it is perhaps unsafe to attempt to define any law of progression, without some means of previously determining a measure for those conditions upon which it essentially depends. I may however suit my present purpose by laying down some limits, which though they may not accurately prescribe the progress of the phenomena, may yet be a sufficient guide to be of some practical use.

I think, therefore, that it may be affirmed safely in regard to common mortars of rich lime and sand mixed with pure water, that when carefully applied in the ordinary way, the progress of induration by the atmosphere cannot be calculated to exceed $\frac{1}{4}$ or $\frac{1}{2}$ of an inch during the first month; that is, that every surface freely exposed to the air will become indurated to a certain depth, which will not exceed $\frac{1}{4}$ or $\frac{1}{2}$ of an inch after the first month's exposure; during the second and following months the progress gradually diminishes, owing to the increasing difficulties encountered by the regenerating principle; and after a time the same depth which is passed over in a month requires years to acquire the necessary hardness.

But to apply this to the experiments which form the subject of this paper, it will be observed, that the depth of penetration of this induration into the mortars contained in the 6th Table was very much inferior to that exhibited by the first, the jaghery cements being indurated in fact only to the depth of $\frac{1}{2}$ ds or 0.156 of an inch; exactly one-fourth of that of the mortars of the first table, which were restored to the depth of $\frac{3}{8}$ ths or 0.625 of an inch. This, which is doubtless owing to the superior tenacity and unity of structure of the more

cohesive jaghery mortar, is observed also to take place in proportion in the other tables, which exhibit a regularly descending progression, in proportion to the quantity of saccharine matter made use of; the penetration given by table I. being 0.625 inch, No. II. 0.5, No. III. 0.383, No. IV. 0.362, No. V. 0.23, No. VI. 0.156. It may therefore be assumed without hesitation that, although increasing very materially the cohesive strength of mortar on first application, and, it may be, improving its tenacity also after final induration, the use of jaghery tends to prolong the term required by this change, and to oppose an obstacle to that influence, upon which the ultimate hardness of the mortar essentially depends.

Bearing in mind, therefore, the much superior cohesion of indurated cements, we come now to the point to which these observations naturally tend; namely, that in making the comparison aimed at by these experiments, if the above important facts bearing upon the relative progress of induration be overlooked, it is not only possible to fail of acquiring decisive evidence towards the establishment of correct results, but the truth may be even inverted, by the unobserved influence of the law above pointed out.

It is obvious, indeed, that if two experimental pairs of bricks could be compared at different periods after their first preparation, there would be a great superiority at first on the side of the more adhesive and compact mortar, which would gradually be diminished as, in the progress of time, the induration of the other advanced with greater rapidity; and according to circumstances, the weaker and more porous cement might gradually become equal to and surpass its rival, by reaching its maximum of strength soonest, and by the induration of its whole mass throughout. The difference would then begin to diminish, by the continuance of the tardier induration of the more compact mixture; which would finally equal, and again surpass the first, attaining probably in the end a firmness and strength as much superior to it, as it before had, on comparing the cohesion of their primitive set.

If tested therefore at different periods, we might have, first the jaghery cement superior, then inferior, and lastly superior, according to the time selected for trial; and it appears to me from this cause alone to be probable, that the most accurate experiments made without attention to the above particulars may fail of establishing the truth: which may be one reason amongst many why the highest authorities have differed upon a question so often agitated, and so easily open to observation.

In the absence of any experiments as to the exact final cohesive strength of common mortars, it is difficult to exemplify the above conclusions; but as it will lead to no error, and will serve my purpose, I may assume such numerical terms as I may consider likely to fall within the limits of truth, as I shall be enabled thereby to exhibit my meaning in a more distinct point of view.

Let us suppose then, that a couple of pairs of surfaces of a foot square each, be united, one by a sugared mor-

tar, of $2\frac{1}{2}$ lbs. cohesion per square inch, the other by a plain mortar of $1\frac{1}{2}$ lbs. At the end of a month the former will have a cohesion of $144 \times 2\frac{1}{2}$ or 360 lbs. plus the increased cohesion of the band or edge of the joint all round, which has become hardened by the influence of the air. Let us suppose this to be of $\frac{1}{4}$ inch width, and that its cohesion after induration is 25 lbs. per inch, giving an increase of $22\frac{1}{2}$ lbs. upon 12 square inches or 270 lbs. The total cohesion after a month may then be represented by 630 lbs.

The plain mortar, on the other hand, which at first had only a cohesion of $1\frac{1}{2}$ lbs. \times 144; or 206 lbs. we will suppose to have been indurated all round to the depth of $\frac{3}{4}$ of an inch; the area of this band will then be 35 inches, which, if we suppose its cohesion after induration to be 15 lbs., will receive an increase of cohesion of $13\frac{1}{2}$ lbs. per square inch. The total cohesion would then after one month's exposure be $678\frac{1}{2}$ lbs. or $48\frac{1}{2}$ lbs. superior to the sugared mortar. But if the two be compared after final induration, the former would be found to possess only a cohesion of $144 \times 15 = 2160$ lbs. while the latter would be measured by $144 \times 25 = 3600$. The relative strength of the two mortars taken at different periods would therefore be as follows.

	Plain mortar.	Sugared mortar.
On first drying.....	206	360
After one month....	$678\frac{1}{2}$	630
After final induration	2160	3600

The last line in this list is not by any means to be made use of as a datum for other calculations, being grounded merely upon an assumption. Experiments upon the final hardness of various mortars are indeed very much wanted, and would not only be highly interesting in themselves, but of the greatest value to the practical Engineer.

It is much to be lamented that we have so few experimentally established facts upon points of such constant enquiry as that here referred to, and I hope that a sense of the important benefits which would be derived from the acquisition of correct data of this kind, may induce those who have leisure to give their attention to the subject, to supply the many deficiencies which exist in this department of Engineering science. Of these, few are more obvious, or would be of greater service, than a comparison between the first and ultimate cohesion of various mortars, and a numerical determination of the latter in as many cases as possible.

On the Theory.

Having already extended my remarks upon the first part of this subject to a much greater length than I anticipated, I shall refrain from dwelling long upon that section in which I can add but little to our real knowledge of truth. I have before remarked, that the experiments here given do not contradict the old established theory of mortars, dependent upon crystallization; but I must say that that theory has, to my mind, never carried with it the conviction of reality. The main prop and foundation of the whole is, in fact, an imaginary process

(to the extent required) which is supposed to be carried on in the interior of the solid mass, whose effects are reasoned upon, and assumed as the basis of explanation, without a single reference to experiment to establish its existence. On the contrary, there are deductions which flow inevitably from it which may be proved to be in opposition to established facts, and the same explanation is ignorantly applied to account for the final induration of common mortars, which is unquestionably due to the combination with carbonic acid from the air.

There are many applications of Mr. Anderson's theory, indeed, which could be at once shown to be erroneous and untrue; but although I must deny its correctness as a general exhibition of the causes of solidification, I by no means wish to exclude it from the share which it no doubt is fairly entitled to. My only object in here expressing my dissent, being to obviate the consequences of its being assumed as a complete explanation of phenomena, to which it has but a partial, and even that obscure relation, and to disabuse the mind of an enquirer from the effects of a doctrine, which, by the support it has received would appear to merit attention, though it may perhaps merely have gained favour owing to the absence of that clear and comprehensive knowledge of facts, by which its pretensions to accuracy could be scrutinized.

Another very ingenious explanation which has been advanced by a correspondent in the 14th Number of the *Madras Journal of Literature and Science*, is founded upon the supposition that the jagherly augments the cohesion of a calcareous cement by facilitating its conversion into carbonate of lime.

It is indeed stated, that a solution of quick lime in jagherly water has the property of depositing carbonate of lime, a supposition which is rendered probable by the known constitution of its elements; but a fundamental proposition of this kind to be fully satisfactory ought to be supported by a more distinct reference to experiment than is given on this occasion; indeed the absence of any notice of the tendency to the formation of carbonates in all experiments open to the access of the air, leaves the reader in the painful uncertainty whether on this occasion the precautions necessary to avoid that too fruitful cause of error had been sufficiently foreseen and guarded against; and I must add to the above, that in experiments of a similar kind, where the solutions were retained in my possession for a few weeks and months only, I have never observed a similar result. Indeed, as regards the immediate consequences of the solution of lime in sugar, I have always been impressed with the opinion, that a real compound, a true saccharate of lime was formed, which yields up its base to the superior affinity of carbonic acid with the greater difficulty, the more the saccharine matter is in excess.

Thus, when the solution is very strong, carbonic acid may be passed through it for a short time without change; and it is not until after standing some time, that the whole becomes converted into a jelly like mass, by the solidification of the nascent carbonate of lime.

In weaker solutions, as I have before observed, I have never observed any change, when carefully secured from the access of the air; a bottle containing such a solution kept for a considerable time is liable to become encrusted with a film of carbonate of lime at the upper edge of the fluid, a circumstance which may be attributed to the influence of the contact of the air in the upper part of the vessel; but though I have had such solutions for considerable periods in my possession, I never recollect to have seen the remainder of the surface of the vessels coated, which would have been the case were a deposit possible without that influence.

These observations tend to throw doubt upon the probability of a deposit being formed in saccharine solutions under any circumstances; and they are strengthened by the consideration, that such a conversion of substance as that explanation supposes, could not take place without the production of either alcohol, or the by-hydrate of carbon, which would necessarily be released by the new arrangement of the remaining constituents of the sugar;* and the existence of either of these principles under the circumstances referred to, has never been reported, that I am aware of, as having been observed.

But setting aside for the present the consideration of the many remaining doubts which require to be removed previous to the admission of the hypothesis above referred to, and even admitting further, that should evidence of its reality be produced, its connection with the ultimate induration of mortars would follow as an easy corollary; there would still remain considerable difficulty in its application to the circumstances to which its agency is referred. It is indispensable, in fact, before the conclusion sought to be obtained could be received, that some proof should be established, of the actual decomposition of the sugar within the period of the production of the effects to be explained; and this, both in relation to the question now at issue, and in its general philosophical connection would be an experiment of the highest interest. I have already remarked that the decomposition of sugar within the interior of a cement is very possible, from the nature of its constituent elements; but it is difficult to suppose the change so rapid as to correspond with the effects which are found to take place in the solidification of cements, and which I have ascertained by direct experiments to be fully marked in the course of two or three days.

Moreover it ought not to be omitted, that the same characters of internal constitution which lend a proba-

* This consequence might be avoided by the supposition that oxygen is absorbed from the atmosphere; but the explanation would then fail to account for the superior cohesion of those parts of the cement to which the air had not penetrated. Moreover it seems difficult to evade the suggestion, that if the assistance of the air be necessary at all, it might at once be supposed to supply the carbonic acid.

bility to this explanation, as applied to sugar, would apply with equal or greater force to solutions of starch, gum, and many other vegetable substances, which all contain the same component principles in proportions very nearly the same as sugar; whereas we know that the property which is supposed to be derived from this peculiarity of internal constitution is possessed by the latter alone.

In this position of the enquiry it will be sufficient for me to add, that independently of other causes, there is evidence to show that the first solidification of semi-fluid and pasty compounds may be influenced in degree by the affinity which exists between the solid particles of the aggregate and the fluid with which it is mixed. Thus the particles of the hydrate of lime which have but a feeble affinity for water, as shown by its sparing solubility, and the ease with which it is yielded up to any other agent, form but a slightly coherent solid after first drying; but the same particles kneaded together with alcohol will not unite into a solid mass at all. The same truth has been verified by application to other substances, and should it be confirmed by a more extended series of observations, would possess a claim to be received as a general law in the phenomena of internal structure. Its bearing upon the question now under consideration would be direct and obvious, since the affinity of saccharine matter for some of the earths and alkalies is known, and its peculiar attraction for lime is so decisively evinced by many well established facts, that if the above suggestion should have any foundation in truth, an indication of its correctness, shown by the marked influence of saccharine solutions in the solidification of calcareous compounds, would be anticipated as a necessary consequence.

Practical remarks.

Whatever difference of opinion there may be as to the causes of the influence of jaghery, there can, I conceive, no longer exist any doubts as to the fact of its being of special advantage, at all events on the first hardening of mortars.

When, therefore, a construction is of such a nature as to demand the utmost solidity and firmness of cohesion in all its parts, and more especially when circumstances are such that it may by any chance be put to the test within the period required for its thorough induration, the very great additional cohesion obtained by this auxiliary must be of the highest importance. It seems to me probable also, that a similar advantage may be exhibited in respect to the final, as in the first hardening of cements in which this substance is used, a probability which is suggested by the much closer unity and superior compactness of structure shown by the jaghery cements in the greater difficulty experienced by them in the absorption of the atmospheric agent attracted by the combining affinity of the lime.

In regard to proportions, there is some difficulty in applying the results given in the experiments to the data in general use, the relations stated by me being those

indicated by the strength of the solution used, and not as is more generally done, those determining the comparative quantities of jaghery and lime. In order to reduce them to the common standard of comparison, therefore, it is necessary to mention, that in ordinary work of the more substantial kind, the quantity of water used by the bricklayers varies from 20 to 40 gallons per man, according as the weather is wet or dry; and if each be supposed to lay 400 bricks, and to use 2 parras of chunam in doing this, the quantity of jaghery to be allowed would be determined at the ratio of from 10 to 20 gallons per parras, according to the strength of the solution determined upon. Thus, if a solution of 1 lb. per gallon was required, no less than from 10 to 20 lbs. of jaghery per parras would be necessary; if the strength were fixed at $\frac{1}{2}$ lb. per gallon, 5 to 10 lbs. per parras would be necessary.

In strong solutions it may perhaps be advisable to confine the proportion to the lowest term here mentioned, by saturating the bricks with plain water before sending them for service to the masons, allowing them to stand for a few minutes previous to use, and avoiding as far as possible the extravagant deluge of fluid which the workmen are usually so fond of. With these precautions it might be sufficiently exact to assume a consumption of 10 gallons per parras in all weathers, and to appropriate the supply of jaghery accordingly; not forgetting that in dry weather, when the bricks are absorbent, it will be diluted to only one half its strength, if they be not attended to.

It may be necessary to explain why it is more satisfactory to refer to the strength of the solution than to the comparative quantities of jaghery and lime, as is now the custom; and which it would have been desirable to have retained, had it not been objectionable.

The reason is, that the improvement made in the cohesion of the cement depending only on the quantity of jaghery which remains within it after drying, must obviously be determined by the degree of saturation of the fluid of admixture, which regulates the quantity of the sugar which is left behind on desiccation.

It is therefore not sufficiently precise to fix the comparative quantities of lime and sugar, unless the quantity of water used be invariably the same. For instance, if a pound of jaghery be allowed per parras of lime, we find by observation this will in wet weather be dissolved in 10, and in dry weather in 20 gallons of fluid; in the latter case half the jaghery will be carried into the substance of the bricks, and the remaining half only will enter into the composition of the mortar. In order therefore to obtain definite results, we have no alternative but to secure the undiminished saturation of that which remains within the cement, by submitting to the sacrifice of all that runs to waste, and were this not done, mortar applied in wet weather might be of double the cohesion (as far as jaghery is concerned) of the same laid on in the drier months.

This explanation is sufficient to account for my having departed, in the experiments above given, from the usual

terms of comparison, and also to show the precautions to be observed in making observations on this subject. I should however be far from wishing to see the change introduced into ordinary practice, in regard to which the simplest possible forms are invariably best in the end.

It only remains now to be decided, to what extent is the use of jaghery to be recommended in actual practice; and here we observe, that the answer is indefinite, and must be decided by the importance of the work, and the urgency of the conditions under which its aid is required. When nothing more than a thorough soundness of structure, and complete durability are aimed at, the decision will be bounded by the opposite considerations of the advantage gained on the one side, and the cost on the other, and the desired conclusion would be that, in which the greatest effect should be obtained at the least comparative expence. Looking over the tables with this object, therefore, we find, that while without any admixture the cohesion is about 1.56 lbs. per square inch—

It is with $\frac{1}{2}$ lb. of jaghery per gallon	2. 328 lbs.
With $\frac{1}{4}$ do. do. do.	3. 48 lbs.
With 1 lb. of jaghery per gallon	3. 61 lbs.
With 2 do. do. do.	4. 84 lbs.

The maximum "useful effect" seems here to be passed when the strength of solution exceeds that of $\frac{1}{2}$ lb. per gallon, and I should think that in few works it would be

found advantageous to exceed the latter measure under any circumstances. I have myself adopted a proportion varying from $\frac{1}{4}$ to $\frac{1}{2}$ lb. per gallon in the most important works; using the former in the great bulk of the masonry, the latter when more than usual attention was requisite, and I find the result to be all that could be desired. This corresponds to, from $2\frac{1}{2}$ to 5 lbs. per parrab (with the precautions noticed above) instead of one as at present allowed, which I certainly consider much too little, though the proportion which I have here stated as being assumed by me in the more important constructions may, perhaps, from motives of economy, be subject to some reduction in ordinary buildings.

Before concluding, I ought not to omit to repeat the caution before given, that the numerical measures of cohesion as above given are chiefly comparative, and ought not to be assumed without further experiments as data for exact calculation. The circumstances under which all these mortars were tried were, in fact, different in some respects from those in which they exist in ordinary practice, it being indispensable to secure exact similarity in all. I have reason to think that, had the most favorable conditions been sought and experimented upon, the results would have been considerably more favorable; until therefore these have become the subject of separate experiment, it cannot be decided that the ultimate terms of comparison have been obtained, nor can the data which they offer be received as final.

COLEROON ANNICUTS,—REPORT BY COLONEL D. SIM.

To

The Chief Secretary to Government,

Fort St. George.

Sir.

Agreeably to the instructions of Government contained in the minutes of consultation of the 20th of April last, I have visited and examined with care, the two annicuts recently constructed across the Coleroon at the recommendation of Captain A. Cotton, to divert a large portion of the water of the Cauvery to the purposes of irrigation, and beg now to submit the result of my enquiries to his Lordship in council.

As the expediency and usefulness of these works are questioned by some, whose opinions on the subject, from their accurate knowledge of the Tanjore Rivers, and experience of the sudden and uncontrollable floods to which they are occasionally liable, are entitled to be received with great respect and consideration, a brief account of the Rivers, and of the progressive changes in their condition which have led to the construction of the Annicuts, seems necessary for fully comprehending the subject.

The River Cauvery, which has its source in the Western Ghats and flows past Seringapatam through the Mysore and Baramahl countries, separates into two streams at the island of Seringham, ten miles to the west of Trichinopoly, and about a hundred miles from the sea. The River above the point of separation is termed the Agunda (broad) Cauvery; the southern branch, which flows through the Tanjore Province, the Cauvery; and the northern branch, the Coleroon. The latter River which is considerably the larger of the two, and irrigates a comparatively small portion of country, has a free and uninterrupted passage to the sea, continuing throughout its course a large and powerful river, while the Cauvery at the distance of twelve miles from its head, begins to throw off branches, some nearly as large as itself, and is speedily reduced to an insignificant stream by the endless number of channels and water courses which are drawn from it as it proceeds, for the purposes of irrigation. The one preserves the character of a large river, and flows direct to the sea, while the waters of the other are distributed among the innumerable channels which irrigate and fertilize the Province of Tanjore, and render it the richest tract of country in the south of India. The Cauvery completely reverses the course of things usually observed in Rivers; instead of following the lowest line of country and increasing in size by the reception of tributary streams as it advances, it flows over a high tract of land, and gradually diminishes, by bestowing its waters to fertilize the coun-

try, and is reduced to a very narrow channel before it reaches the sea.

The Parent stream, as has already been stated, rises among the Western ghats; and is chiefly fed by the south west monsoon, but it is also affected by the north east monsoon, and the many small rivers which it receives in its course through the Coimbatore and Salem districts; so that it generally continues more or less full from the commencement of the South west to the end of the North east monsoon, that is, from the beginning of June till the end of December. The Monsoon rains, it is well known, do not fall uniformly, but irregularly, at intervals of eight or ten days, continuing usually several days without interruption at a time. During these falls of rain which are occasionally very heavy, the freshes, as they are termed, occur; the River receives a sudden and great increase of water, and becomes a deep and rapid stream, sweeping along with it a large quantity of mud and sand washed into its channel by the heavy rains and torrents from the mountains. The current of the Coleroon from its straight and free course and the size of its stream, is sufficiently powerful to preserve its channel comparatively clear, and great part of the mud and sand with which its waters are charged; are carried into the sea, forming opposite to its mouth, an extensive bank known by the name of the Coleroon shoal. But the Cauvery is very differently affected. Being the smaller river, and flowing on a high level, banks of sand are left at its source after every fresh; its stream diminishes in size and velocity very quickly; and the sand and mud carried into its channel are deposited as soon as its water becomes tranquil, forming extensive accumulations along its course which obstruct and retard its current. It is manifest that the inevitable consequence of this state of things must be the progressive rise of the bed of the Cauvery, and necessarily a progressive diminution in the proportion of water which enters in at the separation of the two streams, terminating ultimately in the annihilation of the river, if nothing intervened to modify and retard these effects. It may indeed appear wonderful that this catastrophe has not arrived, considering the very great quantity of earthy matters brought down by the river during freshes, of the extent of which some idea may be formed, from the size of the shoal opposite to the mouth of the Coleroon. Colonel Caldwell who first examined the rivers with care in 1804. was forcibly struck with the unusual character of the Cauvery, and predicted its total annihilation at some future period, unless the river could be restored to what he believed to have been its original condition. But the evil, though progressive, is much slower than might at first be expected. The sand and heavier ingredients are deposited in the bed of the river, but a

considerable portion of the firm soil, from its less specific gravity, remains longer in suspension, and is ultimately carried into the smaller channels, and from them into the rice fields, which it greatly enriches. A part of the sand is also occasionally removed by manual labor from the bed of the river, but the most powerful remedy in this as in other cases, is provided by Providence, which has so ordained that evils when they attain a certain height often work their own cure. In the present case, as soon as the channel becomes so much choked with sand that the stream is greatly obstructed in particular places, the first unusually high flood, and such floods seem to occur once every ten or twelve years, never fails to overflow and destroy the Banks in many places, and through the breaches an enormous quantity of sand is swept and the bed effectually cleared and deepened for miles. These remedies it is true are irregular and partial, and accompanied often by extensive loss of property and damage to the country, but they have had the effect of hitherto retarding the consummation of a much greater evil. The channel of the Cauvery has however continued to rise notwithstanding occasional interruptions from the above causes, and with it, the adjoining land on both sides has also been raised, by slow but constant accumulations of soil deposited on it from the river, through breaches, by manual labor, and the sediment of the muddy water of the freshes, so that the course of the river to the sea is now along nearly the highest ridge of land in the Delta, instead of having followed the lowest, as is the case with rivers generally. The land no doubt was originally the lowest, but it has gradually been raised, and the river with it, by the causes above specified.

During the very high freshes, a larger quantity of water enters the Cauvery than is required for the cultivation of the Province, or than its rivers and channels in their present state can safely carry off to the Sea, the superabundant portion which, if permitted to flow down the river, would at times prove greatly injurious, is allowed to escape back into the Coleroon over what is called the Grand Annicut, which is a work of ancient construction in the North bank of the Cauvery about ten miles below Trichinopoly.

This work regulates in high freshes the supply of water to Tanjore, retaining as much as can be beneficially used, and allowing what would prove hurtful to escape.

It is not improbable that Seringham was, as its name implies (*Vide plate 11 fig. I.*) at one time an Island, the South branch of the river returning into the other through the channel across which the Annicut is built; and that the original object of that work was to prevent the rejunction of the two streams, and turn the south one into its present channel through the Delta of Tanjore.

This conjecture derives further probability from the native name of the work, which signifies a dam built across a stream for the purpose of raising or diverting its water.

The earliest account of the state of the rivers in Tanjore which can be depended on, is that given by Colonel Caldwell, in his diaries of 1804 and 5.

In those years Colonel Caldwell, apparently for the first time examined the rivers, and the state of irrigation of the adjoining country with much care and attention, and his observations and remarks are characterized by his usual sound judgment and talent. The Cauvery was then greatly obstructed by deposits and accumulations of sand throughout its course, and the whole District was suffering from want of water, and more particularly the Eastern Talooks of Myaveram and Shealy. The quantity that entered the Cauvery was in the first place quite insufficient, and the evil was afterwards much aggravated by an unequal distribution of that quantity; for the bed of the Cauvery being much raised and obstructed, was robbed of its just proportion of water by several of the subordinate rivers, particularly the Vennaur, abstracting more than their proper share, and a very large quantity escaped over the Grand Annicut and was entirely lost. That work as has already been observed, was intended to regulate the height of water in the Cauvery during the freshes, and no doubt originally answered its purpose satisfactorily, but from the change which had taken place in the level of the river, it had become much too low to retain the quantity of water which the cultivation required.

The only means by which the inhabitants could at that time procure an increased supply of water, was by constructing annually or oftener, temporary dams of sand and fascine work across the bed of the Coleroon at the head of the Cauvery, so as to divert as large a portion of water as possible into the latter river; and by extending the head of Seringham or point of separation, higher up the parent stream, obtain for it a higher and clearer source—but as these operations interfered with and injured the supply from the Coleroon of several valuable irrigating channels in the Trichinopoly collectorate, they were always forcibly resisted by the inhabitants of that district, and the contentions about water led almost every year to serious breaches of the peace.

It was no unusual thing to see the two Collectors at the spot, attended by several thousands of the people, the one party protecting, and the other attempting to destroy these temporary works.

The Tanjore inhabitants from the great value of water to them, and the increasing want of it, were eager to take advantage of every pretence for extending the point of separation up the river; and though constantly opposed, by the people of Trichinopoly, succeeded so far as to establish it several miles beyond what appeared to have been its original position. The Collectors of the Trichinopoly district represented, and often with reason, that the interests and rights of their people were sacrificed to those of Tanjore, because Government derived a larger revenue from the latter district. The expedients now described, independently of the disputes and enmity which they caused among the people, and the injustice

of favoring one district at the expence of another, were attended with much expense and constant labour, and were yearly becoming less and less efficient, for the cause of the evil remained, and nothing was done to arrest its operation.

For the removal of the sand which obstructed the Cauvery, Colonel Caldwell did not propose any immediate remedy, but in order to enable its channel to retain a larger quantity of water, he raised and improved the Grand Annicut, filling up the notches or deep inequalities in its surface, which he suspected at the time had not been left in it without some purpose.

This alteration had an immediate and most beneficial effect on the District of Tanjore; its cultivation generally was much extended, and in the eastern Talooks was increased six fold. It was however, as stated by Colonel Caldwell, only a temporary improvement. The supply of water was for the time much augmented, but the cause of deterioration in the condition of the river, instead of being removed, was by the alterations in the Annicut materially and permanently increased, for the portion of sand which used previously to escape over the Annicut through the notches and inequalities already noticed, was now retained in the river and deposited in its channel. This was foreseen by Colonel Caldwell, who from the natural effect of the causes which he then observed, and which I have attempted to explain, predicted the entire annihilation of the Cauvery at some future period, if measures were not adopted to restore the river to what he considered to have been its original and natural condition.

For this purpose he recommended that its Channel should be gradually straightened and widened towards its mouth, so that it might continue a large and deep river with a current sufficiently powerful to discharge into the sea the sand and mud brought down by its waters. From what has already been stated, it appears very doubtful whether the Cauvery at any time continued a large or even a considerable river till it reached the sea, and there are local proofs which shew that such could not have been the case, unless at some very remote period. But whatever may have been the original condition of the Cauvery, the course recommended was impracticable, without previously establishing some means of turning into the river at pleasure a much larger body of water than it then received. The channel might have been straightened, but it could not have been materially enlarged in its progress to the sea, without an addition to its stream far beyond what there was any probability at that period of procuring. The advice however is very judicious, and in the future treatment of the river the enlargement of its channel as it advances, and the increase as far as practicable of its volume of water, ought always to be kept in view, in order that the greatest possible quantity of sand may be discharged by its mouth into the sea.

For some years after the Annicut was raised the supply of water continued plentiful, but it then began to diminish, and the former complaints of want of water

and loss of crops were renewed. The head of the river became obstructed, and recourse was had to the old remedies of removing the sand by manual labour, and extending the head of Seringham higher up the river, which was of course loudly protested against, and resisted to the utmost of their power by the inhabitants of Trichinopoly. The rivers had indeed the benefit of being several times most effectually cleared and deepened in some places by floods, particularly in 1818 and in 25.

On the former of these occasions the water rose higher than ever before remembered, and swept away the banks of the rivers in a great number of places, completely deluging the country, and leaving tracts buried in sand. These extraordinary freshes, of course, had a powerful effect, but they were partial and irregular in their influence, being confined to the vicinity of the breaches.

The continued and increasing complaints of want of water from Tanjore, and the fact that the channel of the Cauvery was progressively rising and becoming more and more obstructed, notwithstanding all the expedients to prevent it which had been tried, and the endless contentions between the Tanjore and Trichinopoly inhabitants, naturally attracted the anxious attention of the Officers entrusted with the irrigation department, and the subject was very carefully considered and the nature and cause of the evil investigated. It was evident, as had been remarked by Colonel Caldwell in 1804, that unless some means could be devised to make the river itself the principal agent in discharging the mud and sand which its waters brought down, the evil must continue to increase till it accomplished the destruction of the river; for it was of too great magnitude and extent to yield to manual labour, and the operation of occasional floods was too partial and irregular to produce any permanent effect, even if they could be divested of the extensive damage to the property of the people which always accompanied them. The consequence which had resulted from raising the Grand Annicut and filling up the inequalities in its surface drew particular attention to that work, and the observation of the great quantity of water which in high freshes escaped uselessly over it, without producing any effect to the bed of the river, suggested the first idea of the new system of treatment to which the Cauvery has been subjected since 1830, and which now promises to produce very beneficial and permanent effects. Instead of allowing the surplus water to escape over the top of the Annicut, as it had done since that work was raised, leaving all the sediment behind, it was determined to make a portion of it pass under or through the Annicut, on a level with the lowest bed of the channel, by means of openings or under sluices, through which the water being forced in high freshes with great velocity and at a very low level, would, it was expected, draw with it a large quantity of sand, and gradually reduce the bed of the river to its proper condition. The first set of sluices was constructed in the grand Annicut, which from its proximity to the Coleroon, and the deep and broad

channel connecting them, was very favourably circumstanced for the experiment. They were constructed in 1830, and had soon a perceptible effect on the bed of the river, by the large quantity of sand which escaped through them. Their influence being of course confined to the portion of the river above them, to a distance of nearly 20 miles, two other sets of sluices were subsequently established lower down the river on the same plan, to clear and deepen the channel below the Annicut.

A way for getting rid of the sand by the agency of the superabundant water during the freshes was thus established, but the means could only be brought into operation when the supply in the Cauvery was greater than was required for the purposes of cultivation; and as that was comparatively seldom in ordinary years, from the obstructions near the commencement of the channel, the effect of the sluices in clearing and lowering the bed was neither so rapid nor so extensive as was required. Their influence however was perceptible, and all that seemed necessary to make them accomplish the desired object, was water enough to admit of their being opened more frequently and for longer periods.

About this time Captain A. Cotton who had been instrumental in establishing the under sluices, and had watched their effects attentively, resumed the superintendence of the works of irrigation in Tanjore. He had observed that a very large quantity of water flowed down the Coleroon uselessly to the sea, while the supply that entered Tanjore by means of the Cauvery was uncertain, and generally inadequate to the wants of the people; and that until some work was established across the Coleroon near the separation of the two rivers, to raise and divert a larger portion of the water into the Cauvery, it was vain to look by any other means for the permanent improvement of that river, and consequently for an abundant and lasting supply of water to Tanjore. The head of the river had become so much obstructed and raised by the accumulated deposits of years, that a sufficient portion of the parent stream could not by the means then in use, be turned into it, to give the required effect to any expedients that might be adopted lower down its course for the purpose of keeping its channel clear. This led him to propose the construction of the upper Annicut, which was only substituting a permanent and efficient work in masonry, for the temporary and imperfect bank which the inhabitants were accustomed to erect once, or oftener, every year. Simple and natural as this course may now appear, no one previously to Captain Cotton thought of recommending it, and it was attended by a degree of responsibility and risk which few would have voluntarily undertaken. For the talent and judgment displayed by Captain Cotton in his patient investigation of the causes which were affecting the rivers in Tanjore, and for the boldness with which he proposed and carried into effect what appeared to be the only remedy, I conceive that Officer is entitled to the highest praise.

The Coleroon, tho' of comparatively small value with the Cauvery, as an irrigating river, nevertheless waters

considerable tracts of land; The Lallgoody Talook, and Seringham in the Trichinopoly District, and the Manargoody and Chellumbrum Talooks in south Arcot, are entirely irrigated by the Coleroon, and the Tanjore lands on its south bank partially so. As it formed part of the original project to open the sources of the Trichinopoly irrigating channels above the Annicut, it was evident that they, instead of being injured, would be materially benefited by that work, but it was apprehended with reason, that if nearly the whole of the Coleroon in low freshes, were diverted into the Cauvery, the quantity of water in the former river would be so much reduced, that sufficient would not remain for the irrigation of the Talooks in south Arcot, unless another Annicut were constructed in their vicinity, to draw up and divert the stream into their channels. To remove this objection the lower Annicut was established about 70 miles beneath the upper one, and immediately below the important Vuddavaur Channel.

Having traced briefly the cause and progress of the changes which led to the construction of the two Annicuts, I shall now consider the effects which they have already produced, and the further benefits which may be expected hereafter, and then the objections which have been stated against them, and the danger which those who are opposed to them apprehend from their construction. I shall commence with the upper Annicut, both because that is incomparably the more important work, and because a great part of the observations on it will apply equally to the lower, and I shall consider the Annicuts as if they were already brought to that degree of perfection and stability which is necessary to realize all the benefits they are calculated to produce.

The evil so long and severely felt and loudly complained of by the inhabitants of Tanjore, was an uncertain and insufficient supply of water, not originating generally in any deficiency in the parent river, but produced by an improper division of the water, where that river separates into its two branches, the Coleroon and Cauvery. The former of these having its channel on a lower level and more free from obstructions, abstracted more than its just proportion at all times, and when the river was low, drew off nearly the whole of the water, leaving the other branch almost dry. It will at once be obvious, that the upper Annicut, which is constructed across the Coleroon immediately below the point of separation, and opposes a barrier to the passage of the water down its channel six feet in height, must produce an immediate and great alteration in the relative conditions of the two rivers at that place. The surface of the Coleroon is in reality raised six feet at its source, and no considerable portion of water can flow down it, till it has attained that height; while the source of the Cauvery being left unobstructed, a much larger portion of the parent stream must necessarily be diverted into its Channel than entered it before the Annicut was constructed. In addition to this important advantage, the operation of the Annicut is most powerful and efficient on the occasions when its aid is most wanted,

namely, when the freshes are low, and water is most valuable, and most necessary for the cultivation.

Formerly, in low freshes, comparatively little water entered the Cauvery, and the greater part of it, notwithstanding all the troublesome and imperfect expedients to prevent it, flowed down the Coleroon uselessly to the sea; whereas now any proportion of it that is required may at pleasure be turned entirely into the Cauvery. As the river rises, the influence of the Annicut diminishes, and becomes less and less powerful in proportion to the depth of water; so that in high freshes and floods a large proportion of the water will escape over the Annicut and through its sluices into the Coleroon, and down its channel, as formerly, to the sea. The work is thus most influential, and produces the greatest effects in scanty and unfavorable years, and at the commencement and termination of the freshes, when they are usually the lowest and the water of the greatest value. In regard therefore to the management of the rivers, the Annicut is evidently of the first importance, as supplying that control over their waters which was required, and which all previous expedients had failed to furnish; that is, giving the means of appropriating the whole or any portion of the Agunda Cauvery at pleasure to the purposes of irrigation, and when there is a superfluity of water, allowing the excess to escape down the bed of the Coleroon to the sea. Frequent contentions between the Trichinopoly and Tanjore inhabitants respecting the distribution of the water at the separation of the two streams have been adverted to in the first part of this paper. The Annicut has put an end to these disputes, for the sources of the channels of the Trichinopoly District having been opened immediately above it, they have also derived very great benefit from its effects, and are now far better supplied than they ever were, and without the labor and cost of the temporary embankments which the inhabitants had formerly to construct every year.

In speaking of the under sluices it was stated that their action on the bed of the Cauvery had not been so rapid nor so extensive as was necessary, from the inability of sparing a sufficient quantity of water for the purposes of irrigation, to keep them in action long enough during the year. This defect the Annicut has entirely cured, and the quantity of sand removed by the sluices and discharged by the mouth of the river into the sea, has been sufficient to produce a very great change in its bed, and to deepen it so considerably, that now, instead of suffering from a deficiency of water, it retains too large a proportion, and the Vennaur and Codamoorty are deprived of their just shares, whereas formerly they drew off more than was required for the irrigation of the land depending on them. This is a most desirable alteration as far as regards the Cauvery, and holds out a hope of the possibility of bringing this very valuable river to a degree of perfection and usefulness which it never before possessed. By a judicious system of treatment, its channel may by degrees be considerably enlarged towards the sea, and a sufficient quantity of water and ve-

locity of current preserved, to discharge a considerable proportion of the mud and sand by its mouth, as was rather wished for, than expected to be ever realized by Colonel Caldwell. The Annicut by establishing the means of increasing the quantity of water in the river at pleasure during the freshes, furnishes a power capable of producing very great improvements, but on the skilful and judicious management of that power, the quantity of good very much depends; I may almost go so far as to say, whether the result ultimately shall be good or evil. The Vennaur and Codamoorty I have observed do not now receive their just proportion of water, especially the former river, under which there have been considerable losses during the last season; and as they drew off more than their shares till recently, a material change must have taken place in the relative levels of their channels and that of the Cauvery, since the under sluices and the upper Annicut were established. If the alteration has arisen entirely from the bed of the Cauvery having been lowered, the result is most satisfactory, but I am apprehensive that the Cauvery may now be producing effects on the Vennaur and its other channels, similar to those which the Coleroon formerly inflicted on it, and that while its own bed has been lowered, as it unquestionably has been, the beds of the others may have been raised by the sand being thrown into and deposited in them. This is a consequence which must be attentively watched and guarded against with care, or we shall have only transferred the evil from one part of the district to another.

In estimating the effects already produced by the Annicuts on the cultivation and revenue of the country, several circumstances must be borne in mind. The first of these is, that the Annicuts have only been three years in operation, that these have been unfavourable years, and that some time is requisite to enable the inhabitants of a district to extend their cultivation after the requisite quantity of water has been supplied; confidence must first be established that the supply of water will be permanent, and then additional stock and means are to be acquired to cultivate more land. Another consideration is, that though the first requisite for the perfect irrigation of the lands under the Cauvery is a moderately and uniformly abundant supply of water in that river, commencing with the first freshes, and continuing as long as possible, such in short as the Annicut is capable of furnishing, still it is not the only one. The seed is sown as soon as water can be drawn from the first freshes in June, the plants are reared and the cultivation is carried to a considerable state of forwardness by the freshes of the south west monsoon, but the crops are chiefly brought to maturity by the rains of the north east monsoon. For a plentiful harvest therefore, the rains of the north east monsoon are requisite as well as the freshes of the south west monsoon, and a deficiency in either always affects both the quantity and quality of the produce. The farther forward that the cultivation can be advanced by the south west monsoon, the less risk there is of its suffering from any partial failure of the north east rains, and it is this which,

makes the early freshes so valuable, but for a failure of the south west monsoon there is no remedy. It is possible therefore, and indeed occasionally happens, that in seasons in which the freshes have been sufficiently plentiful, and the cultivation carried on successfully during them, the expectations of a very plentiful harvest may have been disappointed by an unpropitious north east monsoon. On such occasions it would not be just to attribute the disappointment to the Annicut. A third consideration is, that when the south west freshes fail, as has hitherto been the case occasionally, and will no doubt continue to happen hereafter, the Annicuts cannot supply their place, for as has been observed by others, their office is not to create water, but to furnish the power of controlling and beneficially appropriating the water which reaches them.

It will be evident, I think, from a consideration of the above circumstances, that the Annicuts have not yet been sufficiently long in operation to furnish the data which are requisite for forming an accurate judgment of their influence in extending the cultivation and augmenting the public revenue. It is only from an average of a considerable number of years that any thing like a correct comparison can be drawn. In unfavourable seasons when there is a decrease in the produce, the benefit derived from them may be, and no doubt often is greater than in productive years, for it is on such occasions that their influence is most advantageous; but the exact amount of the gain cannot be calculated, from the impossibility of ascertaining how much greater the loss would have been without them. If a register had been kept of the water in the Agunda Cauvery, as well as at the Grand Annicut, a calculation approaching the truth might have been instituted, but in the absence of that information we must trust to the judgment of those who, from their local knowledge, and from having their attention much directed to the river by the nature of their employment, are best able to form an opinion on the subject. There can however exist no doubt in any one's mind, that when an article is very scarce and much required, an agent which furnishes the means of increasing that article at the time it is most indispensable, must be very valuable.

The Collectors of Tanjore, South Arcot, and Trichinopoly, the three districts which are irrigated by the waters of the Cauvery and Coleroon, are certainly the individuals best able to estimate the benefits which the Annicuts have conferred in their respective districts, and when we find the gentlemen who have been entrusted with the management of these districts since the works were established, all concur in considering them as eminently beneficial, and to have already produced important and extensive good, and when further the frequent feuds about water which formerly occurred between the inhabitants of two of the districts are recollected, and which the Annicuts have entirely removed, it would seem to be the height of scepticism to withhold one's assent.

The Collector of Trichinopoly in a letter dated 20th July 1837, about 14 months after the upper Annicut

was completed, in reply to a requisition from the Board of Revenue to furnish a report on the advantages which had resulted from the Annicuts, states that "with regard to the results of the Annicut as it affects this district, they have been most favorable."

"The two channels which were expected to derive the chief advantage from the work, are the Peravully and the Iyen, which irrigate nearly the whole of the wet lands of the Lalgooody Talook, yielding a revenue of Rupees 2,05,326."

"The head of the Peravully Voikal opens into the Iyaur River at its junction with the Cauvery, which as your Board are aware, is immediately above the Annicut. Hitherto it has been necessary every year to carry a Corumboo a considerable distance up the river, when the water was low, to conduct a stream into the Peravully Channel, and in unfavorable seasons it has of course suffered equilly with other channels from scarcity of water.

"During the last season, as unfavourable a one, probably, as regards the state of the river, as has ever been known, the Peravully Voikal, owing to the constant head of water which stood above the Annicut, had not only a sufficient supply of water in it to bring to perfection (with some slight exception) the whole of the cultivation depending upon it, but there was not a single day in the year, in which a stream did not flow into the channel; and this without the labour and expense of constructing the usual Corumboo."

"Besides the great advantage derived by the Marassadars from the abundance of water for their cultivation supplied by this channel, its constant running stream in a season of severe drought like the last, proved a real blessing to the Ryots of the dry villages in many parts of the Talook, who, without this supply, would have been severely distressed for water for themselves and their cattle."

"This new cut has fully answered my expectations, and the land depending on the Iyen Voikal, will now be as favorably circumstanced, as regards a constant supply of water, as those lying under the Peravully. Both channels will in future be saved all the trouble and expense that has hitherto been annually incurred, in constructing Corumboos, which must be considered a very great advantage to the Marassadars."

"There is a third channel in the Lalgooody Talook, called the Nadookarray Nant Voikal, which irrigates the whole of the Nunjah land on the Island of Seringham, comprising about 2500 cawnies. This channel branches off from the Cauvery a few miles below its head, and it has benefitted very considerably by the increased body of water thrown into the river since the construction of the Annicut."

"Besides these channels in the Lalgooody Talook, there are two; the Rom Voitally and Yelanda Voitally, which water part of the land in Conaud Talook, lying on the south bank of the Cauvery, which, from their head sluices being situated below the Annicut have also participated, though in a less degree than the

"Nadookarray channel in the advantages derived from that work."

The Principal Collector of Tanjore, in answer to a similar requisition, in his letter of the 1st July 1837, states, that as to its (the upper Annicut) value to the public and private resources of the province, it is obvious that as the instrument of turning into the Cauvery at low freshes a large body of water which formerly ran waste by the Coleroon into the sea, and thereby increasing and rendering more regular the supply of water to about 500,000 acres of Nunjah land, enabling the cultivation to be commenced earlier, and the crops to be watered later than before, it must be immense; and had the first season of its operation been an ordinary instead of a most disastrous one, its value would have been demonstrable by the result in figures."

"The object of the structure being not to make water, but to direct its course, the extraordinary failure of the freshes subsequent to the 25th September is no more an argument against its efficiency, than the ordinary dry shod passage of the River in March; and that it has answered its professed object is proved by the notorious fact that the Coleroon is now frequently forded with facility, when the Cauvery is impassable without a boat, the very reverse of their relative states before its construction."

"Unprecedented, however, as the failure of the freshes was, and scanty as the North East Monsoon proved to be, the decrease in the gross produce of the wet lands paying full Revenue to Government, which are watered by the rivers, will be, as nearly as the present state of my accounts enable me to judge, but 723,777 Cullums, or 6 3-16 per cent below that of last year; and though it is impossible to shew, or perhaps to guess, within some lacs of Cullums, what it would have been but for the Annicut, one thing is certain, that it would have been, like the failure of the freshes in the parent stream, *unprecedented*; and my conviction is, that Tanjore, instead of largely supplying the wants of the adjacent districts, must have imported grain for her own consumption."

"My opinion however of the value of the Annicut and of its results in an ordinary season is not merely conjectural, as will be seen by a reference to the register of the Cauvery for the months of July, August, and

	1835.	1836.
September, which show that	July.....11	20
out of 91 days, the water stood	August..... 4	23
either even with, or above the	September. 7	23
	22	66

"crown of the Grand Annicut but 22 days in 1835, and 66 in 1836; the freshes all the while being exceedingly moderate; and the result at the end of September, as mentioned in my report upon the state of the season dated 24th October 1836 (to which and to the remarks appended to the statement of Demand, Collection, and Balance for the preceding 3 months I beg to refer) was an increase of 7 1/2 per cent in the extent of Nunjah cul-

tivation. The advantages of this forwardness in the cultivation, in a season the latter part of which was so deplorably bad that all the backward crops perished, are obvious, and supercede the necessity of entering into calculations of the money result either to Government or individuals."

Again, the Principal Collector of Tanjore in a letter dated the 11th of August 1838 to the Board of Revenue replied as follows. "The Board desire more detailed information as to the operation of the upper Annicut, and for this purpose, on the supposed strong similiarity between the seasons Fuslies 1241 and 1246, suggest and partly institute, a comparison between them. The seasons in question so far resembled each other that they were both bad, but differed very much in the degree of unfavourableness, that of Fusly 1246 being by far the worse. But before entering on this comparison, I beg to remind the Board, 1st that with reference to the effects of the Annicut, it will be confined to the *Neerarumbrum* or lands irrigated by the Cauvery, and its branches; 2dly that no Annicut can create water or do more than by raising divert its course; 3rdly that although the *cultivation* of the Delta is carried on by the freshes in the rivers supplied by the S. W. Monsoon, the maturity and abundance of the *crop* depend almost entirely on the rains of the N. E. Monsoon."

"With regard to the comparative abundance of the freshes from the S. W. Monsoon, in the Agunda Cauvery, in the respective years, as no regular register was kept of the rise and fall of the water in either year, it cannot be exhibited in figures. But it is expressly stated in my report for Fusly 1241 that up "to October" the whole period of the S. W. Monsoon, the season continued favourable; whereas, in Fusly 1246 the scantiness of the S. W. Monsoon, and consequently of the freshes, was notoriously unprecedented, and the season is stated in my report to have been, "the most unfavourable ever known." Nevertheless, on a reference to the register of the Cauvery kept at the grand Annicut, after its separation from the Coleroon, it appears that in Fusly 1246 up to September, till when, and during the following month the season of Fusly 1241 was considered favourable, (the upper Annicut threw so large a proportion of these scanty fresh-

	1835.	1836.
September, which show that	July.....11	20
out of 91 days, the water stood	August..... 4	23
either even with, or above the	September. 7	23
	22	66

	1835.	1836.
September, which show that	July.....11	20
out of 91 days, the water stood	August..... 4	23
either even with, or above the	September. 7	23
	22	66

	1835.	1836.
September, which show that	July.....11	20
out of 91 days, the water stood	August..... 4	23
either even with, or above the	September. 7	23
	22	66

" days: in November for 2 days, and in December for 1 day. If the deficiency in the supply of water during the same 3 months in Fusly 1246 is to be attributed to the Annicut, it will not be easy to account for the river having been full during the same 3 months in Fusly 1246 for 55 days! To what then is it to be attributed, but to the failure of the freshes themselves to so much greater an extent than in Fusly 1241, that though the Annicut might, and certainly did, very considerably palliate, it could not entirely remedy the evil.

" With regard to the comparative supply of rain from the N. E. Monsoons, upon which as has been said, the maturity and abundance of the crops even in the Neerarumbrum depend, the best index of it is afforded by the comparative state of those villages which depend entirely on the rains. In Fusly 1241 out of the 322 Cadarumbum villages in the Puttaacottah and Trivady Talooks, remissions were granted on

Fusly.	Standard.		Actual.		Decrease.		per cent.	
	Land.	Grain.	Land.	Grain.	Land.	Grain.	Land.	Grain.
1241	2175	256446	1672	140532	503	115931	23 3/4	45 1/8
1246	4758	538523	1140	132318	3619	406205	76 75/8	76 75/8
Villages.	116							
	305							

" Nunjah Lands in 116 and in Fusly 1246 in 305. The decrease below the standard in the extent of land brought to account (in other words the proportion of waste or entirely unproductive land) was 23 3/4 per cent in the former year and 76 per cent in the latter.

" I trust the board will be satisfied from what has been said, that the season of Fusly 1246 was beyond all comparison worse than that of Fusly 1241, both as regards the freshes and the rains; that as long as there was water for it to act upon the effects of the Annicut were most satisfactory, and that the inference is not only fair but obvious, that when (as was the case after the 25th September) the failure of the supply in the Agunda Cauvery was so great as never to afford a full river for a single day, even with the assistance of the Annicut,

" without it the failure of crops must have been incalculably greater than it was; indeed from the very nature of the work its operation is much more advan-

" tageous in a bad than in a good year, and I have not the slightest doubt that the savings it effected in Fusly 1246, when it gave a full river for but 68 days, were much greater than the profits derived from it in Fusly 1247, when the river was full for 122 days, and yet had the season been reversed not a doubt would have existed of the efficiency of the work.

" The comparison of cultivation and produce instituted by the Board shewing a decrease of 1771 valies and 1,404,516 in Fusly 1246 below Fusly 1241 includes the 322 Cadarumbum villages above alluded to, in which the cultivation and produce in either year is

	Valies.	Calls.
1241	3465	337782
1241	1181	136487
Decrease	2284	201295

" exhibited in the margin. The decrease of 2284 valies in these villages is quite unconnected with the Annicut, and if from it be deducted valies 1771 the decrease upon the whole province we have an increase of 513 valies in the Talook which are Nusurumbum under its influence, despite

" the unfavorableness of the season. It is true that a similar modification of the comparison of produce instead of giving an increase only reduces the per centage of increase from 10 3/8 to 9 1/8 which is easily accounted for by the fact that the cultivation depends upon the freshes from the S. W. and the maturity and abundance of the crops upon the rains of the N. E. monsoon, the failure of which has been shewn to have been beyond all comparison greater in Fusly 1246 than in Fusly 1241.

" Another comparison is instituted by the Board of the cultivation and produce in either fusly in the villages under the Venaur, shewing a decrease in Fusly 1246 of 4 1/2 per cent in the former and 18 per cent in the latter, being a greater per centage than in the whole Neerarumbrum. The object and effect of the Annicut is simply to divert a portion of the waters of the colleroon to the supply of the Cauvery at its root, but can in no way effect

	calls	calls
1241	36098	4646070
1246	34284	3810644
Decrease	813	834414
Per cent	274	18

" their distribution in its several branches, which is ever varying from a variety of causes some of which baffle all research, and is a constant source of labor and anxiety. The Board desire to be informed whether in any of those villages which have benefited largely by the Annicut, a double crop has not been obtained on land which heretofore has yielded only one, or whether there has been any conversion of dry land into wet;

	Fusly 1241	Fusly 1246	Decrease	Per Centage
Whole province	13251974	11847458	1404516	10 3/8
Cadarumbum	337782	136487	201295	59 1/8
Nierarumbum	12914192	117109	1203221	9 1/8

“ whether, on particular lands under the influence of
“ the Annicut, the produce has been increased, and last-
“ ly, whether any addition has been made to the public
“ Revenue, in return for the large amount of money ex-
“ pended on this new work.

“ From what has already been said, the Board will
“ perceive, that the Annicut was not built for the be-
“ nefit of any particular villages or lands, but for that of
“ the whole Delta; and a reference to the report (to the
“ Inspector General 15th July 1834) of Captain A. T.
“ Cotton the projector of the work, will shew that the
“ benefits expected from it were almost entirely resto-
“ rative. For a number of years the proportion of the
“ waters of the Cauvery carried off by the Coleroon had
“ been increasing, and its bed thereby acquiring a lower
“ level, whilst the proportion of water in the Cauvery
“ east of its severance from the Coleroon was gradually
“ diminished, and the level of its bed raised. A variety
“ of expedients, more or less effectual were tried, with a
“ view to remedy, or at least to palliate this evil, a na-
“ tural opening in the bank which separates the two
“ rivers, was closed, to prevent the waters of the Cau-
“ very from flowing into the Coleroon, and several sets
“ of under sluices constructed to carry off the accumu-
“ lation of sand in the bed of the Cauvery, when the sup-
“ ply of water was sufficient to allow of their being used
“ without detriment to the cultivation. But all these
“ measures, although they certainly tended to retard,
“ were found insufficient to prevent the catastrophe to
“ which there was an obvious tendency, viz. the diver-
“ sion of the whole stream of the Cauvery into the Co-
“ leroon, except at highest freshes. At once to obviate
“ this, and to restore the former distribution of water to
“ the two rivers, the Annicut was projected and built.
“ Its primary object was not to increase, but to keep up
“ the cultivation and revenue, not to convert a desert in-
“ to a garden, but to prevent a garden becoming a de-
“ sert. Before the equilibrium of the two rivers was dis-
“ turbed, there were bad years as well as good, and so
“ there will be in spite of its restoration; and the culti-
“ vation, and still more the produce, will vary accord-
“ ingly. It is therefore, only upon an average of years
“ that the effects of the Annicut can be fairly tested,
“ and not by a comparison of any one year, good or bad,
“ with any other. It is notorious that large remissions
“ have been rendered necessary in Tanjore, year by year,
“ by the failure of crops from an insufficient supply of
“ water; and it will not be denied, that throwing a dam
“ across one branch of a divided stream, must increase
“ the supply of water in the other; to doubt the appli-
“ cability of this truth to the rivers in question, and to
“ question the advantages of the Annicut, because,
“ when there was no water in the parent stream no such
“ effect was produced, were as unreasonable as to quar-
“ rel with a dial, for not indicating the hour when the
“ sun does not shine.

“ With some, an increase of wet cultivation and of a
“ second crop, was contemplated as likely to follow the
“ construction of the Annicut is true, and that such will
“ gradually be found to be the case, I have no doubt;

“ but it is surely too much to expect these results to any
“ considerable extent in the very first year, even had not
“ that year been the most unfavourable ever known.

“ With reference to the cost of the work, it is true
“ that it has been considerable, but supposing 150000
“ Rupees to be required from first to last, for securing
“ the Annicut and its dependent works in a state of effi-
“ ciency, it is to be remembered, that they are for the
“ benefit of lands, the standard revenue of which, is at
“ least 30 lacs per annum in Tanjore only; and 5 per
“ cent upon one year's revenue of the lands under a
“ tank, would perhaps not be considered a very formi-
“ dable outlay for the ordinary repairs of its bund in
“ every third year, instead of, as it is hoped will be the
“ case with the Annicut, once for all.

“ I cannot conclude without observing, that whilst so
“ much doubt appears to be entertained of the advanta-
“ ges of the Annicut elsewhere, there is not an indivi-
“ dual in the Province who does not consider it the
“ greatest blessing that has ever been conferred upon it;
“ and I have not the smallest doubt, that the name of
“ its projector will in Tanjore survive those of all the
“ Europeans who have ever been connected with it.

Mr. Dent the Principal Collector of Arcot, in a let-
ter to the Board of Revenue dated the 29th of May
1837, explaining the causes of a small excess in the
cost of the lower Annicut, above the estimates, ob-
serves as follows; “ But the end has been fully ac-
“ complished, the Annicut was completed before the
“ freshes in the river came down, has stood the test of
“ a monsoon without the slightest injury, and has been
“ a very principal cause of saving the cultivation this
“ year, of the two Talooks of Munnargoody and Chel-
“ lumbrum. The utmost vigour and efficiency was re-
“ quired in every department, and a failure in any one
“ would have proved fatal to the whole; and by the
“ outlay of the trifling sum in excess of the estimate,
“ without which the work could not have been complet-
“ ed, an absolute advantage has been derived by go-
“ vernment to the extent of at least half a Lac of Ru-
“ pees, in the saving of the crops in Munnargoody and
“ Chellumbrum, which must otherwise have perished.

The present Principal Collector of the same dis-
trict, in a letter dated the 17th of May 1839, gives me
the following statement of the effect of the lower An-
nicut in the Talooks of Munnargoody and Chellum-
brum in his district. “ I now send you a statement ap-
“ pended to this report, of the Nunjah cultivation of the
“ two Talooks (of Munnargoody and Chellumbrum)
“ which, will shew the increase arising from extended
“ cultivation.

“ I enclose also a statement of the Beriz and actual
“ collections of the two Talooks since 1231, or since the
“ Rent, which shows that while the demand has been
“ increasing, the condition of the Ryots has improved,
“ from the outstanding balances being gradually less.
“ It shows, that the cultivation is now more secure and
“ less liable to the variations of season.

“ In 1246 the monsoon was very scanty, the river also
“ afforded a bad supply, but by the Annicut the tank

" was fuller than usual, and instead of a very great falling off in the cultivation, and consequently of the revenue, there was an actual increase, which would have been greater if the minor arrangement of channel had been further advanced.

" In 1247 the monsoon was no better than in the preceding year, but the subordinate improvements had been further advanced, and the river freshes were more abundant, though still not considered a good year, yet the Annicut secured an abundant supply, and the result is seen in the statement.

" In the current fusly, the monsoon was again deficient, and the river very scanty, but instead of the extensive deficiency which must inevitably have occurred without the Annicut, we have a further increase, both in extended cultivation and in revenue.

" It is also to be noted, that the condition of the ryots has improved with the revenue, and they are now anxious to take up every Cawny of land as soon as the means of irrigation are afforded.

" By comparison of the Nunjah cultivation in the two talooks, or the revenue, with the 5 years averages in the statement No. 1, the increase will be found to be Rupees 86,653.

The following is an extract from a letter to me, dated the 15th instant, from the present Collector of Trichinopoly.

" No alteration has been made in any of the head sluices of the above channels (of Laulgoody and Conaud in Trichinopoly) except that of the Iyen voikal, which was formerly situated about 10 miles below the commencement of the Coleroon. The construction of the Annicut rendered it necessary to give this channel a head above that work, and the result has been most beneficial; formerly in dry seasons water was let into the channel by means of a Corumboo, at the expenditure of great labor and with very uncertain benefit, the water being in a great measure soaked up by the sandy soil through which it had to pass; whereas now, the cut from the new head being in hard firm soil, none of it is wasted. In short, the supply is most abundant, and I cannot do better than point out my predecessors letter, as showing the effects of the new arrangement.

" There are also two channels on the south bank of the Cauvery, Yellandavoytallay, and the new Ulloor channel; the latter of these was dug since the building of the Annicut, for the purpose of affording water for the cultivation of land that had hitherto been dependant on the Yellandavoytallay, which, from a variety of causes, ceased to yield the necessary supply of water; the beneficial effect of the Annicut as regards these channels has been very great, not so much from the increased cultivation resulting from it, as from the protection afforded by it to the existing cultivation, which must in all probability have continued to decrease, but for its aid. It will be perceived from statement No. 4 that in fusly 1246 there was considerable falling off in

" the cultivation of these lands, and that last year it had got up to the usual mark. The accounts of the present year are not sufficiently forward to enable me to state the extent of cultivation, but I have no doubt they will give a favorable result.

These extracts show the opinions which the Collectors of Tanjore, South Arcot, and Trichinopoly, entertain respecting the Annicuts. The people of the districts and native revenue officers, with many of whom I had an opportunity of conversing on the subject, hold similar opinions: from the Governor of the small Danish settlement of Tranquebar I learnt that their landholders received a more abundant and earlier supply of water than formerly, and were now cultivating land which had never been of any value before, from the want of water to irrigate it. What the amount of gain to the state may have been, during the three years that the Annicuts have been in operation, it is impossible from the nature of the subject to estimate; but, there can exist no doubt of its being very large, and I believe much greater than the cost of the works, and what is still required to complete them and the other improvements connected with them. The Board of Revenue in a letter dated 30th April 1838, states that the lower Annicut had saved nearly a Lac of Rupees in the two Talooks of Munnargoody and Chellumbrum, during the preceding two years; the present Principal Collector calculates the gain in these Talooks at nearly a lac of Rupees yearly, which I am inclined to consider too high an estimate at present, though perhaps it may be realized hereafter, when the additional channels are completed, and the people have had sufficient time to increase their stock and means for cultivating more land. In Trichinopoly no material increase of revenue arises, but it has been kept up fully to its average amount, notwithstanding the unfavourableness of the seasons, and without the expensive and troublesome temporary dams which the people had to construct every year formerly. But it is in Tanjore that the beneficial influence of the Annicuts must have been chiefly felt, and there both Collector and people consider them as the greatest blessing that has ever been conferred on the district.

Those who are opposed to the Annicuts, do not I believe altogether deny their utility in deficient or ordinary seasons, though they think that the measure of their usefulness, even at such times, is very greatly overrated; their chief objection proceeds from the apprehension, that during those unusually high floods which occasionally occur, their effects will be ruinous to the country they are meant to benefit, by forcing into the Cauvery a much larger quantity of water than its channels are capable of containing, and thereby destroying the crops and property of the inhabitants, to an extent which those only who have witnessed such calamities can duly estimate. They believe that the amount of injury generally, will be greater than the benefits, and that the damage of one flood may not be compensated by the gain of a number of years.

It must be confessed, that the inundations which occasionally occur in the Tanjore rivers, rise to an alarming height, and have been the cause of most extensive injury to the country and people. The rivers overflow and destroy their banks, producing deep breaches, through which a large proportion of their waters are discharged for days with irresistible velocity and force. The whole country is deluged, the crops irretrievably damaged, and the inhabitants in low situations sometimes obliged to quit their houses and fly for safety to elevated spots. The eastern Talooks of Tanjore in the flood of 1825 are described by the Sub Collector as presenting for many days the appearance of an extensive sea. During such visitations the efforts of man can do nothing. The people must patiently wait, witnessing the destruction of their property and fields, till the inundation subsides; when the whole population and resources of the province are required to stop the breaches, and turn the rivers again into their channels. These evils, great as they are in themselves, are often farther augmented by the permanent destruction of considerable portions of the finest lands, which in some cases are converted into marshes, by the soil being swept away by the torrents, and in others buried in sand. The losses to Government are also very great, from the extensive destruction of the embankments of the rivers, and of the roads and bridges, the restoration of which requires a large disbursement of the public money. In Trichinopoly the repair of the damages of 1818 cost Rupees 35,000; and the expense in Tanjore must have been much larger, though I have not the means of stating its amount; for the damage there was much greater. In 1818, and again 1825, Tanjore was visited by very destructive floods, the effects of which are ably and minutely described by the then Collectors of Trichinopoly and Tanjore. It is not to be wondered at, that those who have witnessed such calamities, and the great and permanent disasters inflicted by them on the people and districts under their care, should view with distrust and apprehension plans which in their opinion are likely to add to their frequency and extent; they naturally fear that works, the object of which is to produce great and immediate changes in the distribution of the water of a large river, and therefore alter the state of things to which the subordinate rivers and channels have gradually adapted themselves, may produce very serious and alarming consequences. If the rivers in Tanjore formerly received more water than they could hold during high floods, how greatly may that evil and the calamities proceeding from it be aggravated, by forcing an increased quantity of water into the district on such occasions.

Admitting then, as I must readily do, the necessity of great caution in constructing works of this nature, and the reasonableness of the fears which have been entertained on the subject, a consideration of the following circumstances will I think shew, that the risk of danger from the Annicuts is not so great as has been apprehended. In the first place, the upper Annicut does not increase the quantity of water which comes down the Agunda Cauvery, it only affects the distribution

of that river, at its separation into the Coleroon and Cauvery, and even in that respect its influence during high floods is not so powerful as might at first be supposed. As has been already observed, when the Agunda Cauvery is low, nearly the whole or any part of its waters may, by means of the Annicut, be at pleasure diverted into the Cauvery; but as that river increases in size, the power of the Annicut on its stream proportionably diminishes, and in full freshes a large proportion of the water will pass over the Annicut and through its sluices into the Coleroon. The higher the rivers rise, as in great floods, the less are they affected by the Annicut; though no doubt at all times the influence will be considerable, even during such inundations as that of 1818. For the relief of the Cauvery on such occasions, three sets of under sluices and two Calingulahs have been constructed within the last ten years, through which a large quantity of water may, when required, be allowed to return to the Coleroon. The channel of the Cauvery has also become deeper, and more free from obstructions of sand, and therefore capable of holding a greater quantity of water than formerly; and this improvement in the capacity of the Cauvery as well as in the other principal rivers of Tanjore may be gradually extended by judicious management of the increased supply, so that a much larger quantity of water may hereafter be turned into them—with great advantage to the country, and without the risk of damage, than they will contain at present. It is also deserving of notice, that during the inundation of 1818, the highest on record, Mr. Hepburn states that the greatest damage done in the Tanjore district, was by the Coleroon rising above its banks and bursting them. Its south bank on that occasion was breached or damaged in ninety places, and the fertile tract of land between it and the Cauvery completely flooded. At the same time the injury caused to the Munnargoody and Chellumbrum Talooks in South Arcot was very extensive, from the Coleroon overflowing and bursting its northern bank. Some modification therefore in the distribution of the water, by which a larger quantity may be thrown into the Cauvery, even during the highest inundations, would, judging from past experience, seem to be rather than an advantage than an evil. I am not therefore disposed to attach so much importance as has been done by others, to the probability of very injurious effects from the annicuts in high floods. On the occurrence of extraordinary inundations, the country has always hitherto sustained more or less damage, and such will no doubt continue to be the case hereafter; for as the annicuts cannot create water when the south western monsoon fails, no more can they diminish the quantity when there is too much. There is reason however to expect, that as the capacity of the rivers is enlarged, and the dimensions of their channels near the sea increased, the damage will neither be so great, nor of so frequent recurrence as it has been hitherto. At the same time I think there are grounds for apprehension, that the change has been introduced too rapidly, and that in the event of any high floods occurring soon, the injury to some parts of the Tanjore province

will be increased by the influence of the upper annicut.

It would have been a more prudent, if not a safer course, to have constructed the annicuts by degrees, instead of raising them to the full height at once. If they had been built only four feet high at first, and afterwards gradually raised, as their effects appeared to justify, and as the rivers adapted themselves for the reception of a progressively increasing supply of water, the risk of danger would have been diminished, and the stability of the works themselves increased; but so great advantages in preventing loss of revenue, of course, would not have been derived from them during the last three scanty seasons, as they appeared to have produced.

A second objection is, that the annicuts have interrupted the water communication by means of the Coleroon between the coast and the Salem and Coimbatore districts, which was of considerable and increasing importance. This objection has been urged with much force to Government by the directors of the Porto Novo Iron Company, in letters dated the 9th of January and 15th of February last, in which they represent that the route by which the ore for the use of their works at Porto Novo had been sent in previous years with facility from the mines, was not available during the last year; and in all probability would never be available again for their purposes; and that in consequence they were under the necessity of sending the ore down to the coast by the Trimulrajan river to Trimulroyapatam, a French settlement within the Karrikal territory, and about 50 miles to the south of Porto Novo, from whence it was transferred by sea in Dhonies to their works. This route they state, is attended with exactly double the expense of the old one, is much more tedious and inconvenient, and accompanied with considerable risk; as had been proved by the loss of a quantity of ore last year, from the Dhoney which was conveying it going to pieces in a squall. They calculate that the additional expense they will be put to yearly, by being prevented from bringing the ore down by the Coleroon will be 22,500 rupees, when there are only two furnaces in blast, and it will be much increased when the works are extended. Merchants and other trading individuals have no doubt sustained similar losses and delays, for all three routes to the sea-coast now open, are longer and more difficult than that by the Coleroon, and two of them have the disadvantage of terminating in the French settlement of Karrikal.

The quantity of Merchandize and grain transported to the coast from the inland districts, by means of the Coleroon, the Cauvery, and their tributary streams, was very considerable, and it will no doubt increase immensely as the resources of the country are developed, and its products and manufactories brought to that degree of perfection of which they are susceptible under European superintendence and enterprize.

Of the several descriptions of communication, that of water by means of rivers and Canals, is perhaps the one which is best adapted to the present state and circumstances of India, for commercial purposes; and though the navigation of the Tanjore rivers must always be of very inferior value to the irrigation of the Delta, still it

is an object intrinsically of very great importance, and its loss or injury would be a very serious and powerful objection to any works, however valuable in other respects, undertaken with the view of extending and improving the cultivation. In the original plan of the upper Annicut the navigation was not overlooked, a lock was constructed to preserve the communication, but it has not been used hitherto, from the difficulty of working it, and from the want of sufficient water to float boats in the Coleroon, except for a few days during the highest freshes, since the Annicut was built.

The want of water, which had not at first been foreseen, rendered it necessary to give up the Coleroon, and look out for some other route by means of the Cauvery and its branches, to restore the navigation. This Lieutenant Bell the acting Civil Engineer had done previously to my arrival in Tanjore, and had selected a line which I had an opportunity of examining in company with that Officer. It proceeds down the Cauvery as far as the Permaul Coil sluices, a distance of some miles, and then runs into the Munnayur a small irrigating river supplied from the Cauvery, which it follows till it approaches the lower Annicut, when it joins the Coleroon a little above that work, by means of a Canal and lock. To complete this line of communication, a lock is required in the Permaul Coil sluice, at the head of the channel connecting the Cauvery and Munny, and a Canal with a lock, to connect the Munny and Coleroon. From the Coleroon the navigation may at some additional expense be completed to Porto Novo, by Khan Sahibs channel.

This appears to me the most convenient and least expensive line that can be adopted, for restoring the inland communication with Porto Novo. It is longer and more tedious than the former route by the Coleroon, but it has the advantages of being less liable to interruption, and will continue open for a considerably longer portion of the year, probably for not less than six months, and is upon the whole I think superior to the Coleroon line. The cost of completing it, and constructing the requisite locks and bridges, I am unable at present to state exactly, but it probably will not exceed 20 or 25,000 Rupees. Lieutenant Bell is preparing detailed plans and estimates of the undertaking, which will be submitted at an early period to Government, through the Revenue Board.

The Annicuts have, it is true, interrupted the navigation of the Coleroon, but they will vastly improve all the other navigable rivers in Tanjore, by the much larger and more regular supply of water which is diverted into them during low freshes; and they will restore the navigation of several others, and among them that of the Cauvery, to the sea, which has, from the want of water, been discontinued for many years.

There remains another objection to be considered, which I have not heard stated, but which appears to me of more weight than any of the preceding. It is the difficulty to be apprehended, in preventing the bed of the Coleroon above the Annicut, from being raised to a level with the top of that work, or nearly so, by the sand and mud which will be arrested by it in its passage

down the river. If this should happen, it is manifest that the bed of the Coleroon being raised at the point of separation several feet higher than that of the Cauvery, a much larger portion of the mud and sand brought down from the mountains by the Agunda Cauvery will be carried into the latter river, than has been the case under any former circumstances, and to a much greater extent than can be discharged by the under sluices or into the sea through the mouth of the river. The object of the Annicut is to raise the water, preserving the bed of the river at its present level; for if the bed is also raised, the remedy, like all former expedients, will be only temporary, with this difference, that the progressive rise in the beds of the Tanjore rivers will be so much accelerated by the increased quantity of sand deposited in them, that it will be soon impracticable to confine them to their channels. Every high fresh will cause them to overflow their banks, flooding the country, and burying the best lands in sand. To prevent this evil, a certain number of under sluices have been constructed in the Annicuts, but these are apparently not of sufficient power, for the bed of the Coleroon at both Annicuts has already been very considerably raised. It is true the sluices have not yet had a fair trial, for they have been seldom opened for any length of time hitherto, partly for want of water, and partly from the fear that the masonry was not sufficiently dry and hard to admit of the sluices being opened with safety; their full power therefore has not yet been shewn, but I am satisfied that it is very unequal to what is required. The way of increasing it will form part of the improvements to be proposed hereafter.

I shall now consider the construction of the Annicuts, their present condition, and the additions and improvements which appear still necessary to render them complete.

Before entering on this part of the subject, it is just to Captain Cotton to observe, that the question is now an entirely different one from what it was when he proposed the works, and that in considering it we possess at the present time the results and experience of three years, which while they have fully established the highly important advantages of the undertaking, have at the same time pointed out certain defects. It was then to be viewed in the light of an experiment to be effected at the least possible expense, the experiment has succeeded, and it is now to be converted into a permanent work with all the improvements which experience may have suggested. The latter is an easy task compared with the former, and involves but little responsibility. No work of the same character and magnitude had previously been executed in this part of India, and in consequence Captain Cotton had much uncertainty and opposition to contend with, and however confident he might have been of the result himself, it was, as he observes, impossible to communicate the same confidence to others. He found it necessary therefore in drawing up his plans, to study economy as much as possible, to use the cheapest materials, and to confine the dimensions of the works to the smallest scale compatible, ac-

ording to his judgment, with stability. When the circumstances under which the Annicuts were constructed are considered, with the total want of experience on the subject, it is not to be wondered that they require additions and improvements, but that they require so few. The failures and disappointments of daily occurrence in Europe notwithstanding all the advantages of extensive experience and great skill and science enjoyed there, prove that there is more uncertainty and risk in such undertakings than is generally supposed. In the execution of the Annicuts there seems to me no lack of judgement and professional knowledge on the part of Captain Cotton and the other Officers who succeeded him, I consider the work highly creditable to all, and that much ingenuity and talent have been displayed in removing difficulties and overcoming unforeseen obstacles, in an undertaking of an entirely new and very delicate character.

The two Annicuts were begun and both completed in the early part of 1836. The upper one crosses the Coleroon about a hundred yards below its separation from the Cauvery, and is 750 yards in length, being divided into three portions of unequal length by two small islands or banks of sand in the bed of the River, as shown in the accompanying sketch (Pl. II.) No 2. The height varies from 5-4 to 7 feet, and is 6 feet thick with a foundation of 3 feet resting on wells six feet in depth. It is protected in rear by a substantial apron 21 feet broad covered with cut stone in chunam. The northern division has an under sluice of six vents near its middle, the centre portion one sluice of four vents, and two of two vents each, and the south part three sluices of two vents. These sluices are for the purpose of allowing the sand to pass through the Annicut in high freshes and prevent its accumulation above the work. This Annicut was completed about the end of the month of April, and was breached in the following June during one of the freshes, about 80 yards of the northern division having been entirely destroyed. Various causes have been assigned for the failure, and it is difficult at this time to ascertain which is the true one. It is supposed by some to have been caused by a tall upright stone which had been fixed in the body of the work where the breach occurred, to indicate the height of the river during the freshes, having got entangled in a quantity of straw and bushes floating down the stream, the large surface exposed by which acted upon by the powerful current, tore it out of the Annicut, and the water thereby getting access into the Masonry, which had not had sufficient time to set, easily destroyed the work. This is not an improbable account, for the portion of the Annicut that was breached, is exposed, as will be seen from the sketch, to the direct and full force of the Iyaur River, which is represented to be liable to sudden and very violent floods, while it has at the same time to resist the deepest and most powerful part of the Coleroon. Others attribute the failure to the Annicut having been undermined by the water being forced through its foundation by the heavy pressure during high freshes and washing from under it the

sand on which it rested. This appears to me the most probable cause of the failure of the lower Annicut, which was breached at the end of the second season, but I think the upper one could scarcely have been destroyed in that manner in the short period of a fortnight or three weeks. Some again think that the Annicuts are not sufficiently strong to resist the rapidity and force of the current, and that they were breached by the pressure of the stream. It is to be wished that they had been constructed much more substantially, and I believe this now to be admitted on all sides even by Captain Cotton himself, though I am far from attributing their being breached to this cause. The water it is evident was forced under the foundations, for it was observed bubbling up in many places through the apron below the Annicuts, whenever there were five or six feet of water standing above them, and if it passed in considerable quantities, which there is reason to believe it did, it would be very liable to wash away the sand by degrees, and leave the work without support.

During the last two years both Annicuts have been materially strengthened by substantial aprons of cut stone in chunam being constructed behind them, to break the overfall of the water, which have been executed in a very efficient manner; since these additions the passage of the water underneath the foundations would seem to be considerably diminished, for it now spouts through the apron in only a few spaces and in small quantities, but I am not inclined to attribute this improvement so much to the aprons as to the large quantity of fine clay and mud which has collected in front of the Annicuts, and prevents the water being forced underneath them.

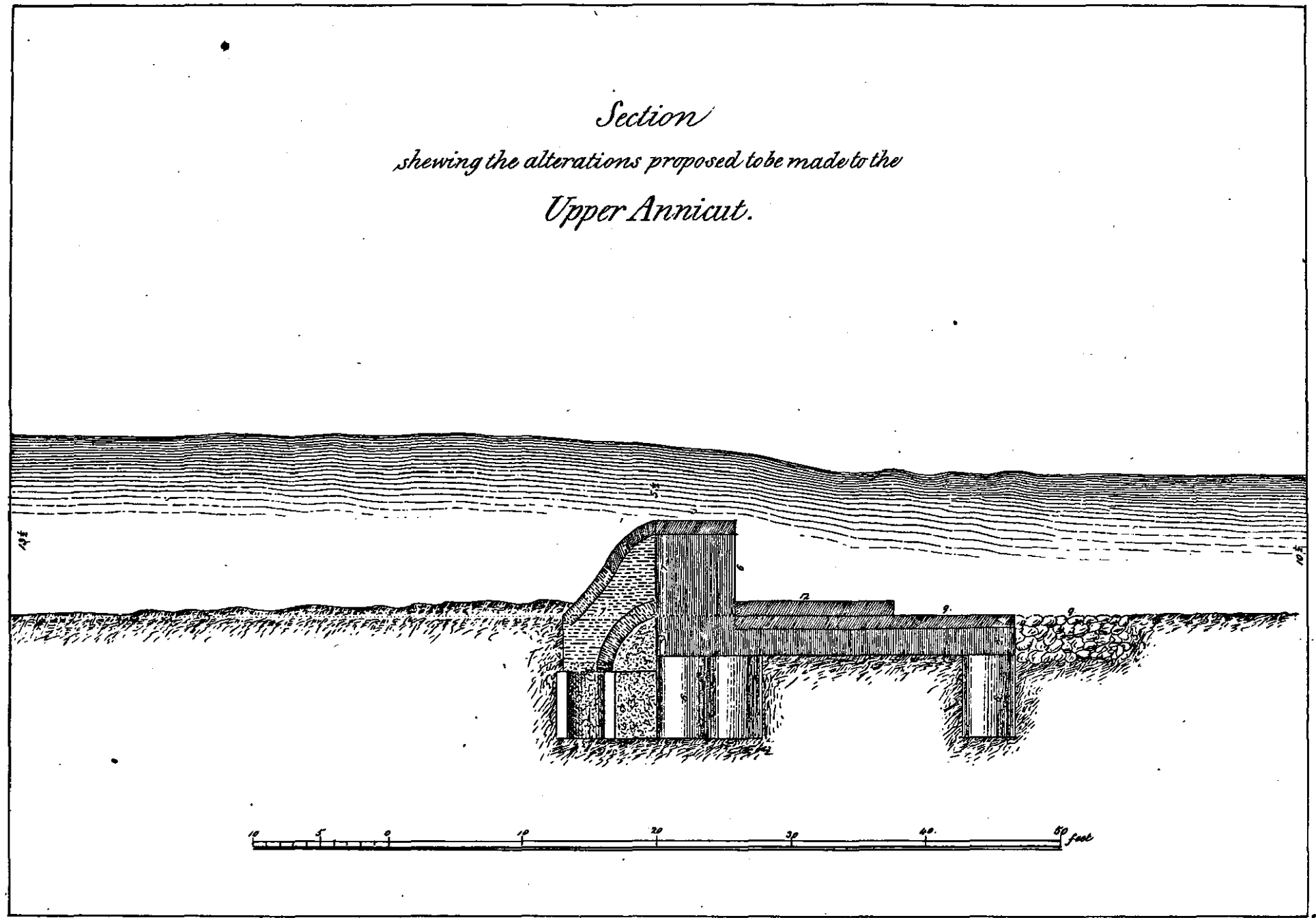
Though these works are now stronger than when first built, I still consider considerable additions to them, and some alterations in their form indispensably necessary to secure them from risk of accidents. That they have withstood the last season is no proof of their being sufficiently strong and durable, for the freshes were low, and they were therefore not exposed to the high floods and rapid currents which they will have hereafter to resist. The first and most important object is to secure the foundations against the risk of being undermined by the water being forced through them. This cannot be efficiently accomplished without considerable expense and labour. In Europe it would be done by a line of sheet piling being driven at six or eight feet in front of the Annicut and parallel with it across the head of the river, the intervening space, after the sand is removed, being filled up with clay worked and pressed firmly into it, technically termed puddling. This forms a barrier impermeable by water, and effectually protects the foundations. In this country a row of wells may be substituted for the sheet piling, but the interior of the wells and the interstices between them, must be carefully puddled to a sufficient depth, in order to obtain the impermeable screen, for it is the puddled clay which obstructs the passage of the water. Above the wells I would recommend an addition in front of the Annicut of the dimensions and form coloured yellow in the sketch, to

strengthen the work and facilitate the passage of the river over it in high floods. The front of the Annicut is made of a curved shape, as that form diminishes the pressure of the current upon it, accelerates the passage of the water over the Annicut, and thereby decreases the rise of the river in inundations, and by the change produced in the direction of the current, prevents in some degree the great collection of mud which takes place before perpendicular walls.

In considering in a preceding part of this paper the objections which have been urged against the Annicuts, I have adverted to the difficulty of preventing the gradual deposition above it of the mud and sand brought down by the river in freshes, and the ruinous consequences which would follow any considerable rise in the bed of the Coleroon at the point of separation from its sister stream.

The evil was not overlooked by Captain Cotton, who provided for its prevention, seven sluices as already described, distributed along the Annicut, having in all twenty-two vents, each about 2 feet in width and 2½ in height. But these are evidently inadequate to the purpose, and are far from being sufficiently powerful to regulate the bed of a river 750 yards wide, having a rapid stream 12 or 14 feet deep in high floods. On such a volume of water, bringing down a large quantity of earthy matter from the mountains, twenty-two small openings can scarcely be expected to exercise sufficient influence. The nature of the deposits also increase greatly the difficulty of their removal. They do not consist entirely of sand or gravel, but contain a considerable proportion of fine clay and soil which, as it dries, hardens and forms with the sand a mass almost impervious to water, and requiring the influence of an extensive and rapid stream to displace it. The accumulations above both Annicuts are already very considerable, and in some parts not far below the top of the works. It is true the sluices have not yet been brought much into operation, from causes already explained, and until they have had a fair trial for one season at least, it is impossible to say with certainty what their effect will be. But I am quite satisfied that it will not be sufficient to restore the bed of the river to its former state. To accomplish that object and prevent future accumulations, sluices or openings of much larger dimensions and on a different construction are necessary. They must be sufficiently capacious to allow large bodies of water to pass freely through the works with a rapid current, so as to exercise during the freshes a powerful influence on the stream and bed of the River, to a considerable distance in all directions. Nothing less than complete cuts or openings in the Annicuts from 6 to 10 or 12 feet in width, will in my opinion be found sufficiently influential to produce the desired effect. The number of such openings may be regulated with more accuracy than it can be at present, after the experience of the approaching freshes; which, from the heavy rains that have fallen lately on the western coast may be expected to prove abundant. Three at least I am inclined to believe will be required in the Upper Annicut, and two in

Section
shewing the alterations proposed to be made to the
Upper Annicut.



of the
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the lower one in addition to the present sluices, and I think it will be found advisable to continue the Upper Annicut across the South sand bank, as has already been proposed both by Colonel Monteith and Captain Cotton, establishing there the largest sluice that can be managed with safety. The Acting Civil Engineer, Lieutenant Bell, who accompanied me in the inspection of the Annicuts, is now on the spot, prepared to make the required observations, and to keep the sluices open as long as practicable, attentively watching their effects, and he is fully qualified in every respect to perform the duty satisfactorily. His observations, if the freshes prove high, will be valuable in fixing the number and position of the sluices.

The best mode of managing sluices of the required size, and the description of shutters for opening and shutting them, as the River rises and falls, require to be well considered and determined by experiment. There is sufficient time for that purpose, as nothing can be done to the Annicuts before next January; and I am now in correspondence with the Officers of the Corps whose attention has been turned to such questions, and with Mr. Brunton the Engineer of the Porto Novo Iron and Steel Company, who possesses considerable practical knowledge on subjects of that nature.

The means already adverted to, which have been provided for discharging part of the water from the Cauvery back into the Coleroon in high floods, and the proposed large sluices in the Upper Annicut, will no doubt operate powerfully in relieving the former River when more water is thrown into it than it can safely contain, but I am apprehensive that these means may not be found sufficient during the extraordinary floods that occasionally occur, and I think it extremely desirable that another Calingulah, with large undersluices in it, should be constructed in the bank of the Cauvery to the Westward of Trichinopoly, at some convenient spot where the difference of level between the two Rivers is sufficient to admit of the undersluices being opened with effect. Such a work will have a most beneficial influence in keeping the upper part of the Cauvery free from sand, as well as in relieving the River from some of its water in great inundations, for it is near the head of the River that the accumulations first commence, and the sand is afterwards carried lower down the bed; and from what has been said it will appear, that according to my opinion, very extensive additions are still required to render the Annicuts perfect, and to give them that strength and stability which are requisite to secure them against the risk of future accidents. The nature and principles of these additions I have described, and the reasons which induce me to recommend them, but I am not prepared at present to give an accurate estimate of their expense, and I should wish to have the advantage of another season's experience, which, as it happens, can be obtained without injury or loss of time, before fixing the extent of the improvements. It is desirable to proceed with caution, both to guard against accidents in a case where accidents might prove so disastrous, and to avoid the necessity of pulling down one

year, what has been built during the preceding. It is easy to strengthen the works, but it is not so easy to determine with the little information that is now possessed, the number, size, and position of the Sluices that are requisite, and sluices cannot afterwards be added without pulling down large portions of the work, and weakening the whole structure.

The course which I would recommend to be followed is, to observe attentively the operation and effects of the Annicuts during the approaching season, keeping the sluices in action as often and as long as circumstances will permit, and commence to strengthen and improve them in January, on the principles suggested in this paper. Before that time I hope their talented and enterprising Projector will have returned in health to resume their superintendence and treatment, and the duty cannot be placed in abler or more zealous hands. The whole of the additions which I consider desirable need not be completed in one season, but may be executed progressively in the course of two or three years.

The cost of the Annicuts to the present time is as follows:

<i>Upper Annicut.</i>		
Construction in 1836.....	Rupees	85,389 8 0
Repairing the breach &c. in 1837. "	"	25,473 5 0
Repairs and improvements in 1838. "	"	10,475 10 0
do. do. do. 1839.		
	estimated at Rupees	18,785 0 0
<hr/>		
Total Rupees..		140,123 7 0
Repairs to the Head of Seringham during the same period.....		3,871 12 0
Excavating new head to the Iyen Voikal and constructing 3 bridges, a head sluice &c., in the Trichinopoly district		15,599 4 0
<hr/>		
Total of Upper Annicut..		159,594 7 9
<i>Lower Annicut.</i>		
Construction of Annicut in 1836.....	Rs.	99,493 0 0
North Rajah Voikal.....		20,850 0 0
Lock and Surplus Sluice.....		8,777 0 0
Improvements to Cawn Saib's channel..		9,352 0 0
In 1837. Completing Rajah Voikal.....		2,188 0 0
Raising and strengthening Annicut....		3,598 0 0
In 1838 Repairing the Breach in Annicut		25,763 0 0
In 1839 Strengthening and improving Annicut estimated at.....		5,077 3 0
Excavating South Rajah Voikal &c., in Tanjore District, estimated at.....		19,951 1 0
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Total of Lower Annicut..		199,979 4 0
<hr/>		
Total of both Annicuts..		354,573 11 0

The expense of the additions which I have proposed will probably exceed a lac of Rupees, raising the cost of the works with the new channels and other improvements connected with them to perhaps five lacs of Rupees. This is certainly a large outlay, but if any con-

confidence is to be placed in the judgment of the Collectors and the people of the districts for the benefit of which the works were constructed, and in the accuracy of the statements given by them, it must be considered to be fully justified by the extensive benefits which have already accrued, and by the still greater advantages which are expected hereafter.

In determining the expediency, or otherwise, of the Annicuts, it is not fair to consider the extended cultivation and increased revenue only, which they are expected to produce. This though large, and apparently sufficient of itself to warrant the expenditure, is by no means the only, nor indeed the chief argument in their favor. Their primary object was to improve and render more certain the irrigation of the land already cultivated, the crops of which generally suffered seriously, and frequently perished to a considerable extent, from the insufficient and decreasing supply of water, in consequence of which it has become necessary to grant almost every year large remissions to the cultivators. To arrest this evil, and furnish to the people the means of bringing the whole of their crops to maturity in ordinary seasons, is an object itself sufficiently important to warrant even a far greater disbursement, in a case where an annual Revenue of 40 Lacs of rupees is at stake. They are unquestionably the works of greatest importance which have been undertaken for the encouragement of Agriculture in this part of India, since the Carnatic came under British rule, and are I trust the first step towards the gradual introduction of a better system of irrigation throughout the Country—to Captain Cotton belongs the entire merit of this first step, and to him the highest praise is due.—Lands which are cultivated from Rivers are generally the least liable to suffer from drought, for even when the Monsoon rains fail, there is always some water in Rivers supplied by the drainage of the Country and springs, and there are many Rivers well suited to the purpose, the waters of which now run waste to the sea.

If the view which I have taken of the subject be a correct one, the Annicuts would seem not only to be expedient, but if not indispensably necessary at the time they were constructed, would soon have become so, to preserve the prosperity of the most fertile Province under this Presidency, and prevent the deterioration of its produce to an extent which would soon have been severely felt both by the Government and the people. The catastrophe foretold 35 years ago by Colonel Caldwell, our most experienced and judicious Civil Engineer was becoming yearly more certain; and tho' no doubt distant, the evils resulting from the operations of its causes were constantly increasing, and becoming more injurious and more difficult to remedy.

The practical question however I believe now is, not whether the construction of the Annicuts was expedient, but what is the most efficient and economical mode of improving and rendering them permanent, so as to draw from them all the benefits they are capable of yielding; for as they are already constructed, no one would I believe wish them to be destroyed.

The nature of the additions which, after a patient and careful investigation of the subject, appear to me best calculated to answer that purpose, I have endeavoured to explain; and if they shall appear to his Lordship in Council to be necessary, and deduced from correct principles, the requisite funds to carry them into effect, will, I am persuaded, not be denied, even if the expence were far greater than it is likely to prove. The expenditure ought not to be viewed in the light of money drawn from the exchequer, but as part of the increased revenue which would not have existed without the annicuts, appropriated to the purpose of improving them and rendering their influence more extended and more beneficial to the state and to the people.

Before concluding this report, there is a subject to which, though not immediately connected with the Annicuts, I would beseech the particular attention of the Collectors of Tanjore and South Arcot, and the Civil Engineer's department of the division. It is the great importance of preventing the formation of islands in the Coleroon, which has been too much neglected of late years. The Banks of the river are planted with durbah grass to protect them from the effects of the current, the seeds of which are blown into the bed of the river, and young plants are seen springing up in all directions. Every plant becomes a nucleus around which sand and soil collect to obstruct and impede the free passage of the stream, and prevent its exercising that influence on the bed which is requisite to preserve its proper level. In time, if the accumulation is allowed to proceed, a small island is formed, which diminishes the capacity of the channel, and forces the current on the banks, which are thereby undermined and often destroyed. To this cause I attribute the frequency of breaches in the Coleroon Banks, and the extensive destruction occasioned in inundations. The growth of grass in the bed of the river has been much promoted since the establishment of the annicuts at the places where it will prove most injurious, viz. in the vicinity of those works, by the fine soil deposited there, in which the plants soon take root and spread rapidly.—

The removal of this evil is of very great importance, and ought to be immediately effected, whatever the cost may be. Every year, as soon as the bed of the river becomes dry, it ought to be inspected carefully, and all the grass rooted out and destroyed, and channels cut through accumulations of sand, in order that the freshes of the following year may remove them. At first the expense and labor will be very considerable, but if once done effectually, and an Officer should be appointed to see it done, the cost will be trifling afterwards.

One of the questions referred for report in the minutes of consultation, is the necessity and expediency of certain new works proposed by the principal Collector and Civil Engineer of Tanjore, and submitted for the sanction of Government by the Board of Revenue on the 29th of last November, the cost of which is estimated at Rupees 46,015-12-4.

These works are intended to regulate the distribution of the water after it enters the province, and to correct and modify certain changes which have taken place of late years in the relative conditions of the principal rivers, chiefly through the agency of the upper Annicut and under sluices, in the banks of the Cauvery. The first and most expensive of these works is a low dam proposed to be constructed across the Cauvery immediately below the head of the Vennaur. It has already been stated, when describing the changes which the Cauvery has undergone, that formerly the Vennaur abstracted from that river much more than its just proportion of water; but that recently, from changes which have been taking place in the relative conditions of the two streams, the Vennaur does not receive its proper share. It appears from inquiries made on the spot, that the lands irrigated by the Cauvery had a fair supply of water last season, while a loss of nearly 20,000 Rupees in the Revenue of the land under the Vennaur was anticipated, from its not containing water enough to bring all the crops to maturity. This is a convincing proof that the distribution of the water is defective, and there is reason to expect that the irregularity will increase, unless rectified by artificial means. The work, proposed for this purpose is a low masonry dam, on a level in the middle with the lowest part of the bed of the Cauvery, and rising slowly by stages towards the banks, thereby contracting the channel sufficiently to turn the requisite quantity of water into the Vennaur, without obstructing the navigation, or preventing the sand from being carried down its channel and discharged by the under sluices into the Coleroon. I am not aware of any better remedy for the evil, but in the execution of the work it will be necessary to proceed with great care, leaving it unfinished near the banks the first year, and raising it afterwards gradually every season as circumstances may require, till the distribution of the water is accurately regulated. Unless this course be followed, there will be great risk of throwing away money, by contracting the channel of the Cauvery too much at first, and also of flooding and destroying its banks. It is probable that the disbursement will be somewhat below the estimate, and it will be distributed over several years.

The next item is a similar work, for the same purpose, at the head of the Codomoorty, which, like the Vennaur, does not now receive a sufficient supply of water. The loss of revenue last season from the lands irrigated by one of the branches of this stream, was estimated at nearly 3,000 Rupees, and there is reason to apprehend, as in the preceding case, that the loss will increase every year, unless means are adopted for giving the river a better supply of water. The work proposed here is of loose stones to be obtained from a ruined Fort in the vicinity.

If the rough stone dam is found insufficient to produce the desired effect, it may be strengthened at

any future period by a masonry wall in front, in which case the loose stone work now intended to be constructed will become the rear apron of the dam.

The 3rd and 4th items are dams proposed to be constructed across the Tremulragen, to raise its waters sufficiently to fill two important channels which have their sources in that river. The Tremulragen flows through a low tract of country, and is one of the principal drains of the surplus water of the Delta, and has from these two conditions a tendency to keep its bed too low to irrigate the higher lands in its vicinity. It appears from the statements of the Principal Collector and Civil Engineer, that the crops in many places are not now sufficiently watered in low freshes, and frequently perish in consequence to a considerable extent, and that the works are much required to remedy the defect. In constructing them, and indeed in the construction of all annicuts across navigable streams, either no upright dam stones ought to be placed in them, or a sufficient space ought to be left unobstructed in the middle of the stream, to allow boats to pass. This is easily arranged in the present case.

The fifth dam is not now required, as the Arselaur no longer derives its supply from the Codomoorty, but from the Cauvery; with this exception all the other works in the estimate appear to me to be requisite, and should be sanctioned; but as already observed, the expenditure will be distributed among the next three or four years.

The points to which I would beg respectfully to solicit the early attention of Government are the following.

1st. Sanction for the construction, progressively, of the four annicuts across the Cauvery and Tremulragen, recommended by the Board of Revenue on the 29th of last November.

2ndly. Instructions for the bed of the Coleroon being completely cleared, immediately after the approaching monsoon, of the Durbah Grass which has been allowed to grow in it, and obstructs its current.

3rdly. Authority to make some experiments here and at Porto Novo, for the purpose of determining the description of sluice best suited to the annicuts, and most likely to prevent deposits of mud and sand above them. The requisite experiments here may, with the permission of His Lordship in Council, be made without any expense in the Arsenal, and those at Porto Novo will not I hope cost above 150 or 200 Rupees.

I have the honor to be,

Sir,

Your most obedient Servant,

(Signed) D. SIM, Lieut. Col.

Engineers,

Stip. Member Mily. Board.

FORT S. GEORGE, }
16th July 1839. }

**NOTICES ON A WINDMILL PUMP CONSTRUCTED AT MASULIPATAM
IN 1839, FOR DRAINAGE PURPOSES. BY CAPTAIN BUCKLE
CIVIL ENGINEER 2ND DIVISION.**

A small canal being under execution in the year 1839, to give boats conveying grain, wood, &c., a passage from the backwater at Masulipatam across an intervening swamp to the Pettah, and some difficulty being experienced in getting rid of the water from the excavation, and more difficulty of the kind being expected, it was judged expedient by the Civil Engineer, to endeavour to establish a draining pump worked by a windmill, to assist in carrying on the work.

The localities at Masulipatam appeared eminently calculated to favour the design, as the height which it would be necessary to raise the water would never exceed 10 feet, and the open position of the marshes exposes them to every current of wind.

The first attempt of the kind could be no more than an experiment, but it was hoped, that if successful, an extension of the application of windmills of a cheap and simple construction, might be carried out to raising water from the Kistna for fertilizing the land on its banks, or to drawing water from wells for garden cultivation; perhaps also to aid in the clearing operations of the Fort ditch at Masulipatam.

Originally it was intended to put up the machine where the entrance gate to the canal was building, as the springs were troublesome when laying the foundation, but the windmill could not be got out of hand in time for this: it may be mentioned here, that the canal is a simple but capacious cut, about 2000 yards long from the entrance gate at one end to the basin at the other, and this 2000 yards may be considered in the light of one long lock, as the basin has also a gate; the water is entirely supplied by the sea, through the backwater or sound at the entrance side; the object of the public work being to bring direct to the pettah the imports of Masulipatam, whether from the sea or from the Kistna, whereas at present they are obliged to be all landed at the Fort, and after being warehoused there, to be again conveyed two miles by a troublesome land carriage to the pettah, which is the point of sale and consumption; the pettah of Masulipatam being perhaps the largest town between Madras and Calcutta, the Fort is a place of no consideration.

The great obstacle to the Civil Engineer's attempting to put up a windmill, lay in the entire absence of any workmen or artificers to comprehend and execute his instructions, while his general duties would not permit him ever to make a continuous stay of any duration at Masulipatam, and considerations of economy opposed his undertaking the work, unless under close superintendence; these difficulties however were overcome through the friendship of Mr. Rohde of the Civil Service residing at the station, a gentleman of mechanical ac-

quirements, and who was much in the habit of directing and instructing native artificers in the execution of superior and novel descriptions of work; and it was on Mr. Rohde's suggestions that the windmill and pump were eventually built on the accompanying plan, while through his private resources also, much assistance was derived in accomplishing many of the details of the work. Nearly four months was consumed in getting up this windmill, nor will this statement surprise any who have had experience in directing a new undertaking by means of native agency; where the minutest portions have to be explained to them, and where, through misconception, or want of skill, failures will constantly occur.

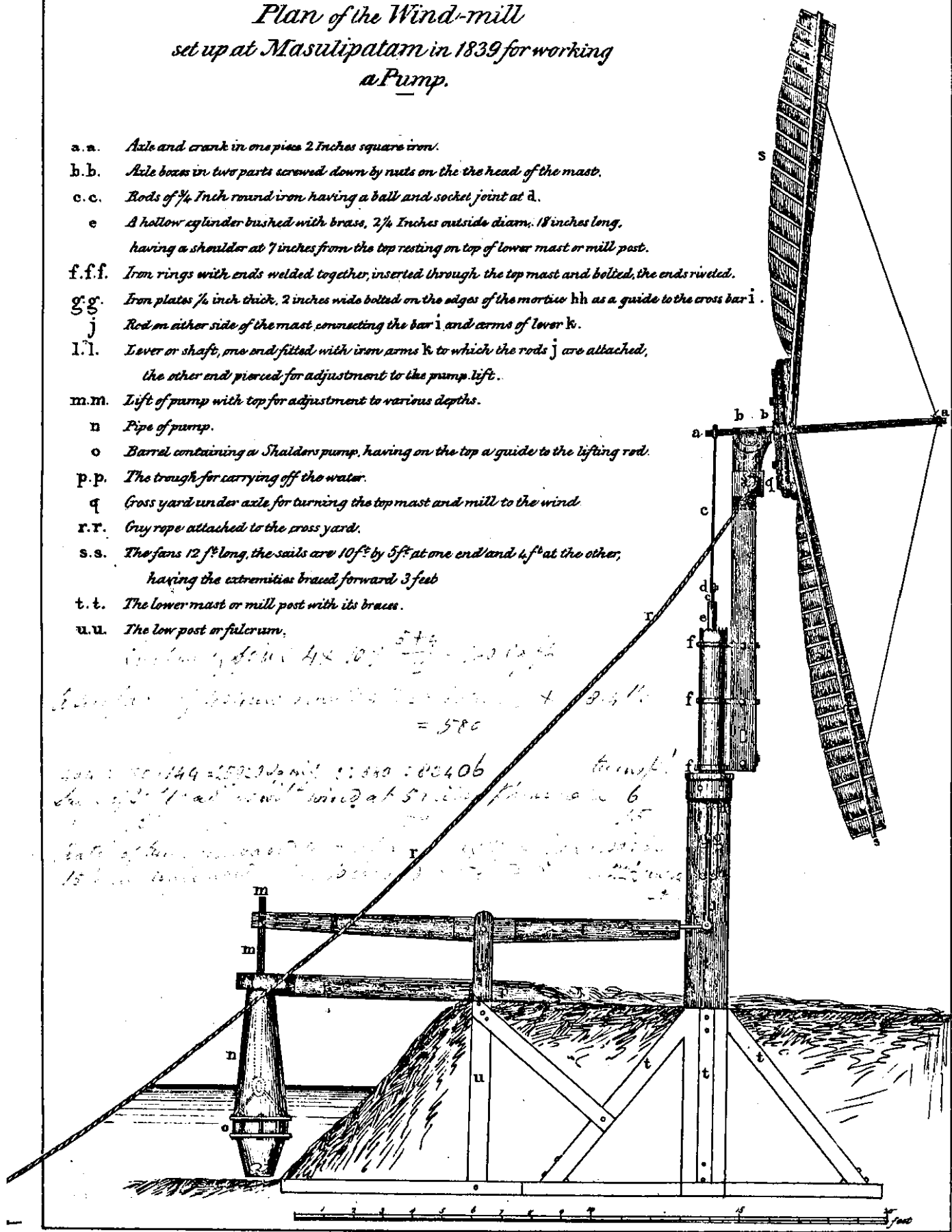
The construction of the windmill is as follows; a lower mast about 18 feet long is firmly fixed by spars and braces, to a cross piece buried 6 feet deep in the ground; round the head of this mast traverses a top-mast, on which rests the axle of the fans; the latter are 24 feet in diameter, from tip to tip, but each sail is 10 feet long only, the 2 feet adjoining the axle being left clear; the breadth of the outer extremities of the sails is 5 feet, that of the inner 4 feet, the driving side is triangular, one foot broad at the outer end, tapering away to nothing towards the axle; this side was boarded over; the broad or rectangular sides of the sails was 10 feet by 4 feet, composed of teak battens crossed by slips of bamboos, and covered with Europe canvas. In inserting the battens an error occurred, which reversed the proper weathering of the sails, making the angle with the plane of motion greater at the end than at the centre. The method employed of securing the whips to the axle, was by first attaching to the axle a very strong cross piece of tooma wood, having iron plates in front and rear, through which the axle, there 2 inches square, passed; to this cross piece the whips were bolted with screws and nuts, wedges being first inserted between the whips and cross piece, in order to throw forward the arms.

The axle was formed of a gun carriage axle tapered off to the outer end, where a four eyed nut was screwed on, for bracing forward the sails; the other end was formed into a crank of 8½ inches radius, very substantially made; the axle was elevated 7°

Attached to the crank by a loop was the first suspending rod, which at its opposite end is secured to the second rod by a ball and socket joint; the second rod passes down a bore through the lower mast, and at the foot of the second rod is a cross bar fastened, which with the rod slides up and down by the motion of the crank, the cross bar projecting through the sides of the mast in grooves cut for the purpose. From the ends of the cross

*Plan of the Wind-mill
set up at Masulipatam in 1839 for working
a Pump.*

- a.a. *Axle and crank in one piece 2 Inches square iron.*
- b.b. *Axle brass in two parts screwed down by nuts on the the head of the mast.*
- c.c. *Rods of 3/4 Inch round iron having a ball and socket joint at d.*
- e *A hollow cylinder bushed with brass, 2 1/4 Inches outside diam., 18 inches long,
having a shoulder at 7 inches from the top resting on top of lower mast or mill post.*
- f.f.f. *Iron rings with ends welded together, inserted through the top mast and bolted, the ends riveted.*
- g.g. *Iron plates 3/4 inch thick, 2 inches wide bolted on the edges of the mortise hh as a guide to the cross bar i.*
- j *Rod on either side of the mast connecting the bar i and arms of lever k.*
- l.l. *Lever or shaft, one end fitted with iron arms k to which the rods j are attached,
the other end pierced for adjustment to the pump lift.*
- m.m. *Lift of pump with top for adjustment to various depths.*
- n *Pipe of pump.*
- o *Barrel containing a Shalders pump, having on the top a guide to the lifting rod.*
- p.p. *The trough for carrying off the water.*
- q *Gross yard under axle for turning the top mast and mill to the wind*
- r.r. *Guy rope attached to the cross yard.*
- s.s. *The fans 12 ft long, the sails are 10 ft by 5 ft at one end and 4 ft at the other,
having the extremities braced forward 3 feet*
- t.t. *The lower mast or mill post with its braces.*
- u.u. *The low post or fulcrum.*



*Velocity of wind 4 x 10 = 40 ft per sec
Area of sails = 12 x 10 = 120 sq ft
= 580
... ..
... ..
... ..
... ..
... ..*

bar, rods fall to the boom iron, which projecting from the pump lever embraces the mast, and at the opposite end of the lever is the pump lift. The above description, without entering into smith and carpentry details will give an intelligible outline of the machine.

The pump was on the Schalder principle, the diameter of the upper circle of the conic frustrum was 8 inches, that of the lower was 13 inches, the height $8\frac{1}{2}$ inches, the contents therefore 750 cubic inches. Butterfly valves were made use of, both for the fixed and moveable parts of the pump:—the manner in which the leather was secured to the rings was, by making the latter, which were of brass, double, and the leather was held between them by screws and nuts securing the rings together. The pump lift was of iron, the upper end being pierced for adjustment with the end of the lever, which was pierced also; the lower end of the lift was serewed to a double or mitre stirrup, that was secured to the top of the pump.

When the whole was set up for trial, it was found to work extremely steadily, without obstruction or jarring of any kind; at first the windmill was tried without the pump, weights to the arms and lever only being attached. It was also found perfectly easy to bring the sails to the wind always by means of the guy ropes at the ends of a cross yard fixed to the topmast, a little below

the axle, which is also serviceable in enabling workmen to reach the bed of the axle, for applying oil, or for other purposes.

In consequence of a leak in the pipe attached to the pump, no accurate results were obtained of the exact discharge by the machine, nor of the height to which it was capable of raising the water, but the experiment was so far satisfactory, that the pump worked with great ease, and raised the water several feet; the number of revolutions per minute in a fresh sea breeze was thirty, when blowing strong, forty revolutions were made, at a time when the pump was not working; but the work of this pump it was clear would have retarded the mill very little. It did not appear desirable that the revolutions should exceed thirty per minute, this number of strokes being quite as rapid as the pump ought to make; it could not be ascertained whether the cap filled at each stroke, if it did, the discharge by the pump might certainly be rated at 15 cubic feet a minute, or 33 cubic yards per hour; The work of 2 pairs of bullocks in raising water 27 feet, is said to be about 50 cubic yards per diem.

The cost of executing this windmill was altogether about 300 Rupees, but a second of the same description might, it is supposed, be constructed at the same station for about 200 Rupees; for permanent purposes however, a different kind of pump would be called for.

NOTICE REGARDING THE MINERAL FUSIBLE CEMENT BY CAPTAIN J. T. SMITH.

The following is a brief account of a cement, which ought to be known to every practical Engineer in this country, from the valuable service it is calculated to afford in those circumstances wherein ordinary resources fail, and which so frequently occur, even in common undertakings. Of the varied and important uses to which this substance may be applied, a judgment will be best formed by a perusal of the subjoined account of the experiments made with it; and these are of a two-fold value in this country, where we are cut off from those other auxiliaries, which in Europe might be called in to supply its place.

This composition is sold in England under the name of "Mineral fusible cement" and is stated to have been for some years in use on the Continent, particularly in Sweden and Denmark, where it is employed by the Government for the Public works. The nature of the composition and the mode of the manufacture is kept secret, but a small specimen of it having fallen into my possession, I was enabled to discover it by means of a chemical analysis, which distinctly showed it to be compounded of about two parts by weight of chalk powder, to one of resin. These proportions having been therefore melted together, an imitation was effected, which in every respect corresponded with, and is similar to the part of the original specimen remaining in my possession, and larger quantities have since been prepared and made use of with success. A mere inspection of a joint formed by this material is quite sufficient to satisfy the spectator of its title to the great merit which the experiments show to be due to it, and as these will form the best introduction to the account of the mode of manufacture and application, I shall here at once insert them.

The experiments are stated to have been made by direction of the Board of Ordnance, and were conducted by an Engineer Officer in presence of several scientific gentlemen. They are as follows:—

"*First*—A case of wood was united with cement only, lined with it, and in less than half an hour filled with water; it was perfectly tight"

"*Second*—A large tank was built one half brick in thickness, with the cement, rendered or coated there-with inside, and immediately filled with water; it was perfectly tight, and so continued."

"*Third*—To show its adhesive qualities. Two plates of iron four inches square, with a hook in each, were united with the cement by a seam or joint of one eighth of an inch; on being suspended it bore a weight of 80 lb. before they separated."

"*Fourth*. The flat-side of a brick was united to an upright board lengthwise by the cement, another to that, and so on, until the twentieth brick was attached, when one of the bricks split, but none of the joints

"gave way. This experiment was repeated frequently, but in every instance the cement proved stronger than the bricks—Each brick weighed 5lbs."

"*Fifth*. A piece of iron with a hook at the upper end and shank three inches long, was inserted in a hole in a block of granite, and there fixed with this cement, instead of lead; the block of granite was attached by the cement to another of the same size, weighing together about 300lbs. The two were suspended by the hook, and weights to the extent of 300lbs were placed upon the stone, but nothing gave way; the iron was not dove-tailed at the bottom, and this weight of upwards of 600lbs was supported entirely by the adhesion of the cement to the iron plug and the granite."

"Some further experiments were made at the Tower under the direction of Mr. Wright the Clerk of the works, when one bushel of dry sand was found to weigh 130lbs, and one bushel of the "Mineral fusible cement" in a solid body 114lbs. The experiments were made with a composition of 228lbs of sand and 114lbs of cement, mixed together by melting."

First. Two bricks were united by a joint of one fourth of an inch with this gauged cement, and suspended by a chain which bore a weight of 1344lbs, when one of the bricks split, but the joint with about one fourth of an inch of the brick attached to it remained perfect.

Second. Bricks were united with the gauged cement in the same manner as described in experiment No. 4 of the last series, and extended to eighteen joints, when the second brick broke.

"The cement being thus properly gauged will unite bricks so firmly, that when coated with a mixture of three fourths sand and one fourth cement, they will form a solid body superior in strength and quality to sandstone, and applicable to similar purposes—The following are the results of some further public experiments made at Liverpool, by Mr. Shepherd Surveyor."

"*First*. A brick was united to a block of granite with the cement, which set immediately, and when forcibly separated, a portion of the brick adhered to the cement, the joint remaining perfect."

"*Second*. A wooden tank of inch deal was put together with the cement (*no nails being used*) and the inside coated with it; being completed, it set firmly in a few minutes, was immediately filled with water, and found perfectly tight."

"*Third*. A cistern or tank consisting of a bottom formed of bricks, a side and end of inch deal, one side of plate iron, and the other end of fire tiles, was united with the cement, and the inside rendered or coated

" therewith was instantly filled with water, and proved perfectly tight."

Fourth. Two blocks of granite weighing 1 cwt were joined together, and the shank of an iron hook let in only one and a half inch in depth, and run with the fused cement, and after standing about two hours and a half they were suspended by the hook, and 10 cwt attached to the stones by ropes and chains, without the plug being in the least degree affected; it was afterwards forcibly and with great difficulty removed, and being heated was replaced in its former situation only one inch deep, but not re-run, and an hour being allowed for its setting, 9½ cwt were suspended to it for a considerable period, but on increasing the weight to 10 cwt it was drawn.

Fifth. Several bricks were attached to one another flatwise and lengthwise, with the cement gauged with twice its weight of sand, the first joint being between brick and wood, which carried the weight and leverage of 17 bricks, each weighing 8lbs, but on attaching another, the joint next the wood divided, tearing away a portion of the board. The bricks were ultimately divided by forcibly throwing them on the pavement, but the joints remained sound.

Sixth. Two bricks secured in bevilled iron frames were united with the cement, and at the expiration of an hour were suspended, and 11 cwt attached to the lower one, when the bricks divided in different directions, and flushed every way, but the joints continued sound and perfect."

Seventh. Seven bricks were united to each other end-wise, and attached to and projected from a brick wall in a horizontal direction, when the second brick broke, and was reunited, when the face of the wall ultimately gave way, but the joints remained perfect."

Eighth. Fire tiles of one inch in thickness were united to the stone quoin of a wall, and considerable weights placed at the extremity and borne without the joints breaking, but the face of the stone at last gave way, adhering firmly to the tiles."

For the preparation of this cement the following precautions ought to be attended to. The requisite quantity of the two ingredients having been procured, they are each to be reduced separately to an impalpable powder, by the usual methods of grinding and sifting, and then separately heated, the chalk in any convenient vessel, and the resin in a similar vessel placed in a sand bath. Lest this last mentioned part of the process should seem to indicate the necessity of providing any unusually strange or expensive apparatus for its accomplishment, I ought to explain, that the operation and use of the sand-bath is merely the interposition of some non-conducting material between the substance to be heated and the fire, to prevent the heat being communicated by sudden additions, and that sand is used as the most convenient and cheapest procurable; the necessities of the case merely demand that a sufficient quantity of it be interposed between the vessel containing the article to be heated, and the fire, to obtain the effect desired.—In experiments on the small scale, where the meltings were confined to the contents

of the small earthen chatties which hold about a gallon, I have prepared the sand bath by putting another flat open chatty over the fire, and pouring into it sufficient sand to cover its bottom to the depth of 2 or 3 inches; the vessel containing the resin was placed upon this, and the whole upon the fire. It must be recollected however, that the use of a sand bath of some kind is *essential*, and any attempt to dispense with the precaution is pretty sure to occasion disappointment, or imperfect results, owing to the liability of the resin to decomposition. The use of the sand bath, it is true, has also a tendency to occasion doubts in the operator's mind, owing to the very great delay it occasions in the melting; but this objection, though it is felt forcibly in regard to a single trial, is of less consequence when the operations are extensive, as it is only in the first heating of the sand bath that the delay occurs, which once done, the further operations are altogether unimpeded. It is important to be prepared for this, and to recollect that time must be allowed for the resin to become perfectly liquid, before the heated chalk be applied to it.

To produce the utmost possible adhesion, the surfaces to be united by this cement ought to be also warmed before its application, and the greater the heat which can be applied to them without danger, (short of that of the melted cement), the better. In using it myself I have done all that was necessary in this way, by strewing a few lighted charcoal cinders over the parts, and blowing them occasionally.

I have not yet succeeded in the small way to make a satisfactory use of this article in its gauged state—when greater cheapness is desired, I have found that the common country dammer may be used as a substitute for the resin, with apparently a similar effect, but the preparation is rather more difficult, owing to smaller fusibility of the dammer. But even prepared in the manner above described, this material is by no means costly, and for the particular purposes for which it is required the expence of its preparation will never be any obstacle.

It would be difficult to particularise the various uses in which its value will be most appreciated, but there are few large undertakings in which something of the kind is not desired, for some part or other. The following occur to me at present. The formation and lining of tanks and cisterns—the lining of damp rooms or cellars—the formation of gutters on the roofs of houses, the building of turrets, minarets, projecting cornices, pendants &c. where the firmest union of parts is required—fixing iron railings, stone copings, and generally to all purposes, wherein the very desirable properties of powerful adhesion and resistance to moisture are required, or the union of such heterogeneous substances as wood, iron, stone, brick, tiles, slate, &c. any of which bodies, indiscriminately, may be forcibly bound to each other by the aid of this invaluable agent. From the experiment quoted above (No. 3, 1st series) it will be observed, that the adhesion of this composition in its pure state averages about 50 lbs. per square inch, which may be considered as equal to about 15 times that of the cohesion, on first setting, of the best chunam as ordinarily made in Madras.

GLOSSARY OF INDIAN TERMS MADE USE OF IN THIS VOLUME.*

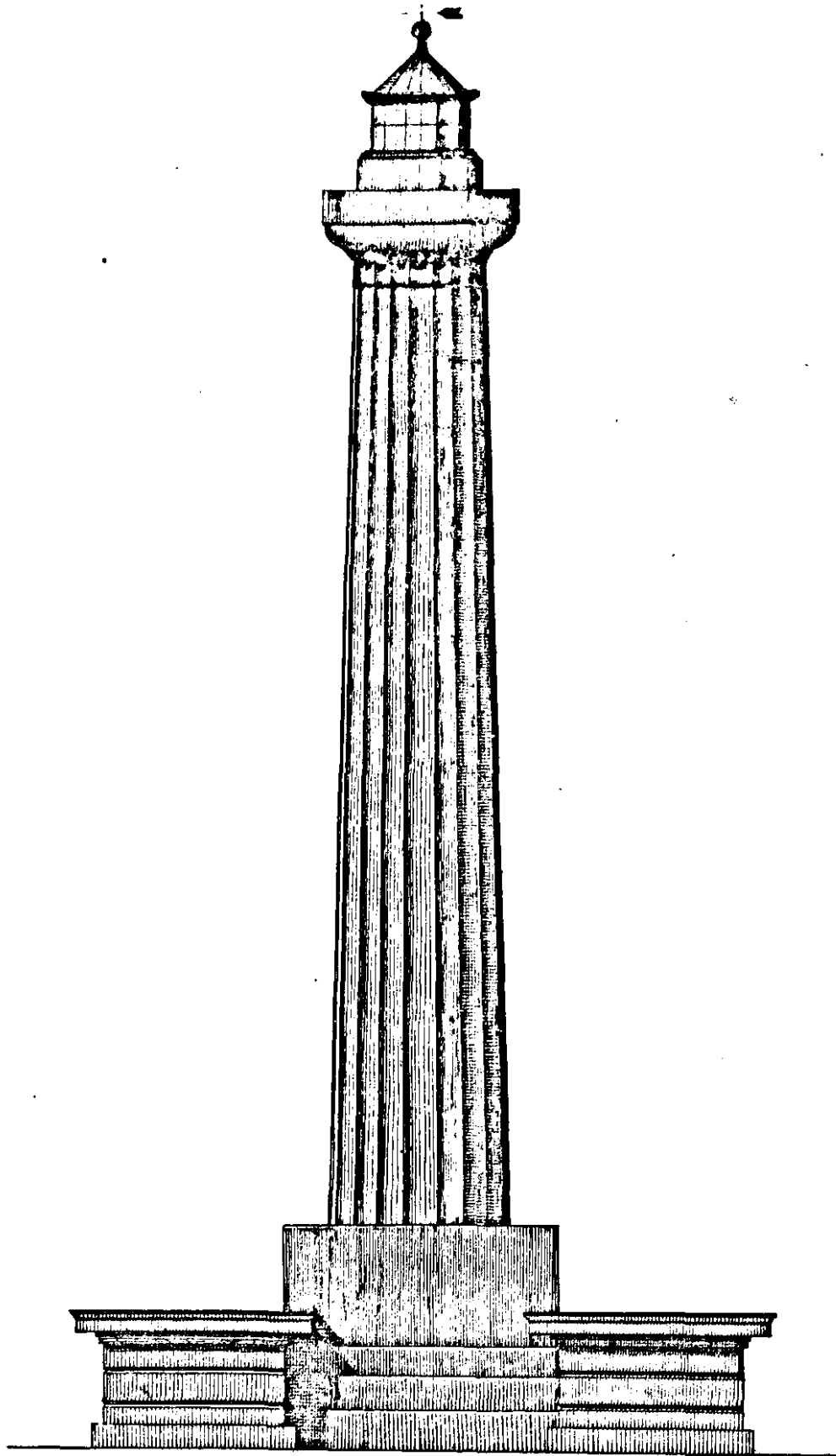


<i>Aumauny</i>	Under the immediate management of Government; or applied to a settlement under which the Government receives its share of the produce of the land from each cultivator, in kind, instead of stipulating for a pecuniary commutation, (in contradistinction to Ezarah?)
<i>Anna</i>	The sixteenth part of a Rupee, or of a yard.
<i>Annicut</i>	A masonry or earthen dam across a River.
<i>Apron</i>	That part of an Annicut on which the water falls after passing over the top of the work.
<i>Ayacut</i>	Total cultivable land; also signifies the whole of the lands of a village.
<i>Bamboo</i>	A large species of reed or cane, used for making baskets, frame work of boats, mats, &c. &c.
<i>Bandy</i>	A cart, usually drawn by two bullocks or Buffaloes.
<i>Bazaar</i>	A market.
<i>Beetul</i>	A species of the pepper vine, the leaves of which are commonly chewed by the Natives of India.
<i>Beriz</i>	Rent, Revenue.
<i>Bund</i>	The artificial bank of a Tank, Lake, Pond or other Reservoir for water. ●
<i>Cadarumbum</i>	Dry or waste lands.
<i>Calingula</i>	A masonry work in the margin of a Tank, or in the bank of a channel, to allow surplus water to flow freely off.
<i>Candy</i>	500 lb. avoirdupoise.
<i>Catamaran</i>	A rude raft, made usually of 3 logs tied together, on which Fishermen sit and paddle about in the water.
<i>Cawney</i>	A land measure equal to 6,400 square yards.
<i>Chatty</i>	An earthen pot.
<i>Chumba</i>	The name of one of the Rice Crops in Southern India, the Chumba harvest begins about the middle of July, and ends about the end of January.
<i>Chunam</i>	Lime, or Mortar.
<i>Circar</i>	The state; or Government; head of affairs.
<i>Codamoorty</i>	The name of a branch of the Cauvery river; also a small river in the Trichinopoly district.
<i>Corumboo</i>	A temporary dam of mud or sand and grass, stretching obliquely across a river, to turn a portion or the whole of its waters into a side channel.
<i>Cuddoopoo</i>	The name of one of the rice crops in Southern India.
<i>Cuddoopoo-car</i> ..	A species of coarse rice—The harvest for which begins about the middle of August, and ends about the beginning of December.
<i>Cullum</i>	A dry measure, equal to about 19 Gallons and 1 Quart, or 12 Marcalls.
<i>Catwah</i>	A Channel.
<i>Cutcherry</i>	A building in which Public business in the Revenue or Judicial Department is carried on—also a Court.
<i>Dasewandum Tanks</i> .	Tanks which are kept in repair by the Cultivators, and for which they agree to give up 1 10-th of the Revenue.
<i>Dasevinedum</i> ...	An allowance of land or rent, given as a compensation for the construction of a Tank, or assignment for making a Tank.
<i>Dhoney</i>	A country coasting Vessel of from 10 to 100 Tons burthen, used by the Natives.
<i>Dittum</i>	Settlement—Literally fixed, applied to the engagement which a Ryot makes at the commencement of the year.
<i>Enam-lands</i>	Lands which are partially, or altogether exempted from the Government Land Tax. Also Grants of land free of rent; or assignments of the Government share of the produce of a portion of land, for the support of religious Establishments and Priests, and for charitable purposes, also to Revenue Officers, and the public servants of a Village.
<i>Fanam</i>	A fraction of a Rupee, rather more than 1-13th.
<i>Fascine</i>	A bundle of sticks tied together.
<i>Fresh</i>	A sudden rise in the water of a river.
<i>Fusly</i>	Revenue year, the Era commencing on the 12th to 15th July—the year 1839 being Fusly 1248-49.

* The Orthography of these terms is not to be strictly insisted upon; various modes of spelling being in use, and mistakes having unavoidably occurred in printing them.

<i>Ghauts</i>	Ranges of mountains running parallel to the coasts of the Peninsula of India. Also a pier a wharf.
<i>Godowns</i>	Buildings for storing articles of commerce; or the out-houses of dwelling-houses.
<i>Jagherry</i>	Coarse unrefined sugar.
<i>Jaghire</i>	Lands, &c. within the limits of the Chingleput Collectorate.
<i>Jetty</i>	Broken Bricks, or Gravel, and mortar mixed—or simple metalling for the surface of roads.
<i>Jungle</i>	A Forest, or wood, or waste land covered with Brushwood.
<i>Kist</i>	Stated payment; instalment of rent—the Government demand, or land tax.
<i>Kuller</i>	A particular class of Natives living near Tanjore and Trichinopoly, who are all more or less Thieves and Robbers, though they cultivate a good deal of land. The head of this Tribe is the Tondiman-Rajah, who lives at Poodocottah, 38 Miles south of Tanjore.
<i>Kunker</i>	Nodulous limestone.
<i>Lac</i>	100,000—also a resinous matter.
<i>Lascar</i>	A Man who is usually employed in pitching Tents &c. moving stores, and in Arsenals.
<i>Maistry</i>	A Master-Bricklayer, Carpenter, Smith, Tailor &c. &c.
<i>Malabar trusses</i> ..	A peculiar and simple kind of framing used in building roofs in Southern India.
<i>Maunium</i>	The same as "Enam."
<i>Mamool</i>	Practised; established; usual; customary.
<i>Maramut</i>	Repair (of Buildings, or other works) particularly those connected with irrigation.
<i>Marcas</i>	A measure equal to 13-30ths of a Cubic foot or about 25 1-7th lbs of Paddy.
<i>Merassidar</i>	A Land-holder who sublets his ground to the Ryots.
<i>Mohout</i>	The man who directs, and sits on the head of an Elephant.
<i>Monsoon</i>	A division of the year indicating the season, and named after the prevailing wind; one part of it being the N. E. and the rest the S. W.
<i>Moochie</i>	The man of that trade who carries on the business of Printer, Book-binder &c.
<i>Mordant</i>	A substance, as "Alum", used in dyeing, to make the colouring matter combine with, and adhere to the substance on which it is applied.
<i>Munnargoody</i> ...	The name of a Talook, or division in the Tanjore, as well as the S. Arcot Districts.
<i>Neerarumbum</i> ..	Irrigated lands.
<i>Nilometer</i>	A gauge used on the river Nile to register the height of the water.
<i>Nullah</i>	A stream, or the dry bed of one.
<i>Nunjay</i>	Wet land; Land which from its situation may be irrigated, and therefore fit for the cultivation of Paddy &c.
<i>Oopenaur</i>	A river or channel communicating with, and opening to the sea.
<i>Paddy</i>	Rice in the husk.
<i>Pagoda</i>	A sacred temple of the Hindoos; a coin equal about 3½ Rupees.
<i>Palmirah-stakes</i> ...	Stakes cut from the trunk of the Palmyrah (a species of Palm) tree.
<i>Parras</i>	A measure 2 ft. × 2 ft. × 6½ Inches.
<i>Peshanum</i>	A species of fine rice—the peshanum harvest begins about the latter end of January, and ends about the beginning of June.
<i>Peon</i>	A messenger, generally in the Public service—Policeman.
<i>Pettah</i>	The Town outside a Fort or Cantonment.
<i>Pice</i>	A small coin—the twelfth part of an Anna.
<i>Picottah</i>	A simple machine for raising water, consisting of a balance lever with a weight at one end and a vertical rod and bucket at the other.
<i>Pisé</i>	Earth made into "puddle" with water and rammed in between planks.
<i>Poonjah or</i>	A crop, or land which does not require flooding to produce a proper return.
<i>Poonjay</i>	Land that cannot be easily watered by artificial means, chiefly depending on the falling rains for irrigation, and therefore unfit for the cultivation of rice. Vide "Poonjah"
<i>Rajah</i>	A Hindoo Prince.
<i>Ram Voitally</i> ...	The name of a channel in the Trichinopoly district.
<i>Ryot</i>	A Cultivator—a tenant.
<i>Seer</i>	A measure—a weight.
<i>Seycal-land</i> ..	Waste land, capable of being cultivated, or fit for cultivation.
<i>Silt</i>	Mud, Slime.
<i>Sluice</i>	A work for regulating the ingress or egress of water.
<i>Tahsildar</i>	The head Native revenue Officer in a Talook.
<i>Tamping</i>	Filling up holes in stone, masonry, &c. which have been bored for blasting.
<i>Talook</i>	A subdivision of a District, or Collectorate.
<i>Tank</i>	An artificial Lake, or pond.

<i>Tappal</i>	The Post—for Letters.
<i>Teakwood</i>	An excellent kind of wood sometimes called “ the Indian oak.” (Tectona Grandis.)
<i>Teerwah</i>	Money rent; rate; custom; toll; rent.
<i>Totie, of the tank</i>	The deepest part, generally opposite to, or between, the lowest sluices.
<i>Tursee</i>	Waste uncultivated land.
<i>Voykal</i>	An artificial irrigating channel
<i>(Iyen) Voykal</i> ..	The name of a channel in the Trichinopoly District.
<i>(Peravally) Voykal.</i>	Do. Do. Do. Do.
<i>(Rajuh) Voykal..</i>	A main Channel, from which smaller channels are led.
<i>Valey or Vaytie..</i>	A Land measure equal to 5 Cawnies.
<i>Vennaur</i>	The name of a River, and the main south branch of the Cauvery River.
<i>Veranutairy</i>	The name of a large Tank 12 Miles long, filled by a channel (the Vuddavaur) from the Coleroon, just above the lower Annicut.
<i>Vettar</i>	The name of a river, a branch of the Vennaur, and the principal drain of Tanjore.
<i>Voloongoo rate</i>	A rate in Tanjore, where the Ryots pay their taxes according to the existing prices of grain at the time of demand.
<i>Undersluices</i>	Sluices on a lower level than the bed of the River or Channel in the bank of which they may be constructed.
<i>Yelanda Voitally..</i>	The name of a channel in the Tirchinopoly district.
<i>Zemindar</i>	A land-holder.



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REPORTS,
CORRESPONDENCE AND ORIGINAL PAPERS,
ON
VARIOUS PROFESSIONAL SUBJECTS
CONNECTED WITH THE DUTIES
OF THE
CORPS OF ENGINEERS,
MADRAS PRESIDENCY.

ARRANGED AND PRINTED FOR PRIVATE CIRCULATION

BY

CAPTAIN J. T. SMITH, F. R. S. F. R. S. N. A.

ASSOC. MEM. CIV. ENG^{RS}. INSTIT^N.

VOL. II.

MADRAS:

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PROMOTING CHRISTIAN KNOWLEDGE.

1846.

To

Lieutenant General the Most Noble the

MARQUIS OF TWEEDDALE,

&c. &c. &c.

MY LORD MARQUIS,

In availing myself of your kind permission to present the following pages in behalf of my Brother Officers for your Lordship's approbation and patronage, it affords me much pleasure to address them to one whose own varied experience so well enables him to appreciate the labours they record. I am glad also to think that your Lordship recognises the important truth so strikingly illustrated in some of the valuable official reports contained in this volume, respecting the vast amount of improvement required for the development of the natural resources of this country. I am sure that your Lordship will concur in the opinion that the condition of its agriculture is among the most important elements of a nation's prosperity, and that we in vain strive to graft upon a people the ennobling influence of education, or a taste for the refinements of our own land, while its masses are struggling with poverty, the consequence of ill directed endeavours to attain subsistence by an inefficient application of their labour to the soil.

Should the information contained in the accompanying pages afford any assistance to your Lordship, in the enlightened endeavour to remove the obstacles which obstruct the improvement of this Presidency, it will afford me much happiness to have been the means of introducing it to your Lordship's notice.

I have the honor to remain,

My Lord Marquis,

Your Lordship's most obedient

and humble Servant,

J. T. SMITH.

PREFACE.

THE completion of this volume has been retarded by delays, partly arising from my own very numerous professional engagements, and partly from difficulties connected with the press and the artist. These circumstances combined must also be offered as an apology for the many errors which I fear will be found throughout its pages, and which, as they have occurred unavoidably, spite of much endeavour and care on my part, will I trust be excused.

There is much in the present volume relative to the openings which present themselves for the improvement of the productiveness of the soil, which will be interesting to every well-wisher of this country; and I hope that the labour which has been bestowed upon the task of presenting it in an accessible form to my Brother Officers will prove to have been not altogether thrown away. Indeed I am encouraged by the belief that great benefit has already been derived from the spread of the valuable information contained in some of the papers belonging to the first volume, especially those respecting the Coleroon Annicuts. These important works mark the commencement of a new era in the development of the resources of the country, and prove to demonstration the sound economy of a liberal outlay in the scientific management of the noble streams upon whose waters the fertility of the land in this precarious climate can alone safely depend.

I regret that I am unable, from causes beyond my control, to give my Brother Officers the opportunity of perusing the official papers connected with the still nobler project, by the same talented Engineer, for improving the fertility of the delta of the Godavery, whereby 100,000 acres of rich alluvial soil, at present lying in comparative desolation, from no other cause than the ignorance of its owners of the commonest principles of hydraulic science; backed it may be, by the paralysing effects of the Zemindary tenure, is proposed to be at once rendered fit for cultivation, and a large part of it for sugar. I trust, however, in a future volume to be able to make use of these valuable papers, which I shall be glad to do at as early a period as possible.

• J. T. S.

NOTICE.

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REPORT ON THE RESOURCES OF THE DISTRICTS BORDERING THE KISTNA WITH REFERENCE TO THEIR IRRIGATION FROM THAT RIVER.

Information recently acquired on the subject of irrigation from the Kistna.

Since the month of April 1836, when the first Report on this subject was submitted to the Board of Revenue, much additional information of a practical character has been derived, bearing upon the suggestions then made.—Two large channels from the River have been opened, one of them in time to receive a supply from the freshes of 1837, and the other was opened in 1838. Though neither of these works can be regarded as altogether complete, yet in their partial operation, they yielded some useful data, which being brought prominently forward, in connection with the whole subject of Revenue to be derived from this source, may prove of use to the Honorable the Court of Directors, by whose orders this additional Report is now prepared.

A general view given of the nature of the advantages attending the flow of the river through Guntoor and Masulipatam.

Before proceeding farther, however, it may be expedient briefly to point out the nature of the advantages which attend the flow of the Kistna, through the Masulipatam and Guntoor Districts. The Honorable the Court of Directors draw attention also to the Godavery, but this part of the subject I must leave to be disposed of by the Civil Engineer in the 1st Division, having satisfied myself only of one improvement which ought immediately to be effected by its means, and which has reference to the Rajahmundry, as well as to the Masulipatam District.

The section of the Kistna.

The Kistna in the last 80 miles of its passage to the sea, has a broad sandy bed generally from 1½ to 2½ miles across, and with considerable islands scattered along it; these are both inhabited and cultivated. The bed of the river is from 20 to 40 feet below its banks, but at the depth of 30 feet below them, there is usually even in the dry months, or from November to June, a small stream running; this is quite shallow and fed merely by the springs in the sand. From June to November the river is constantly swelling and falling, occasionally for a day or two, outtopping its banks, that is from below Baizwarah, or 60 miles from the sea, and then perhaps in twenty four hours going down 6 or 8 feet, and after that running for a week or ten days at from 8 to 10 feet below its banks. In the year 1837, there were 25 days in the course of the months July, August, September, October and November, in which the river was within 9 feet of the lip of the bank at Wulloorpollem, a village about 14 miles below Baizwarah on the Masulipatam side; during three of these days, the river was full, or more than full, and for eight

The nature of the freshes.

other days it was only five feet below the top of the bank; but for the remaining 24 days, the river was from 5 to 9 feet below the brim, at all other times it was from 9 to 15 feet under the bank, and therefore occupying only the deeper parts of its bed.

The rate of the current and fall of the river.

This will give a general idea of the character of the river; the flood when at its highest, in the part under consideration, has never been observed to exceed 3 miles an hour, the fall of the surface is about 13 inches per mile above Baizwarah, at the time when the water is 9 feet below the top of the bank; and about 11 inches per mile through its course below Baizwarah, at which place it receives its last check from any hills, and its width there is suddenly contracted by them to about 1300 yards.

Reference made to the rise of the Kistna, and to certain fallacious inferences connected therewith.

A common impression with regard to the Kistna has been, that as it derives its source at no great distance from Sattara, on the opposite side of the Peninsula, its supply would usually be independent of the monsoons on this side of India; this however appears very questionable, for experience declares a copious monsoon on the east coast, and a full river, usually to occur together, and an attentive investigation of facts will satisfactorily account for it.

The Kistna, until joined by the Toongabuddra below Kurnool, is to be regarded as a very ordinary stream, one whose waters would not half fill the bed which it occupies in the last 100 miles of its course; consequently, the supply of its western branches only would produce no useful effect in the Guntoor and Masulipatam districts, because a half river without an anicut to raise the water, is as unavailing as no river at all. Even after the contribution of the Toongabuddra, the Kistna would be but inadequately supplied, as to fill its channel requires the drainings of a great part of the Hyderabad country, as well as of the hilly ranges on the north of Cuddapah, and Palnaud; and finally, it has to receive the Moonyair, quite an important river, which falls into it in the latter part of its career, about 20 miles above Baizwarah, and is its last tributary that deserves any notice.

Connection between the rains on the East side of India and the rise of the Kistna.

From these remarks, it will readily be inferred, that unless the rains fall heavily between the range of the Ceded districts and the sea, any irrigation of Masulipatam from the Kistna must be defective. And

this inference is corroborated by the facts, that in the famine years of 1791 and 1793 when the rains on this side of the Peninsula failed, so did the Kistna inundation, as noted in Major Beatson's report of 10th June 1798; and lately in 1837, when 40 inches of rain fell at Masulipatam, about thirty five million cubic yards of water, passed through the Pullieroo Sluice from the Kistna, while in 1838, when only 13 inches of rain fell, the discharge by the Sluice did not amount to more than two millions of cubic yards, or not one sixteenth of the more favorable season. The Boodemair also, which is a channel still more recently excavated from the Kistna, and having its mouth at a point 24 miles higher up the river than that of the Pullieroo, and its bed 13 feet below the top of the river bank, received only 2 feet water along it in 1838 but the bed is now being deepened to 15 feet, which will place it on a par with the Pullieroo as regards the freshes, and being so much farther up the stream, will enable it to water lands on a level 21 feet higher. These two Channels, the Boodemair and the Pullieroo, it will be observed are deep and important irrigation canals; their operation in a financial point of view remains to be examined.

The two systems of deriving irrigation from the Kistna stated.

There are two principles on which Channels may be led from the Kistna, and which have remained disregarded on record for nearly half a century; the one pointed out by General Beatson, of throwing an anicut across the river, so as to connect the Seetanagerum with the Baizwarah hill, and thus dam up the water to a level which should command the whole of the country on both sides of the river over which it might be distributed with ease by a well arranged series of Channels. To this plan, the only objection is expense; the work would be a stupendous one, still it is one which would, beyond all doubt, repay its cost, provided only that Government could ensure a proper administration of the revenue details, which should accompany it.

Of an ancient or dam at Baizwarah.

To accomplish a dam 1300 yards long and 7 yards high, including the foundation, ought not to defy the executive powers of the country where the material also is all found at hand, and where it might speedily be prepared for the work by the most ordinary blasting processes, nor would it be difficult to submit a project and estimate for the object, based on practical data; but unless it can be shown that Government would reap any benefit from the work, either directly or indirectly, it would be a mere waste of time to enter on a discussion of the plan of operations to be pursued.

Of simple river channels.

The second method of deriving benefit from the river, is simply making cuts from it, the fall of which being less than the bank of the river itself, would in the course of a certain distance flow out on the surface of the plains; this is the plan noticed by Mr. Topping formerly, who doubted its practicability on account of the gentle fall of the river

bank, the manner in which his conclusion was drawn may be more fully explained as follows; supposing the slope of the Kistna bank, to be 13 inches in a mile, which is more than the truth, and allow a fall of 9 inches per mile for the bed of the projected cut, which is rather less than desirable, then it will be obvious that to gain every 4 inches of level, an excavation a mile long must be made, or if the mouth of the channel is to be 15 feet deep, the length of the cut would be 45 miles, before the surface of the plain adjoining the river could be watered by it. Under this point of view, irrigation from the Kistna would be nearly hopeless; yet no deduction could be made from the suggested depth of the channel at its mouth, since less than 15 feet would not be certain of a supply; on the other hand, more than that would draw in a large quantity of sand.

Statement made relative to the interior of the Masulipatam district and its adaptable irrigation, from the Kistna

When Mr. Topping and General Beatson wrote, they had not the same extent of information regarding the country, which is now possessed, at that time there was no authentic survey of the districts, and both these Gentlemen had other duties to attend to. Mr. Topping even appears to have been ignorant of the very important fact, that in the Masulipatam District, the ground falls away from the river towards a cavity in the interior; known as the Colair Lake, the bed of which is below the rise of the high tides, as the sea water ascending by the Samuldivy River has on former occasions been driven into it; this lake is distant only 22 miles from the Kistna, and its bed is extensively cultivated when the rains subside; the margin of the lake also is very low, and this formerly for a width of 8 miles, was a sheet of tanks and paddy fields, the whole sustained and nourished by the Pullieroo and

Relative level of the Colair lake to the Kistna channels Boodemair and Pullieroo.

Boodemair cuts from the Kistna. The ease and simplicity with which this effect was attained, becomes manifest, on stating that the border of the lake is 58, and 33 feet respectively, below the top of the Kistna bank, where the present mouth of the Boodemair and Pullieroo are situated, the direct distance being from the lake to the former but 38 miles, and to the latter 26 miles. This is sufficient to show that there are no natural difficulties to a system of River irrigation, for the head of the Boodemair being dug 15 feet deep could still afford a fall of nearly 14 inches per mile to the lake, or its windings taken into account, a fall of 9 inches. In like manner, the Pullieroo, were it carried direct to the lake, might afford a fall of 10 inches per mile, having its mouth 11 feet below the bank, but both Channels have seemingly followed natural water-courses, to avoid the expense of excavation, and they each supply tanks and cultivation, at sites nearer their sources, the Boodemair at 27 miles, and the Pullieroo at 7 miles; the latter channel does not fall into the Colair lake at all. The Boodemair however, might be rendered available for irrigation, within as short a distance as the Pullieroo, did it run through Government lands, and of this the people are aware, suggestions hav-

ing been made for an early appropriation of its waters. The above river Channels and their dependant tanks, were in existence before these possessions were ceded to us, in 1766, when reported on; but within 40 years of that time, they were represented by Messrs. Beatson and Caldwell as being in utter decay or disuse; while in 1795 Mr. Topping, the astronomer, also was appointed to enquire into the means of drawing water from the Kistna, and subsequently Mr. Hodgson, the Secretary to the special commission, in his letter under date 27th September 1802, suggests to Captain Caldwell, the propriety of making use even of steam engines, if necessary, for the purpose of raising water for irrigation.

Comparison drawn between the past and present condition of the Masulipatam district.

It will be obvious, from the foregoing statements, that at one period the Masulipatam district was judiciously watered, the great river channels affording an early contribution to the tanks, according to which supply the ryots could arrange their cultivation, for it is most important, that there should be tanks in which to store water, to compensate for any deficiency of the after rains, or of the latter freshes. In Tanjore, it is understood, that notwithstanding the perfection of its channel irrigation, there is often an extensive failure in the crop, for want of some reserve of water, when the river has subsided early. The Masulipatam district, is by nature more favored than Tanjore itself; not only is the Kistna a nobler river than the Cauvery, and the fall from it probably as favorable, but tanks have, in Masulipatam been provided without number, and the soil is the richest possible; no one can doubt the district having once enjoyed a high degree of prosperity, nor can it be concealed, that its ruin is mainly attributable to misgovernment.

The periodical famines adverted to.

Although it is true that famine has repeatedly desolated the country, yet nothing can in the present day be clearer, than that famine is little else than a natural consequence of defective administration. In the best regulated districts in our own territory, famine to the same extent and accompanied by such disastrous consequences is almost unknown, and even in the midst of Zemindaries, and where natural advantages have been most sparingly furnished, the Government territory rapidly recovers from its temporary prostration; this is most clearly developed in tracing the circumstances of the Palnaud, or Government Division of the Guntoor district, which from the time it was ceded to us, has steadily improved, though subject to fluctuation; and even now, after the late trying seasons, yields five or six times as much as it did originally; while the neighbouring Zemindaries have sunk lower and lower, Palnaud, is already recovering the severe visitation of drought and disease, of five years since.

The unfavourable

The present deplorable condition

able operation of the Zemindary system on the country shows both as to the past and as to its prospects.

of a country possessed of every advantage, as Masulipatam is, demonstrates the incapacity of Zemindars for the management of their estates, or rather the entire misconception on which the system was founded, nothing has ever been done by them, while every thing has been done for them; the utmost efforts have been made to prop up their condition. Yet notwithstanding all their former experience in collecting their revenues, the support yielded them by the British Government, together with the virtual disannulling of the claims upon their estates in 1802, they have constantly been sinking into debt, falling into arrears with their piehush, and therefore exacting the utmost from the ryot, while doing nothing whatever for the improvement of the estate, till at length, frequently by decree of Court, the Zemindary is transferred to the management of the Collector, who thus receives it, under accumulated disadvantages, notwithstanding which, the result has almost uniformly been, that the estate administered by the Collector, satisfies all demands, and in cases of minority, is afterwards made over to the heir with a large balance on hand, thus demonstrating that the piehush is not too heavy, or that if it has become so, this is solely ascribable to the culpable mismanagement of the estates. It should be stated also, that Zemindaries administered by Collectors are by no means thereby placed on the same footing as Government lands, since the public servants view them quite as a foreign charge, while the native Officers locally appointed, look upon their employment as merely temporary, the consequences of which on the estate need not be pointed out; indeed, this fact is sufficient to account for the species of notoriety that has attached to the public servants in the Masulipatam district.

The intricate connection between the system of Government and the success of any measures for local improvements dwell upon.

Confining my remarks entirely to the connection between the improvements for the Masulipatam district, and the estates they are intended to benefit, I must observe that nothing can be more distressing than the condition of the villages, or rather the remains of villages, in Goodewadah and Vinnacotta, and while a sympathy is constantly expressed for the Zemindars themselves, ought not this to be felt a thousand fold for their ryots, who steeped in the depths of poverty are the real sufferers by famines, these are the parties who starve and die, whose houses are now bare walls, and this through the misfortune of having been transferred to middlemen, or revenue contractors, with the title of land-lords, but who can do nothing for the ryot, not even where the Zemindar individually may be amiable and intelligent, since he must of necessity be rapacious, if not for himself, still for his creditors public or private. A Zemindar also has comparatively little choice in his Tahasildars and servants, and little control over them; in short, there is every combination of circumstance against him, calculated to produce exactly the effects which are witnessed; there is reason even to believe, that

the superior Zemindars in the Masulipatam District, as well as those of a lower order, would be glad to transfer the estates to the Government for the most moderate consideration, the charge being one which they exercise only for the benefit of parties who prey upon them, and whose interest it also is, by any means to maintain them in their present unhappy position. Much, no doubt, may be argued abstractedly in favour of upholding the Zemindars, and this too in the very face of experience, but in India to attempt to carry out a theory by the mere guarantee of legal provisions and exactments, against the force of habit and circumstances, must always terminate in an adverse result.

Necessity of considering under one view the moral as well as physical obstacles to local improvements.

The foregoing remarks will scarcely be objected to as foreign to the subject of local improvements projected on an extensive scale, for it is not merely in respect to them, necessary to exhibit the nature of the physical obstacles, and the method by which they may be surmounted, but also to state what actual effect on the prosperity of the people and the public revenue may be expected; this, in one undertaking of considerable promise already executed, has fallen so lamentably short of the prospective result originally entertained, as to demand a full investigation of the causes which have occasioned the disappointment. If it can be shown that no works executed on Zemindars' estates will make a return to Government, unless the same are placed under their control, both for the preservation of the works for themselves, and for ensuring their being properly availed of, such becomes nearly equivalent to relieving the Zemindars from the management of their estates, the attempt to exercise simultaneously, Revenue authority in the same villages, both by Collectors and Zemindars, would be impracticable.

Substantial protection to the ryot and the cultivation of good faith towards him the first of all considerations.

It is very clear, that unless the ryot is secure of deriving benefit from extending his cultivation, or changing its character, he will not undertake the operation, it is also sufficiently evident that the Zemindary ryot is always apprehensive lest, under any improvement in his circumstances, a demand should be made on him for old balances or claims of some other description, and hence local improvements are, even in our better regulated Districts, too often rendered abortive, from the absence of confidence between the revenue payer, and revenue collector, which is the basis of all prosperity in this country, and lies at the root of many existing evils; without it, it is next to useless to lay out money on tanks, or channels, canals or roads; the great check on the improvement of the country seems to be this want of confidence, whether arising from unauthorized revenue exaction, or deficient security and protection of civil rights.

Basis of the Honorable Court

The Honorable the Court of Directors have manifestly penned their in-

of Directors instructions relative to undertakings for developing the resources of the country considered.

structions, under date 11th July 1838, relative to projects for developing the resources of the country, on the impression that the establishment of useful works of irrigation would secure the public revenue leviable on the Zemindars; but this appears utterly hopeless, where the Zemindars are insolvent paupers, and their estates comparatively waste, while not even a very extensive reduction in the amount of peishcush payable, would be of any real advantage; for a brief period, it would enable the Zemindar to extend his personal expenditure, until pressure recurred from unfavorable seasons, when he would be again reduced to the same condition as before, and the only effect produced, would prove to be lowering the standard of productiveness of his estate, on which taking place, there would be the same grounds for a further abatement in the demand against him, so that the more mismanaged the estate is, and the more reduced its inhabitants are, the greater indulgence is to be claimed for the party presiding over it. In the year 1836, the condition of the Vinnacotta Zemindary was this, the whole jumma, or estimated value of the revenue, was but 50,000 Rupees, the peishcush being 80,000 Rupees while the nature of the country is such, that it ought to yield lacs annually; that it does not do so, may constitute proper grounds for resuming it from the hands into which it has fallen, but scarcely for confirming such management in the hands of an insolvent proprietor.

On expending money on the estates when regarded as Government lands.

Viewing the estates as purchased by Government, or forfeited, from the terms on which they were granted never having been fulfilled, and the proprietors pensioned, if necessary, it yet becomes a question with some, how far it is advisable to expend money on works in so thinly peopled a territory, the argument is constantly put thus, "of what use is water where there are no ryots?" to which it might be as laconically rejoined, "what can ryots effect without water?" of course, there are many essentials to the prosperity of the cultivating class in this country, and therefore even under the first of physical advantages, good soil with abundance of water, a province may decay; nevertheless, without a good supply of water, it is almost impossible for ryots to flourish, and the common experience is, that generally the finest villages will always be observed near the most permanent and abundant sources of irrigation, as along the banks of rivers, the borders of large tanks or on a line of springs; water and equitable revenue arrangements, will at any time speedily attract ryots, but without the security of moderate assessments, freedom from extortion, and duly regulated collections, no benefit can accrue from the most powerful local advantages; primarily, fair dealing with the ryots, secondarily, affording them means of irrigation must be secured; this order cannot be inverted, and the following sketch of the result of some late operations may illustrate these points.

Results of a late enquiry into the capabilities of the Masulipatam district.

In 1835, the orders of Government were issued to the Civil Engineer in the Northern Division to investigate the resources of the country adjoining the Kistna and Godavery, with reference to irrigation, and also as connected with certain old records on the same subject, being reports by Messrs. Topping, Beatson, and Caldwell, between the years 1795 and 1805. Part of the year 1835, and nearly the whole of 1836 were devoted by the Civil Engineer to this duty, and the eventual result was, a determination on the part of Government to re-open the Pullieroo, a large channel from the Kistna, flowing through many miles of the Masulipatam district, and supplying a large series of tanks; the cost of the work was estimated altogether at 13,000 Rupees, or including the repair of tanks at 20,000 Rupees, the lowest estimate of the returns expected from the operations was 70,000 Rupees, but it was thought possible that double this would eventually be derived from it; both European and Native Officers were sanguine regarding the harvest to be reaped from the work, and the insolvent Zemindar whose estate was to be benefited by it, rejoiced much at seeing the project undertaken by Government. The quantity of water which passed down the channel during 1837 was about 34 million cubic yards, which in that year, had it been properly appropriated, should have yielded a return of at least 50,000 Rupees, but what was the actual outturn? the Collector of Masulipatam in a letter dated the 26th August 1838, gives it at Rupees 4797. This very tame result might be accounted for, partly by the people having been taken by surprise, as they did not anticipate any effect from the work that season, and in some measure probably, from the real extent of cultivation being concealed, though at all times the natives are very slow in deviating from any system of cultivation to which they have become habituated.

The case of the Cavilashapooram tank detailed as an illustration of different points bearing on this question.

The tank most benefited by the Pullieroo in 1837, was that of Cavilashapooram, which is the first that the channel reaches, while it is also the largest of its dependencies; when the water first came down, the bed of the tank was bearing a dry crop, which was at once destroyed and gladly abandoned by the people on this occasion, who with great eagerness reverted to their wet cultivation; the crop also which I had opportunities of inspecting at different periods, was a most extensive one, and of the richest order, quite equal, apparently, to a revenue of 4,000 Rupees in itself, if not much more. The village is under the Nozied Zemindar, who probably did not succeed in obtaining his full share of produce on this occasion, but there appears to be a mutual want of confidence between the parties, the one apprehending that revenue is withheld; the other fearful of extending cultivation, lest undue exactions should be made. The

history of the Cavilashapooram wet cultivation is rather peculiar, it had been totally relinquished, and the tank gone to decay, at the end of the last century; Captain Caldwell about that time projected its restoration at considerable expense, but finding the ryots so utterly indifferent to the matter, he felt disposed to abandon it. Mr. Oakes, however, the Collector of that period, took a lively interest on the subject, and resolved on executing the work; he conversed with the people, pointed out the advantages they would gain by this superior description of cultivation, and in short, from his personal influence, vigour, and activity, he entirely revived their spirits, and after the tank was repaired and supplied, the cultivation was carried on with so much ardour, as to excite Captain Caldwell's unqualified surprise, when he next visited the spot; but here we see merely what may be done by the British Collector, and how entirely his administration differs from that of the Zemindar, likewise, how opposite a spirit can by him be infused into the people.

Returning to the Pullieroo, it is to be observed, that the year 1838 was unfavorable to its success, little was done towards completing the excavation, or repairing the tanks, and eventually both the rains and the river failed in that year, consequently very little advantage could be derived from the channel.

The Boodemair channel brought under review.

The Boodemair is a channel similar to the Pullieroo, its general character was mentioned at the commencement of this report, the work was only undertaken in 1838, but from the Kistna freshes being so scanty in that season, it was of little effect, and therefore has not yet been tested; the excavation and the sluice are now completed, much, though remains to be done in repairing the old tanks and embankments, for the full working out of the project; however, as the path along it is open to the *Colair Lake*, much benefit is likely to accrue to the District, from the undertaking; the great draw back to an entire success, is the deplorable, it may be said, hopeless, condition of the Villages in the Goodewadah Zemindary, so that although the outlay of 9,000 Rupees promises to be immediately reimbursed, yet the revenue of ten times that amount, which should be derived from it, cannot be realized, until the country is rescued from its present holder.

Summary of the effects likely to be realized from undertaking works in the Masulipatam District.

All that I have seen of the Masulipatam District, and a great part of it has fallen under my inspection, forces the conviction on my mind, that its restoration to prosperity is quite incompatible with Zemindary tenure, and that the efforts of Government to restore the old works of irrigation, or furnish the District with new ones will effect no permanent good, nor produce any amendment in its condition worthy of notice by the state, there is nothing to ensure, or to render prob-

able, the preservation of the works which may be constructed; but in fact under such a system of management as prevails in these parts, even the fertile and well watered District of Tanjore itself, were it cut up into Zemindaries would soon resemble this impoverished territory, and all its fine works be consigned to decay; in short, whether an argument, by analogy, is sought from the past history of the District, or from the existing condition of other provinces, under native rule, as we see it at present exercised, as the neighbouring territories of Hydrabad or Mysore, the conclusion is equally unfavorable towards undertaking any large works which are certain of being allowed to go to ruin and thus to fail of their intended object.

A channel from the Godavery mentioned. There is one small cut from the Godavery, which being executed, would prove very useful to the Masulipatam district, by connecting the Colair lake with that river.

The Colair lake and its borders may be regarded as one immense paddy field, but its productiveness is quite uncertain, from the little pains ever taken to secure it a supply of water, although lying under the command both of the Kistna and Godavery; a channel called the Apparow calwah, was indeed once dug from the latter, uniting it to the Weyairoo, which is a river flowing into the Colair lake; but owing apparently, to the natives not being acquainted with the expedient of a river Sluice for regulating the admission of water, the channel seems to have been shut up and abandoned; there is not the slightest valid reason though, that I am aware of, why this important channel should not be again rendered effective; Rupees 4,000 would more than cover the cost, one half being applied to the channel, the other to a river Sluice, while the Rajahmundry district would at the same time benefit extensively from the operation.

The Divy Zemindary under the Kistna noticed. There is another Zemindary in the Masulipatam district, for the present under the Collector's management, which also is in a very depressed condition, though formerly extremely rich, it is the Divy Purgunnah, which is formed by the Delta of the Kistna. This river, and one of its arms, encompass it on three sides; on the fourth is the sea. The whole of the land may be regarded as an alluvial deposit very rich towards the north, but shelving down to the sea it becomes poor, and is mixed with various marine substances:—In remote times it was periodically some feet under water by the river floods, but the deposit of successive ages must speedily have raised the soil; added to which, the annual decay of shrubs and grasses, combined with the drift sand arrested by the vegetation, must have tended to the same result, in which manner the surface has probably continued to rise 2 or 3 feet in a century until at length the tract has to a great extent outgrown the level of inundation, losing by those changes its

capability of presenting a sheet of paddy after every monsoon. In 1802, this deterioration of the sources of its wealth was felt, and the special commission urged means being adopted to remedy it; but from that time to the present, nothing has been done.

Remedial measures to be adopted in Divy. The face of the Divy Purgunnah is covered with extensive but shallow tanks, established to collect the waters of the inundation, an object in which they now constantly fail. The remedial measures for this tract, would be the gradual construction of tanks on the low part of Divy towards the sea, encouraging ryots to cultivate under them, by adopting a moderate assessment, and securing the people from extortion and vexatious interference, on the part of the revenue servants. At the same time also, a large channel may be opened from the very head of the island, for the supply of as many of the old tanks as possible, and abandoning those paddy fields which have attained too high a level, by placing the dry land assessment on them, and permitting the ryots to improve their circumstances by converting them into gardens, where disposed to dig wells for the purpose, at their own expense, and not having the demand on the land raised upon them. It will be observed that these improvements could only be undertaken by the rulers of the country, or, practically speaking, only by the Government through the medium of an experienced Revenue Officer; all that is now open to the Civil Engineer Department, is to investigate the actual condition and resources of the country, and report the same for information.

Concluding remarks on the capability of the Masulipatam District for irrigation from the Kistna. The foregoing portion of this report comprises all that is here intended to be offered, relative to the resources of the Masulipatam District with reference to irrigation; and these resources, it will be observed, are singularly great; also that they have once been most extensively availed of, but under ages of mismanagement have gone to decay, which has consigned the people at the same time to all the ills of poverty and distress, and consequently of oppression and extortion.

It remains now to enter on the investigation of the facilities afforded by the Kistna, for irrigation in the Guntoor District; for this purpose a circle of levels, exceeding 100 miles in length, was lately accomplished by me, added to which a series of branch levels were also undertaken, so as to render the whole more comprehensive.

Description of the Guntoor District. The Guntoor District has always been one of dry cultivation, though formerly it possessed resources for the growth of paddy, which have in a great measure disappeared. On the Western side of Guntoor among the hills, the usual

rain water tanks have been formed, some of which have been abandoned, while others are decayed from their beds becoming charged with sediment. At Nullapaud, for instance, within the immediate vicinity of Guntoor, is a tank of some magnitude, to which Sluices were built, and every inducement apparently held out, to the ryots, to cultivate paddy, still they have preferred adhering to their dry crops. The tank at Tadicondah again, is an example of a still larger reservoir being voluntarily allowed to go to decay, its repair has been contemplated at different periods, but the ryots have not given encouragement to the proposition, and this seems to have been the case, from the date of Captain Caldwell's visit in 1801, to the present hour. The black soil of the Guntoor district it may be observed, is

extremely favorable to the growth of dry grain; in cultivating which, also, few difficulties are encountered, and its low assessment easily paid; much rain is not required for the crops, and though the harvest is materially affected, either by too great, or too restricted, a monsoon, yet on the whole a return is gained, which yields a subsistence without much care or labour. With wet cultivation the case is different; the preservation of the tank alone, its channel of supply, and channels of irrigation, Sluices, &c. entail a considerable degree of trouble, and what is worse, of communication and arrangement with the Talook servants; besides which there is in the first instance, the formation of the fields, and finally, above all, the uncertainty of result; for by a partial failure of the rains the crop may never reach maturity, and then the degree of remission to be granted must be negotiated, which in itself is an endless source of exaction and vexation; and hence

we may infer, that it is not so unreasonable in the ryots to adhere to a low standard of farming and profits, when that preserves them comparatively from interference on the part of the public servants. In all stages of Indian experience, from the earliest periods to the present day, the great bane under which the people have suffered, is the practices of our native servants; the interests of the latter are quite distinct from and opposed to those of the ryots, the state of independence to which it is endeavoured to raise the productive class would if attained, cut off those profits, and reduce that tone of authority, which renders revenue employment under us the highest object of a native's ambition, and for which no sacrifice ever seems too great; were the ryot to become independent, the native authorities would sink to mere servants, Collectors, and Registrars of revenue, instead of possessing a power which makes itself felt in the affairs of every man.

These considerations may serve to show, that even where facilities do exist for wet cultivation, they are under certain circumstances liable to be neglected, and will naturally be so, unless the revenue administration

be one of vigour; this it proves difficult to attain even in our own provinces, much more so under the lax control of a Zemindar.

Demand for water in the Guntoor district. In the Guntoor district, however, the demand for water is irrespective of cultivation, and for more important purposes, being for the very preservation of life to men and cattle; the scarcity which prevails in every hot season is very distressing to the people at large, and the trouble and the labour to which they are in consequence subjected, would appear incredible to those who are strangers to the fact. The poor have often to go miles for their supplies of water, or to wait day and night till sufficient oozes from the springs at the bottom of wells, to fill their vessels; those who can afford it dig private wells in the beds of tanks during the hot season, maintaining a watch over them, others purchase their water; this takes place in Guntoor itself, in the interior of the district all these sufferings are aggravated. Collectors have been by no means wanting in endeavouring to alleviate this state of things, but the nature of the country is most unfavorable, as far as wells are concerned, rock constantly presenting itself at the depth of 30 to 50 feet; this it is too expensive to work through to any great extent, and the springs met with are generally very poor.

On the maintenance of reservoirs of every description. It is a commonly acknowledged fact, that the most favourable sites for wells are in the fields under tanks, and their advantage in this position is very great, because the inadequacy of the supply of the tank is frequently compensated to the ryot, by the water in his well, which thus enables him to get up his crop; this is a constant practice in the Ceded districts, and it may be witnessed in the Palnaud division of Guntoor. In former times even when no wet cultivation could be raised, every village had its tank for watering cattle, and for domestic convenience: often a mere pond, though sometimes of considerable size, these with us have generally been neglected, as showing no financial return, and therefore rejected from estimates; a proceeding which it may be feared has been impolitic; every receptacle for water, every description of reservoir, turns to account in a country liable to drought, and should be maintained independent of revenue considerations.

The wet cultivation in Guntoor. The only tracts of wet cultivation of any consequence, in the Guntoor district lie towards the coast, where are some large tanks, as those of Chercoor, Baupetlah and Moorcundapaud, which are receptacles for minor rivers flowing from the interior, ere they terminate their course in the sea. Guntoor, however, like Masulipatam, labours under the Zemindary tenure, and now presents much the same consequences in the condition of the people, though

as its prosperity was never so eminent, its decline has been less marked, a certain average revenue has always accrued from the dry cultivation, while the greater part of the Masulipatam district being wet land, and bearing that high assessment exclusively, the fields could never be appropriated to dry grain, the decay of the cultivation and revenue there, would more rapidly follow the decay of the means of irrigation, the ryots in this manner becoming irretrievably involved in arrears, until this terminated in pauperism and depopulation. As the Zemindaries, in which the tanks above specified are situated, have fallen under the Collector's management for arrears of peishcush, or other causes, great attention has been paid to their condition; it was so thirty years ago, and is so still; at the former period Captain Caldwell devoted much attention to the Cheicoor and Baupetlah tanks, and eight or nine years ago the Moorcondapaud tank was repaired by Mr. Whish; under the Zemindars the bunds invariably go to ruin.

Similar tanks to that of Baupetlah might probably be established on the same belt of low ground, near the coast, but it would be fruitless to suggest such a measure unless the country were permanently in the hands of Government, and the redeemed cultivation could be fostered and encouraged on a sure basis.

Of the cultivation under the river flood. Formerly, a large crop of the inferior grain called black paddy was often raised on the plains adjoining the Kistna, under the agency of the inundation of that river, which flooded many square miles on its bank; however as the rise of the stream was quite uncertain, it often came down not only when the people were unprepared for it, but when dry grain was on the ground, which consequently was destroyed; about 12 years ago therefore, an embankment was carried along the south edge of the river confining it to its own proper channel. The effect thus produced, though advantageous to a majority of the ryots, was not altogether devoid of injury to some, it cut off both a direct and indirect source of supply to some tanks, and put a stop to the acquisition of rich soil on the poorer lands, while it also ceased to furnish a large annual scour to the Nizampatam backwater and bar, the effect of which is now very perceptibly felt: efforts have lately been made to remedy a part of these evils, by opening a channel from the river to supply some of the tanks, and in other parts along the bank the people wish for sluices so constructed as to admit the river flood, when circumstances render this desirable to themselves; but as great cheapness is to be combined with great power, the object is not altogether easy; and what is more material, is the fact that the river inundation is likely to be much more rare in its occurrence than they contemplate; the effect of having confined the river by embankments naturally being to deepen the course of its waters, so that by regular river channels of

the usual form only, are the ryots ever again likely to fertilize their lands from the Kistna. It is very difficult, though, to impress the native mind with a sense of the gradual changes which take place in the circumstances of their tanks and channels, or to induce the parties most interested to concur in the measures which ought to be adopted, where these involve any considerable changes.

The condition of Palnaud stated with respect to irrigation.

In Palnaud there are several tanks of an ordinary description, supplied by the streams which flow from the hills, and probably more of this character might be formed, or the present tanks improved, but there are no river channels in that part of the country, nor even reservoirs of any magnitude; two large tanks did, at one period exist; the one at Machirla, the other at Karempoody; both have long been abandoned, the former annually bears now a valuable crop of dry grain in its bed, and no wishes are expressed for its restoration. The Karempoody tank was of vast extent, occupying a plain sheet in the hills, through a gorge of the latter runs the Nagulairoo river, this was formerly closed by an artificial bund about 500 feet long and 70 feet high, but it was carried away, and has never been restored, in the middle of its bed is now a village and some hamlets, and at present it does not appear necessary to take up the subject of the restoration of this great reservoir; the people are not prepared for it, and to ensure success, it would require watching over for years by the Collector. The general character of Palnaud is that of a high stony hilly tract, the watercourses of its vallies all running down to the Kistna.

The Kistna in its relation to Guntour investigated.

It now remains to speak of the relation of the Kistna to the Guntour district. The river first skirts the whole of Palnaud, taking a north-easterly direction up to Muchtalah, which is the northern-most point of the Guntour district, it then turns to the south east, as far as Baizwarah, from which point it takes a south westerly direction to the sea, and thus it embraces a large portion of the district.

The whole sweep of the Kistna, as it traverses the boundary of the district, measures about 230 miles, but the breadth of the district taken from where the river enters Palnaud, across to the sea near Baupetlah, is only 90 miles; consequently, as has been noticed by Mr. Topping, there is a most favorable fall of the country in that direction, but all advantages from this source appear to be cut off, by the ranges of hills bordering the Kistna; judging from the delineations of which in the surveys, and from the course of all the nullahs in Palnaud, as well as from inspections made in that part of the country, there seems but little probability of its being possible to draw a supply from the Kistna, on the west side of the district. The whole Palnaud may be said to

Its features described.

The section of the Toongabuddra, as already observed, varies excessively; wherever the flow of water has been accelerated it has cut itself a deep well defined passage, where the country is more level, the section is less bold. A broad unoccupied margin may be said to characterize this stream, for although its waters seldom occupy a passage wider than from 20 to 50 yards, and indeed their own proper channel is from 10 to 30 yards only, yet for a full breadth of 150 yards, the ground has been left free to be overrun by the Toomma tree and grass, this probably is highly valuable to the people, as affording their cattle shade and pasturage, and themselves wood for fences, as well as for implements of husbandry, and fuel.

Good water always attainable in the Toongabuddra.

Another peculiarity of this nullah is, that good water is at all times procurable, by digging in its bed; an excavation of from 3 to 6 feet deep will at all times command a supply; this is a blessing that cannot be appreciated too highly, and its happy effects are manifested in the contrast which the villages on the banks of the Toongabuddra afford, to the appearance of the district generally; adjoining all these villages are fine garden wells, which never fail the inhabitants, the water being always found within from 20 to 30 feet of the surface, and this is the source of their prosperity.

Only one tank supplied by the Toongabuddra.

The Toongabuddra, it may be said, has not been found available for the supply of a single tank, throughout its course, with the exception of one at its very extremity; near the village of Yazali, a bund is thrown across the Toongabuddra to divert its waters to the Alloor tank, but the country is so easily inundated in that part, that this proceeding is constantly objected to by other villages; while the ebb and flow of the tide finds its way close up to the bund in question, the nullah having its natural termination in the Nizampatam backwater, which is at a direct distance of about 6 miles.

Sources of the error regarding the Toongabuddra.

Two circumstances have given rise to the impression that the Toongabuddra was a Kistna channel; first the assertion of natives that the waters of that river did flow along its path, and second the delineation on old maps of the nullah taking its rise from the Kistna, just above the Seetanagaram hill, whereas, in reference to the latter the fact is a stream falls in at that very spot, called the Oondelly Calwah, while the Toongabuddra has its head between the Tadicondah and Seetanagaram hills, at about half a mile from the Oondelly Calwah, but without being in the least degree connected with it, and flowing at right angles from it. As regards the Kistna supply to the Toongabuddra, it is perfectly true, that before the year 1827 this nullah used to carry off a large portion of its overflow, but after the Kistna embankment was established, this source of supply ceased, and the consequence has been material, as affects the Nizampatam

bar, and the cultivation of the low flats towards the coast, as has been already alluded to in para 29.

Having now explained, both what the Toongabuddra is, and what it is not, I may proceed with the general results obtained from its survey and levels; in doing this, it will be best to make all comparisons of elevation with some well known point, and in the present instance, it will be preferable to take for this, the top of the Kistna bank just above the Seetanagaram hill, rather than the level of the sea, since the question is to be one of irrigation from the Kistna. The point selected is the lip of the river, at 450 yards above the Seetanagaram hill, or 350 yards above the Oondelly Calwah, in this part of the river, the bank is high and scarcely ever overflowed, so that to ensure a moderate supply of water, by a channel drawn off at the spot, it would be requisite to make the mouth at least 15 feet deep.

Levels and fall of the Toongabuddra and the country it traverses.

It has been intimated, that the distance from this point on the Kistna, to where the Toongabuddra meets the tides, is about 36 miles in a direct line; but following the course of the nullah, the distance is about 57 miles; the total fall from one point to the other, was found to be 61 feet, and this result tallies well with Mr. Topping's observations, conducted on the opposite side of the river.

This difference gives a fall, from the top of the Kistna bank to the end of the nullah, of only 13 inches per mile; but if a cut 15 feet deep were made as proposed, the fall would then be reduced to less than 10 inches per mile, whereas the plains, being every where much higher than the bed of the nullah, the conclusion at first sight seems inevitable, that with the small fall which the bed of the channel would have, it would be impossible to bring it out on the plains; however, it is worth while examining this subject farther, in order to ascertain whether, independent of the Toongabuddra, advantage may not be taken of the Kistna, for the irrigation of the plains adjoining the river, on the Guntoor side.

Examination into the practical advantages that may be derived from connecting the Toongabuddra with the Kistna.

Commencing from the point on the Kistna denoted above, and comparing its elevation with that of the plains 7 miles lower down, on the course of the Toongabuddra, being a mile and a half below the village of Goodemada, I find the difference of level to be only 15 feet, and as a fall of 10 feet would be required for the flow of the water, it is obvious that only 5 feet can be afforded, for the depth of the river channel at its mouth, which would be next to useless, as for any purposes of regular irrigation, the channel should be 15 feet deep there. The plains, also, which border the nullah, are about 4 feet higher than its bed. The Toongabuddra, as far almost as Goodemada, runs nearly parallel with the Kistna, and

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bar, and the cultivation of the low flats towards the coast, as has been already alluded to in para 29.

Having now explained, both what the Toongabuddra is, and what it is not, I may proceed with the general results obtained from its survey and levels; in doing this, it will be best to make all comparisons of elevation with some well known point, and in the present instance, it will be preferable to take for this, the top of the Kistna bank just above the Seetanagaram hill, rather than the level of the sea, since the question is to be one of irrigation from the Kistna. The point selected is the lip of the river, at 450 yards above the Seetanagaram hill, or 350 yards above the Oondelly Calwah, in this part of the river, the bank is high and scarcely ever overflowed, so that to ensure a moderate supply of water, by a channel drawn off at the spot, it would be requisite to make the mouth at least 15 feet deep.

Levels and fall of the Toongabuddra and the country it traverses. It has been intimated, that the distance from this point on the Kistna, to where the Toongabuddra meets the tides, is about 36 miles in a direct line; but following the course of the nullah, the distance is about 57 miles; the total fall from one point to the other, was found to be 61 feet, and this result tallies well with Mr. Topping's observations, conducted on the opposite side of the river.

This difference gives a fall, from the top of the Kistna bank to the end of the nullah, of only 13 inches per mile; but if a cut 15 feet deep were made as proposed, the fall would then be reduced to less than 10 inches per mile, whereas the plains, being every where much higher than the bed of the nullah, the conclusion at first sight seems inevitable, that with the small fall which the bed of the channel would have, it would be impossible to bring it out on the plains; however, it is worth while examining this subject farther, in order to ascertain whether, independent of the Toongabuddra, advantage may not be taken of the Kistna, for the irrigation of the plains adjoining the river, on the Guntoor side.

Examination into the practical advantages that may be derived from connecting the Toongabuddra with the Kistna. Commencing from the point on the Kistna denoted above, and comparing its elevation with that of the plains 7 miles lower down, on the course of the Toongabuddra, being a mile and a half below the village of Goodemada, I find the difference of level to be only 15 feet, and as a fall of 10 feet would be required for the flow of the water, it is obvious that only 5 feet can be afforded, for the depth of the river channel at its mouth, which would be next to useless, as for any purposes of regular irrigation, the channel should be 15 feet deep there. The plains, also, which border the nullah, are about 4 feet higher than its bed. The Toongabuddra, as far almost as Goodemada, runs nearly parallel with the Kistna, and

at a distance of about half a mile from it; a little above Goodemada, however, it turns more to the southward, and at the village of Doogeralla, which is 16 miles down the Toongabuddra, the latter is $6\frac{1}{2}$ miles from the Kistna, the space between them being an open plain, possessing near Ivani a dip of perhaps 4 feet, which has recently been occupied by a tank.

The plains adjoining Doogeralla are 22 feet below the bank of the Kistna, where the supposed channel would issue, but the distance by the Toongabuddra being 16 miles, requiring a fall of 12 feet through so winding a path, only 10 feet would be left for the excavation at the head, which as before represented, would be inadequate for any permanent benefit, as the river stream attains that level only for a short time in the season, while to do any good the channel must flow 6 feet deep, for some days together.

The bed of the Toongabuddra at Doogeralla is 6 feet below the adjacent fields, and there the channel can be of no avail for their irrigation. These fields are about 3 feet lower than the Kistna bank, a little above Wallabapooram, the latter being high.

Cultivation from the Kistna may commence at about 23 miles down the Toongabuddra.

The next position on the Toongabuddra which should be pointed out, is that of Chagurlamoody; as about a mile above this village the Kondairoo, a nullah from Guntoor, falls into it, and this is one of the spots also, from which cross levels were taken to the south west. The bed of the Toongabuddra, exactly where the Kondairoo falls into it, is 40 feet below the Kistna bank, at the 1st station, but the plains are 8 feet higher than the bed of the Toongabuddra; the fall to them therefore is 32 feet, while the distance being $23\frac{1}{4}$ miles, a fall of $17\frac{1}{4}$ feet would be required for the channel; and this would admit of the latter, at its mouth, being dug $14\frac{1}{2}$ feet deep. But it would be possible to excavate an entirely new channel, independent of the Toongabuddra, the direct length of which should not exceed 19 miles, nor demand a fall of more than 12 feet; however, though a command of 20 feet would thus be obtained, it would only be at considerable sacrifices; first, by taking a line of cultivation which would be objected to by the people; secondly, by the additional depth of excavation requisite for penetrating the open plain; so that, practically considered, it would be best as far, or nearly as far, as this point, to adhere to the Toongabuddra, because, although the bed is so much lower than is necessary, yet the waters might easily be dammed up to the desired height, as they never can possess any formidable velocity. Chagurlamoody (the village) I have stated, is at the distance of the $24\frac{1}{2}$ miles from the head of the Toongabuddra, and at this point the waters might be turned to an account in irrigating the banks; nor in doing this would any practical difficulty be experienc-

ed; a strong earthen bund could, with ease, be fixed across the channel, and then a channel being cut on either side for irrigating the fields, this channel, or branches from it, might again fall into the Toongabuddra below the bund, and the water thus pursue its course; but even this will not be necessary, because the whole of the water that can be collected, will be required by the tanks on the west side of the nullah, and to these it can be led with ease. The first of the tanks in question is that of Kummamoor, then the Appiacutla and Bauputlah tanks; the former of these is distant from Chagurlamoody 13 miles, the level of its bed below the Kistna bank is 48 feet, or deducting 15 feet for the depth of the channel at its mouth, the difference is 33 feet; while from the channel to Chagurlamoody is $23\frac{1}{4}$ miles, and from the latter to Kummamoor tank 13 miles, being altogether $36\frac{1}{4}$ miles, or allowing for the windings in the supposed new cut, the total distance becomes 37 miles, to a fall of 33 feet, or $10\frac{1}{2}$ inches per mile, which is more than enough. From the Kummamoor tank, the water will freely flow to the others, and any surplus will revert to the Toongabuddra, and may thus fall into the Alloor tank.

The latter reservoir, though, is of sufficient importance to demand a distinct channel for itself, and this might easily be obtained by damming up the Toongabuddra, a little above Moodukee, and making a direct cut, 12 miles long, across the plains for the purpose; by this arrangement, a fall of 10 inches per mile might be given the whole way. It is needless, however, to enter upon details of the suggestion; what has been stated will show, that in the direction of the lower part of the Toongabuddra, an unlimited field of wet cultivation lies open for irrigation from the Kistna. It farther appears, that the expense of opening a channel from the Kistna for the purpose, would be by no means considerable, if the depth at the mouth be limited to 5 yards, because, in this case, with the exception of a few hundred yards, the depth of excavation will be limited to 3 yards, which will be continued for 5 miles; beyond this, scarcely any excavation will be called for, unless it be for embanking the sides, to prevent the water escaping over the cultivation on the borders.

The branch channel, from Chagurlamoody to Kummamoor on the one hand, and from Moodukee to the Alloor tank on the other, would only be $1\frac{1}{2}$ yard deep, but throughout, the waterway should be as wide as practicable, as the rise of the river to the required height is for short periods only, and consequently the channel should be of a capacity to take full advantage of these brief floods.

The series of cross levels from the Chaybrole

tanks to the bed of Toongabuddra above Chagurlamoody, proved the tanks to be too high to be supplied by the projected Kistna source, but not so the tract of paddy fields under the tanks; these are 38 feet below the Kistna bank, or deducting 15 feet for the head of the channel, they are 23 feet below the Kistna bank, the distance by the Toongabuddra being 30 miles, which admits of a fall of 9 inches per mile, this is important, the cultivation at Chaybrole being valuable, admitting also of extension, and the tanks at present are entirely dependant on the rain falling at the spot.

From the Chaybrole plains the water would flow on towards Kummamoor and Bauputlah.

Statement of tanks and revenue that would be supplied from the river channel.

The following is a brief enumeration of some of the principal tanks, and their dependant cultivation and revenue, which would be supplied by the projected channel, and which at present are precariously fed by the local rains;

	Coochools.	Veess.	Peerahs.	Rs.	A.	P.
Chaybrole....	13	12	„	assmt. 4365	14	4
Kummamoor.	33	14	9½	.. 10,814	7	4
Appiacutlah..	42	3	8	.. 10,669	6	0
Bauputlah..	228	7	„	.. 46,410	9	7
Nulloor.....	39	5	8	.. 12,022	10	4
Yazali.....	7	4	„	.. 12x9	6	5
Alloor.....	54	„	„	.. 16,498	12	9
Total.....	418	14	9½	.. 102,301	2	9

Present collections small and fluctuating.

Of course, however, though the assessment is thus high, the actual collections on an average can hardly be taken to exceed one third of the sum, as the Bauputlah tank alone yields any steady returns, all the others are very uncertain sources of revenue, being so inadequately supplied; and in consequence, the villages are all gone to decay. Supposing a breadth of 10 yards be given to the bottom of the channel, and the slopes of the sides made equal to the height, then for the Toongabuddra itself, 18,000 Rupees would be required; and for the two branch channels and embankments, Rupees 15,000 additional; altogether Rupees 33,000; which does not exceed the return that should be made in a single season, but how to realize the return, in the depressed, the exhausted, the thinly peopled state of the country, labouring also under Zemindary disadvantages, is a problem not so easily solved.

Inducements for undertaking the channel.

The capabilities of wet cultivation, towards the coast in the Guntoor district, have now I think, been satisfactorily shown, and the habits of the people in these parts incline them towards this description of produce, so that there would appear to be every inducement to undertake the river

channel scheme sketched out above; indeed, the only objection is that the supply by it is not altogether so certain as could be wished for; seasons are occasionally experienced, in which the river does not continue to flow long within 12 or 15 feet of the top of its banks, but this is a defect which it shares with all other channels from the Kistna, and in the ordinary run of seasons, a large supply would be received, and in the worst some, so that no doubt on an average the country would be extensively, though gradually, benefited by the execution of this project.

Other advantages to be derived from the Kistna.

This single channel, thus sketched out, is by no means the sole improvement which might be derived from the Kistna, as a similar channel opened 20 miles lower down, might convey means of irrigation to a vast number of villages all down the bank of the river, and thus supersede the numerous little inefficient cuts that have been made from the river to tanks adjoining it; but the obstacle here is the land being in possession of the Zemindars.

An anicut across the Kistna at Baizwarah the work that would be of almost benefit.

The undertaking, however, which would benefit the country in the most extensive and permanent manner, would be an anicut at Baizwarah, which would at once supply both sides of the river with water for irrigation, and thus for ever remove the prospect of famine, for want of the means of raising paddy; for so long as the courses of the season endure, the quantity of water which, even in the most unfavorable years, flows past between the Baizwarah and Sctanagaram hills, would suffice for the cultivation of square miles.

Feasibility of attempting the regeneration of the country under the existing system of Revenue administration.

Beyond stating the capabilities of the country for raising the grain, and the practicability of executing the work, it does not appear expedient to enter farther on the question in this place, my conviction being, that until the estates are under Government management, it would be a mere waste of means to enter on a work of the kind; every portion of it, whether as to its execution, or the direction of the ulterior measures relative to the cultivation under it, being equally beyond the scope of the principles and prejudices, most familiar to a Zemindar's mind.

Summary.

This report has now disposed of the question referred to it, on the means of irrigation derivable from the Kistna, explaining that no advantages are to be obtained from the river, until it arrives within 70 miles of the close of its course; in this part, channels may be led off from it, with very great advantage, on the Masulipatam side, and with some, though a less degree of advantage, on that of Guntoor, these channels, in favorable years, will yield a very large return, but without an anicut, the returns will va-

ry considerably. With an anicut, a failure in the cultivation ought to be almost unknown, and its extent would be such, as to alter the whole state of the country; nature has distinctly pointed out the site for such a work at Baizwarah, and at some future day its construction would appear inevitable, though not until an arrangement has been made with the Zemindars, to relieve the country from this obstruction to its advance in prosperity.

Kistna and Godavery junction Canal. The second point, on which the Honorable the Court of Directors have called for information, is that of inland navigation, between the rivers Kistna and Godavery.

In the year 1836 Captain Arthur Cotton, Engineers, submitted a valuable report to Government on the subject of improving the internal communications of the country, by means of railways and Canals; this paper was circulated and commented on both by Collectors and Civil Engineers, by which it is probable that some additional light was thrown on the subject.

Facility of executing the scheme. The question, physically considered, as regards the connection of the Kistna and Godavery is the simplest possible: with a degree of excavation rarely to exceed two yards in depth, a cut supplied by the tides, might be established the whole way, without the necessity for a single lock, the canal would be drawn from near Maddapollem, on the Godavery, to Masulipatam, from whence there exists a water communication with the north arm of the Kistna.

Direction of the proposed Canal. The line of canal would be first from Maddapollem to near Mogultoor, a distance of about 8 miles, such a cut, indeed is said to have been in existence formerly, and in use by salt boats; application has even been made to me for its restoration, as alluded to in my Diary for December 1835. From near Mogultoor, there is a water communication as far as Chinna Gollapollem, and from thence to Masulipatam a cut might easily be effected, through the salt swamp; the distance being but 26 miles, and the expense would not exceed 1200 Rupees per mile. In para 19 of my report on this very subject, dated August 1836, it is pointed out that this line of canal might be extended for 170 miles farther towards the south, at a cost of about 1000 Rupees per mile, or in short that about 200 miles of coast canal, might be rendered navigable for 2 lacs of Rupees, exclusive of Superintendance. As regards the restricted question of connecting the Kistna and Godavery, it appears singular that this object should not have been effected long ago, considering the assistance which might be expected to be derived from

it, both by the grain, and salt trade; there being a general impression, that the great desideratum for our provinces is a cheap system of communication, by which their produce might be brought to market; nevertheless, many will doubt whether the canal in question would be made use of by the people to any extent; the canal would traverse a very poor part of the country, and merely unite two ports, it may be said, by an inland canal, which already are open to the very same imports. It is peculiarly difficult to acquire satisfactory, intelligent, and trust-worthy information, on such a question as that of engaging capital in a new direction; and indeed, the non-existence of any surplus capital, or unemployed funds, among the people, is what strikes at the very root of all these schemes of improvement, by which civilization is so much advanced in England; in the latter country, measures of the kind are at once understood, and confidently acted upon; but here, prejudice and want of confidence oppose themselves to any thing that involves a change, and in my opinion, it is moral deficiencies, and not physical difficulties, that obstruct the progress of improvement, rendering futile, the zealous attempts that have frequently been made, at advancing the condition of the people! the latter, with a high degree of ingenuity and acuteness, are perfectly capable of comprehending our projects, but are naturally very suspicious of novelties, and standing possessed of no available capital, are extremely averse to embarking their small means in any new undertaking.

Concluding observations. In conclusion, my conviction is, that without a considerable change in the system of Government in these provinces, it would be fruitless to endow them with canals or roads, except so far as may be required for the immediate objects of Government.

Physically viewed, I may repeat what I have often before stated, that the whole of the country towards the coast, between the Kistna and Godavery might from these rivers be watered like a garden, while by an anicut across the Kistna at Baizwarah, a portion of the Guntoor district might also be made to partake of the advantages, and further, that the Kistna and Godavery may, with the greatest ease, be united by a canal.

I beg to apologize for having extended this Report to so unexpected a length, and for having, with professional questions, intermingled so much that relates to the condition of the people, but it must be evident, that to dwell on the one, without reference to the other, would tend only to the most fallacious inferences on the part of those unacquainted with the country.

(Signed) E. BUCKLE

24th July, 1839.

Civil Engineer.

DESCRIPTION OF THE GUNNER'S SLIDING RULE

AN INSTRUMENT INTENDED TO SUPERSEDE THE CALCULATIONS NOW REQUIRED IN GUNNERY, BY CAPTAIN J. T. SMITH, ENGINEERS, F. R. S.

The following paper is a reprint of the little pamphlet which accompanied an instrument submitted by me to the Artillery service many years ago, to which is added a report of the experiments which were made with it, and the opinion formed in consequence as to its probable usefulness.

I am induced to insert this notice in the present volume because, with perhaps a parental partiality, I am inclined to consider the instrument worthy of the further attention of practical Artillery Officers; and therefore think that an opportunity of introducing it to the notice of those who have never heard of or seen it may be without impropriety availed of; and the more so as no efforts were ever made to publish the first description of it, and I find after the lapse of seven years, that while many of those officers to whom it might be interesting have ~~never~~ heard of it, those who acquired a knowledge of it on its first completion express an increased confidence in it, and desire to extend its use.

I have endeavoured to supply the want of the instrument itself as the subject of reference, by giving all the representations of it which would be useful, in the plate No. 1.—and an attempt has been even made to illustrate the use of the rule further, by adapting a slip of paper to act the part of the moveable slide.—It is needless to observe that no accuracy can be expected in any attempt to solve questions by this paper diagram, but still, it may perhaps suffice to shew the principle on which the instrument itself works, and thus to explain its operation. The paper slide is an incomplete representation of the ivory slide in the rule, because it is impossible to represent on paper the index, *part* of which only is shewn on the paper slip (that part on which "Elevation for Range" &c. is written) For the real index is so much wider than the slide, as to reach to the upper edge of the instrument, where it folds round it and is applied at the back, and points to the *charges*; but as it would be impossible to imitate this no attempt has been made, but a drawing of the back of the rule being placed just above, and parallel with that of the front, it will be easily understood, that if the double lines which represent the left chamfered edge of the index were produced till they reached the scale of "*charges*" belonging to the figure representing the back of the rule, the effect would be the same as if, in the solid instrument itself, the index travelled round to the back to reach the same point. Thus the use of the scales of charges may be learned by any one who will take the trouble to apply to a straight edge (to represent the edge of the index,) at right angles to the slide at the point just beyond the figures 40, 50—and carry his eye along the line pointed by it till it reach

the table suited to the strength of powder his question refers to. With these explanations it is almost superfluous to add, that the lowest figure in the plate represents the *edge* of the rule—the figure next above this the front of the instrument and its slide, the next above this the back of it, containing one of the ivory tables of charges in its proper place, the five next, other tables supposed to be removed from the cell in which they fit in the back of the instrument—and lastly the sliding scale shewn separately, with part of the index attached to it.

THE object of this Instrument is to provide a simple and ready substitute, for the tedious and intricate calculations necessary to adapt the Parabolic Theory of Gunnery to its practice in the field; and at the same time to furnish in a condensed form, peculiarly convenient for use, the results of the experimental practice upon which these calculations must necessarily depend.

The great obstacle which has hitherto been opposed to the adoption of any contrivance of this kind, has been the difficulty which has been met with, in the endeavour to devise an arrangement which should be adapted both to all kinds of ordnance, and to powder of every degree of strength; but on looking over the description hereafter given of this Instrument, it will be seen that this difficulty has been entirely overcome by its peculiar construction, which not only fits it to experiments which have been already made, but leaves it capable of being adjusted to any future ones, whatever may be the strength or quality of the propelling agent made use of.

I shall first give a brief general description of the different parts of the Instrument, and shall afterwards proceed to explain more particularly in detail, the manner in which they are applied to use; for which rules will be laid down, illustrated by examples in the solution of problems, &c.

The front of the rule is engraved with six divided lines, three above, and three below the "*slider*," which is a slip of ivory riding in a groove ploughed through the middle of the rule, and carrying on its right extremity a piece of brass called the "*index*," one edge of which (being that nearest the divisions) is chamfered, to adapt it for pointing to the divisions of the three scales above it. The brass index is also carried beyond the upper edge of the rule, where it is bent round twice at right angles, and made to apply to

a part of the reverse of the Instrument also, for the purpose of referring to a table of charges which will presently be adverted to. The slider may be made to traverse backwards and forwards along the groove,* by means of a little button projecting from it, on the end farthest from the index; and when once fixed in its place, no farther adjustment is required, to obtain any answer which the question may admit.

At one end, the Instrument is covered by a thin brass plate secured by a screw and button, by which it is locked. This plate may be made to revolve a half turn round the screw which secures it, (previously taking the precaution to move the ivory slider an inch to the right, to free it from its engagement in the brass plate,) by which means will be disclosed to view the end of a box formed in the interior of the Instrument, for the purpose of containing four slips of ivory, each surface of which is engraved with tables of charges of powder arranged in a peculiar form. When the box is thus opened, these ivory leaves may all be taken out, and any one of the surfaces exhibiting the table required for use, put uppermost and exposed to view†.

The reverse of the instrument contains merely a single line, at top, divided into parts which are numbered from right to left, commencing with 100 representing 100 yards, and increasing by fifties as far as 2,000 yards, which terminates the scale; the intervals or spaces between each successive point of division not being equal, but diminishing in a geometric ratio, so as to correspond exactly with similar divisions of another graduated line on the front of the scale, of which it is the counterpart. The line now under description is marked "yards range at 45°," and its object more particularly is to interpret the meaning and application of the tables engraved on the slides of ivory, which fit into the Instrument as before described. These tables contain the various charges for the different kinds of ordnance, for each sort of which there is a distinct column, (in all‡ four,) separated from one another by lines traversing the slides from end to end, and parallel to the length of the rule. The different charges are kept distinct by lines crossing these at right angles, and cor-

* Should the slider move stiffly, owing to the rule becoming warped by the heat, the best mode of remedying it is to remove the surface at the parts where it is observed to be too tight, by means of a fine file, or by scraping it with a sharp penknife, and a piece of sand-paper; and afterwards to rub over it a piece of dry soap.

† The contrivance here described having been found liable to derangement, another has been substituted for it which seems to answer very well, and to be likely to last. The end of the box is now closed by a lid moving on a hinge and secured by a snap.

‡ Should it be thought desirable to have separate tables for the iron and brass mortars, (those at present given are for brass,) and also for any other pieces not included at present, it would be necessary, in order to accommodate them, to devote both sides of each slide to every different proof of powder, placing the charges for half the pieces on one side, and half on the other. If, however, no more than six different kinds of ordnance need be provided for, then room could be made for these within the space now taken up by four, by noting down the charges entirely in ounces and parts, instead of pounds, ounces, and drachms, as at present.

responding exactly with the divisions of the scale of "Ranges at 45°," so that they are not at equal distances from one another, but become gradually closer and closer as they approach the left end of the scale.

Thus each division of the line of "Ranges at 45°" has a line drawn to correspond with it, and a charge engraved close to this line, to the right hand of it, in each of the four columns appropriated to the different species of ordnance; this charge being in fact such, as has been found by experiment to produce the range at 45° elevation to which it is attached. It is plain, therefore, that the various charges occupy their respective places, merely in virtue of their power of producing certain ranges at 45° elevation; and therefore, that to adapt this Instrument to the use of any new kind of gunpowder or propelling agent, nothing more is required, than to write under each division of the scale of "ranges at 45°" the charge or quantity of the propelling agent necessary to produce the range indicated by it. It is also manifest, that whenever the "index" of the Instrument points to the range at 45° of any projectile, it will at the same time indicate the charge with which the piece must be loaded to effect it; and *vice versa*.

Now it was before mentioned, that the scale of "ranges at 45°," corresponds exactly with another on the front of the Instrument, viz. the third from the top, (adjoining the ivory "slider,") and also denominated the line of "Ranges." These two divided scales are identical, except, that the one in front of the Instrument, is minutely sub-divided*, and that at the back, merely to 50 yards; but the size of the corresponding divisions is exactly the same in each, as also is the situation they occupy, or their distance from either end of the Instrument; so that whatsoever number the "index" points to on one line, it ought to indicate the very same on the other. Now the index is in front attached to the ivory slider, on which is engraved a scale of angles of "elevation for range" and their complements, from one degree (and its complement 89°) to 45°, which terminates the scale, and is hidden by the chamfered edge of the index. Moreover, the places of the various points of division for these different angles of elevation are so adjusted, that when the index points to any range whatever on the scale, and to the charge necessary to produce it at 45°, (by its connection with the table on the back of the instrument,) the degree

* Some precaution is requisite in reading off this line of ranges, in consequence of the unequal values of the divisions in various parts of it; a circumstance which is very apt to lead to error. This is more particularly felt in estimating a range between 200 and 400 yards, where each sub-division represents 4 yards, and attention must be carefully paid to this for the first few trials, after which a little practice will render the use of the Instrument familiar. The above defect did not strike me until it was too late to remedy it, but it would be easily avoided were the lines to be graduated a second time.

Since the above was written this has been in part remedied, by inserting figures to show the nature of the graduation in this part of the scale; but there is still a slight obscurity from the same cause between the numbers 400 and 600.

45 will also be opposed to it on the slider, inasmuch as the edge of the index occupies the place of that angle upon it; and then also, the proper range for every other angle of elevation (and its complement), will be opposite to such angle on the slider. Thus, if the index be fixed to 500 yards, then the range opposite 20° (and its complement 70°), will be about 320 yards; which is the correct range at that angle, with such a charge as is sufficient to throw a shell 500 yards at 45° elevation.

Again, if the range required by a projectile and the angle of elevation be given, it is evident that by bringing them in opposition to one another, the slider will not only show (by looking opposite the other divisions) what the corresponding ranges for the same charge at other angles would be, but by means of the index, will also indicate the range at 45° ; and as before explained the charge necessary to produce them. And *vice versa*, when the charge or range at 45° is given, and it is required to ascertain what would be the range at any other angle, nothing more is necessary than to bring the index to the given charge, or the given amplitude (range at 45°), and then, opposite the given elevation, read off the required range.

The "Impetus" is an element used in theoretical questions, as a measure of the propelling force, and signifies the space through which the projectile would ascend vertically if the piece were fired at an elevation of 90° . Now this has been proved to be always exactly equal to half the amplitude, so that when one is given the other is known; and the "velocity" also, which varies according to a constant law with the impetus, is equally a function of this quantity, so that in fact when the amplitude is known, these other circumstances are also discovered, or when any one is given all the rest are determined; and therefore, by adjusting their respective situations on the scale, it has been contrived that the index cuts them all at once, viz. the amplitude, the impetus, the velocity, and the charge. In all questions in Gunnery therefore, in which these quantities are involved, they may be classed as follows:—

A	B	C
Amplitude		
Impetus —	}	Angle of
Velocity —		Elevation
Charge —		
		Range.

Any two of these being given, the third may be found by means of the Sliding Rule, taking care to bear in mind, that all the quantities grouped together under letter A are shown by the *index*, and that B and C must always be looked for in contact, or opposition to one another.

Any one of the first four, will of course answer equally well; and by attending to this circumstance, the

following simple rules will be easily applied to any one of the numerous questions they embrace; and will fully illustrate the application of the Sliding Rule, to all cases wherein the above quantities are concerned:—

FIRST.—Given A and B to find C.

RULE.—Bring the index to the given amplitude, impetus, velocity, or charge; and then, having found on the slider the given angle of elevation, read off the range which is in immediate contact with it.

EXAMPLE.—(From Hutton's Practical Gunnery.)—

"If a shell be found to range 1,000 yards when discharged at an elevation of 45° ; how far will it range, when the elevation is $30^\circ 16'$, the charge of powder remaining the same? Answer, 871 yards."—Here the index is made to coincide with the given amplitude (1,000 yards) on the line of *Ranges*, and opposite $30^\circ 16'$ on the slider, will be found the answer 871 nearly.

PROBLEM 2d.—Given A and C to find B.

RULE.—Bring the index to A as before, and opposite the given range, read off the required elevation.

EXAMPLE.—(From Hutton.)—"The range of a shell at 45° elevation, being found to be 1,250 yards; at what elevation must the piece be set to strike an object at the distance of 936 $\frac{1}{2}$ yards?—Answer at $24^\circ 16'$, or $65^\circ 44'$."

PROBLEM 3d.—Given B and C to find A.

RULE.—Bring the given angle opposite the given range, and then, by means of the *index*, read off the four quantities classed together under A.

EXAMPLE.—(From Hutton.)—"With what impetus, velocity and charge of powder, must a 13-inch shell be fired, at an elevation of $32^\circ 12'$, to strike an object at the distance of 1,083 $\frac{1}{2}$ yards:—Answer: Impetus 600 $\frac{1}{2}$ yards; Velocity 340; Charge 2.95 lbs.

N.B. Here the $32^\circ 12'$, must coincide with the given range 1083 $\frac{1}{2}$, that is, the division of 32° must be a very small space behind that of 1080, (the intervals 1050, 1100, and $32^\circ 33'$ being nearly equal, and $3\frac{1}{2}$ being one-sixth of the former; and $12'$ being one-fifth of the latter.) It is unnecessary however to be so exact, so these two divisions may be brought in contact. The answers will be given very correctly to the first two questions, but the last of course depends upon the quality of the powder used; when Madras powder, of 1400 yards proof is considered, the charge would be about 3 lbs. 14 oz.

PROBLEM 4th.—Given the range at one elevation, to find the range at any other.

RULE.—Bring the given range opposite its elevation; then opposite the other given elevation read off the required range.

EXAMPLE.—(From *Hutton*.)—“A shell being found to range 1,166 yards, when discharged at an elevation of $25^{\circ} 12'$, how far then will it range at an elevation of $36^{\circ} 15'$, with the same charge of powder?—Answer: 1,444 yards.”

N.B. It will be sufficiently near if the division 25° , be made to coincide with 1,160 yards, and the answer will then be shown with very tolerable exactness, (opposite $36^{\circ} 15'$;) but the graduation is not so perfect, as to give this answer absolutely free from error.

I now proceed to describe the lower line on the slider, and the three scales which are connected with it, and which are intended to furnish the “time of flight,” the length of fuze, and the greatest altitude to which the projectile rises above the horizontal plane.

This lower line on the slider, as well as the upper one, represents the *angle* at which the piece is fired; but since with reference to the range, the effect of elevation reaches its maximum at 45° , so as to equalize the results given by angles at the same distances above and below that point yet, such is not the case in respect to the influence of elevation on the time of flight, which is gradually augmented in a certain ratio with the angle of elevation, and reaches its maximum at 90° . Hence the necessity for using two lines of different descriptions, to represent the influence of the same variable element, when considered in relation to different results. I may remark in passing, that it has for the sake of convenience been arranged*, that whenever the index of the Instrument points at the propelling power used, then any angle of elevation on the lower line of the slider will stand opposite to its own time of flight, in the same way that each angle on the upper line is in opposition to its proper range; by which contrivance no new adjustment of the Instrument is rendered necessary; and when once the index has been set at the charge, the range, time of flight, together with every other answer required, may be read off at once by inspection. Thus, if the index (or 45°) point to 600 yards on the line of ranges, and we desire to ascertain how long the shell would remain in the air at that elevation, we have merely to inspect the line marked “seconds time of flight,” and observe what number corresponds with the elevation 45° , which we shall find to be $10\frac{1}{2}$ seconds, (rather more,) the calculat-

* Should this Instrument meet with sufficient notice to justify the expense and trouble of laying down the different lines again in a more accurate manner, very material improvement might be made in it, in regard to convenience as well as utility. At the time these lines were graduated, I supposed that all useful questions would be embraced, if the scale of the times of flight were made to commence at five seconds: but I have since thought that it would be preferable to extend it farther, more particularly with a view to adapt it to Howitzer practice, which might very easily be done.

ed time from the formula $T=2s\sqrt{\frac{a}{g}}$ being 10.58 seconds nearly.

Again, if with the same charge the piece were fired at 60° , then the range would be 521 yards, and the time 13 seconds nearly, (by the formula 12.95,) both answers being found in the same way, being opposite the angle of elevation.

Immediately below the time of flight is a line divided into inches and tenths, to show the length of the *fuze* requisite; five seconds being allowed to each inch of fuze, or two-tenths to each second.

By carrying the eye a little further down also, to the corresponding division on the third or lowest line, it will read off the greatest height to which the shell will rise above the plane. Thus in the last question, the time at 60° elevation having been found to be 13 seconds nearly, the length of fuze will be 2 inches and six tenths, and the greatest height to which the shell will rise will be 225 yards nearly, (calculated by the formula

$$H = \frac{sR}{4c} \text{—it is } 225.2.)$$

The following rules and examples, illustrative of the use of this part of the Instrument, will I hope render its description quite complete.—

PROBLEM 1st.—Given the angle of elevation and time of flight, to find the range, impetus, velocity and charge.

RULE.—Bring the given angle of elevation on the *lower* line of the slider, (or line of “elevation for flight,”) opposite the given time; then look for the same elevation on the *upper* line of the slider, (or line of “elevation for range,”) and opposite to it read off the range. The impetus, velocity, and charge, will then be shown, where the index cuts those scales.

EXAMPLE.—At 40° elevation, the flight of a thirteen inch shell was observed to be 9.69 seconds. What was the range, impetus, and velocity, and what would have been the charge of powder, supposing it were of Madras manufacture, proof 1,200 yards?

ANSWER.—Range 600 yards; Impetus 305 nearly; Velocity $242\frac{1}{2}$; Charge—*about* 2 lbs. 2 oz.

PROBLEM 2d.—Given the charge and time, to find the range.

RULE.—Bring the index to the charge, and opposite the time read the angle of elevation; then on the *upper* line of the slider opposite the elevation just found, look for the range.

EXAMPLE.—A 13-inch shell, fired with a charge of 3 lbs. 13 oz. 4 drs. of Madras powder of 1,200 yards proof, was observed to be $19\frac{1}{2}$ seconds in the air; how far did it range, and at what angle of elevation must the piece have been pointed?

ANSWER.—(By calculation) Range, 789 yards; Elevation, $68^{\circ} 20'$.

The method of obtaining the time, when the charge and elevation are given, has already been explained; so that nothing more remains to be added, except, that as the time of flight, length of fuze, and greatest altitude, are all read off at once, any one will answer equally well, as a substitute for the other two; and questions regarding the two last will be more conveniently worked, by substituting the *time* to which they correspond, which can with greater facility be compared with the divisions of the slider.

There is still one kind of problem as yet unnoticed, which may occasionally be of importance; and, as it also comes within the limits of the operation of this Instrument, I shall describe it. It is the case of its being required to produce a certain range *within* a given time, or within the limits of a certain elevation above the plane. As for instance, suppose it were necessary to produce a range of 500 yards, and no fuze was to be had of more than an inch in length; at what elevation must the piece be pointed, and what charge given? Here the time must plainly be not more than five seconds, on account of the limited size of the fuze; and to solve the problem, we should commence with the index at 500 yards, the slider being moved gradually to the right, till it is observed that the same angle (as registered on each of the lines of the slider) is opposed at the same time to the given range 500 yards, and the given time 5 seconds; and by doing this slowly, we find that 15° will nearly coincide with both at the same time. The index will then tell the charge, which for Madras powder 1200 yards proof, will be about 3 lbs. 6 oz.

EXAMPLE.—How must a 13-inch mortar be pointed, and what charge given, to effect a range of 450 yards, without allowing the shell to rise more than 150 yards above the level of the plane?

ANSWER.—(By calculation.)—Elevation, $53^{\circ} 8'$
Charge of powder 1200 yards proof (by Instrument); about 1 lb. 12 oz. 8 drs.

N. B. Here the time corresponding to the greatest altitude 150 yards, is a very little more than $10\frac{1}{2}$ seconds; and it facilitates working the question, to make a pencil mark on the spot to which to refer, in comparing the angles which successively pass it on shifting the slider, with those passing the given range. In estimating the *charge* also, when the index does not exactly point at

any one of the divisions of the line of "ranges at 45° ," the same aliquot parts of the difference between the charge next above and that next below it is added to the latter, as appears to be indicated by the distance at which the index is removed from the lowest division.

I hope it will be found, that when the principle of this Instrument is once understood, its application in practice will be so easy, and its advantages so obvious, as at once to recommend it for adoption in the Artillery Service. Indeed the encouragement which has prompted me to the labour and expense attending its completion, has been the hope, that in presenting it I should supply a want much felt by Artillery Officers; being impressed with the conviction that the present state of the science of Gunnery is such, as in spite of every endeavour at improvement, to make it almost impossible to advance a single step towards perfection; from the increasing difficulty occasioned by the very addition of every new set of experiments, to the use of the undigested mass of facts already heaped together; and which have now become almost practically useless, from their very number and want of arrangement.

It will be unnecessary to explain to the Artillery Officer, that the principle of this contrivance is that of the Logarithmic scale; but it is important not to allow it to escape notice, that in applying this principle to the solution of questions in Gunnery, an adaptation has been made of the calculations of theory to the results of actual practice. Thus the ranges at the elevation of 45° which are pointed out by this Instrument as being effected by certain charges, are such as have been ascertained to be correct by the mean of repeated trials, as reported in the tables of the Madras Artillery practice; while the *proportional* ranges due to different other angles, are such as are shown by *theory* to be proper to them. Thus for example, it is found by experiment, that a 13 inch shell fired at an elevation of 45° , with a charge of powder (1,200 yards proof) of 3 lbs. 6 oz. 15 drs. will range 1,000 yards. This therefore is the result shown by the instrument; while the *theoretical* proportions to the range of 1,000 yards at 45° , are exhibited opposite the other different angles and their complements, viz.

	40°	60°
	—	—
	50°	30°
	—	—
	70°	80°
	—	—
	20°	10°

866 yards, — 643 yards, — 342 yards, and so on.

Thus the *practical* part of the Instrument connects the charges with the ranges they produce at 45° ; and the *theoretical* points out the influence of different angles of elevation in diminishing that maximum range. In examining, therefore, the correctness of the principle or action of the rule, reference can only be made to the theoretical part; and the results it indicates can only be compared with similar results obtained by calculation on the *same* data. For, if the practical part should be in any respect incorrect, it is manifestly no defect in

the principle of this contrivance; being entirely owing to a want of accuracy in the experiments from which it is taken, and which can be remedied at any time, by substituting the determinations of others more carefully made.

I wish here to mention, that in bringing forward this invention and submitting it to the opinion of practical Artillery Officers, I would by no means be supposed to recommend it as perfect. In fact, the discrepancies between theory and practice have been so long known, that it has been considered almost impossible to contrive any thing which should be even of moderate assistance in the field. Yet from the very close accordance between the indications of this instrument and the reported results of actual practice*, and the extreme facility with which it may be consulted, I am induced to hope that even in its present state it may on some occasions be of much practical aid; while I shall proceed to show, that by a further extension of its principle, and by enlarging the practical basis on which it is supported, it may be made to approach, as nearly as is possible under existing circumstances, to the averages of experiment itself. For instance, let us suppose the index of the Instrument points at 1000 yards, and at the back indicates the charge required to produce this range. As near as is possible in the present state of Artillery practice, this must be correct; since it is the mean of a number of repeated trials. Now the positions of the other different angles of elevation on the slider, (as the scale is at present constructed,) and their distance from the index, or in other words, the

* In a table of the "mortar practice at different degrees of elevation, taken from actual practice carried on at St. Thomas' Mount in 1626, 1627, and 1628," are the actual ranges and times of flight of a 13-inch mortar, given by the mean of three trials each, under 78 different circumstances of elevation, charge, &c. And the following is a statement of the comparison of these practical results (as respects the observed range and time,) with the indications of the Gunner's Sliding Rule:—

Of the 78	19 were given exact.
In	38 the error was 0.25 of a second.
In	15 ditto 0.50 ditto.
In	6 ditto 0.75 ditto.

78 Mean error, 0.28 ditto.

The ranges produced by the various charges were not compared; for the powder used in those trials not being of an even proof, it would have been necessary to have made an allowance on the charges made up from powders of different degrees of strength from those tabulated on the scale; an operation which would have cost more time and labour than I could spare to bestow upon it.

In examining in the same way the experiments with the 8-inch mortar, in which from the smaller comparative weight of the shell, and consequently greater relative atmospheric resistance, it was expected that the accordance would be less, I found that the mean of 70 experiments gave a difference between the calculations by the instrument and the observed times, of 0.657 of a second; but the practice appeared to be more irregular, (the greatest error being 2½ seconds;) and the discrepancy being much greater in those cases, where with a low elevation a high charge was combined; the calculated and observed times being very nearly identical at the elevation of 45°. With a 5½ inch mortar, the influence of the resistance of the air at low elevations and high charges, would no doubt be still more marked; but those extreme cases are but seldom likely to occur on service, and an Artillery Officer will find little difficulty, with a large series of recorded experiments at command, in eliminating a rule for the compensation necessary to be made on such occasions.

quantity by which they diminish this whole range of 1,000 yards, are in a certain relation which theory assigns to their respective ranges; viz. as the logarithm of the sine of double the angle. Suppose we take 35° for example, the place which theory assigns to this angle is such as to make it point to 940 yards on the scale. But it might be found by trial, that with the same charge which at 45° produces 1000 yards, the range at 35° would be 980; owing to the resistance of the air altering the curve traced by the projectile from the true parabolic form; and that similar deviations from the theory were experienced at all other angles. Now, if accurate tables, from the mean of many experiments, were made to exhibit the true practical relations between the ranges at all the different angles and the amplitude or maximum range, it would be equally easy to lay down those proportions on the slider, in preference to the theoretical ones now on it; by which improvement it will I hope be clear, that the results then indicated would be entirely the fruits of previous experiments.

In submitting the Instrument, therefore, in its present state, to the test of trial and comparison with the standard of unerring calculation, I have little fear, imperfect as its execution has been, but that it will exhibit a sufficiently close agreement, to demonstrate the truth of its principle; I should however mention, as an apology for the trifling errors which will be found to adhere to it, that the different lines are by no means exact in graduation, a failing which it would have cost too much labour and expense to remedy on the first attempt. Of numerous trials however which I have made with it, comparing its answers with calculated ones, the difference has never amounted to ten yards in 1,000, being 1-100th from the truth; and the average of many trials was less than 1-500th. With a more perfectly finished Instrument, these errors would of course entirely vanish, but even such as they are, they would in no case, I imagine, be of the slightest consequence; as of all the practical sciences, Gunnery may be singled out as being preeminently one, in which very minute accuracy in previous calculation is of the least value; in consequence of the uncertainty inseparable from the practical part of the art. In regard to the indications of the times of flight, however, I should mention that the Sliding Rule gives answers more free from error; the divisions being so large as to relieve it in great measure from the inaccuracies in graduation. In fact it is necessary to hold out a warning, regarding its comparison with one of the empirical rules usually given for estimating the time of flight of a shell, lest from its being in reality more accurate, and giving an answer more close to the truth than the rule itself, it should be thought to only approximate it. The common method of finding the time of flight of a shell at 45° elevation, is to take ¼ of the square root of the range in feet. Now this is very nearly correct in

most cases, but the precise rule is $T = 2s \sqrt{\frac{a}{g}}$ or $T^2 = 4s^2 \times \frac{a}{g}$, whence casting out $4s^2$ (as the sine of the angle of 45° is equal to radius divided by $\sqrt{2}$), and substituting $2r^2$, the equation thus continues, $T^2 = 2r^2 \times \frac{a}{g}$ equal to $2r^2 \times \frac{1}{g} = r^2 \times \frac{R}{g} = \frac{Rr}{g} = \frac{R}{16\frac{1}{2}}$, whence, if we

cast out the small fraction $\frac{1}{16}$, we have $T^2 = \frac{R}{16}$ or $T = \frac{1}{4} \sqrt{R}$. but by this neglect, a slight error is introduced, which will be found to exist when the Instrument is compared with results obtained by the above rule; as its indications are made to include the fraction; and it must therefore be remembered in this case, that the disagreement is in favour of, and not against its accuracy.

To save the labour of calculation, I have myself in many of the trials I have made, compared this Instrument with a set of tables lithographed at the Artillery Depot, Madras, in 1833, and prepared by Conductor W. Wheeler, Ordnance Department, and with which the agreement is very conspicuous in all questions affecting the ranges of different shells at various elevations. The tables at the end of the pamphlet, however, which profess to give the flights of shells, have unfortunately been calculated on an improper formula, the times having, as stated in the introduction, been made proportional to "the sines of the angles of elevation," a relation which holds good when the velocities or charges are constant, but which is not true in the case in which it has been applied, viz. when the range is invariable; in which case the times are as the square roots of the tangents of the angles of elevation. I must therefore, here enter a particular caution against a comparison of the Gunner's Sliding Rule with the contents of this table; the whole of the times therein laid down being in some degree incorrect, and some deviating as far as two seconds or more from the truth. With a view however to supply a standard for easy reference, whereby to judge of the accuracy of the Instrument in this part of its work, I have recalculated a portion of the above table of flights, of which an abridgement is here subjoined. In using it as a test of comparison with the Sliding Rule, it must be recollected, that in each question, the angle of elevation on the upper line of the slider must be brought opposite

* Since the impetus s is equal to half the amplitude; or $\frac{1}{2}R$.

† Because r represents the radius = 1. and therefore $r^2 = 1$.

‡ This will be made clear by an example; thus, the range being 1,000 yards, the time at 30° elevation according to the table, will be 10", and hence, if the times be proportional to the sines of the angles, as Mr. Wheeler supposes, and since the sine of 90° is double the sine of 30° , the time at 90° for the above range of 1,000 yards would by that rule be 20", whereas to produce a range of 1,000 yards at 90° elevation, the time must be infinite; since no lapse of time whatever would create any range at all at that angle.

to the range; and the time looked for opposite the same angle on the lower line of the slider:—

TABLE OF THE FLIGHTS OF SHELLS AT VARIOUS ANGLES OF ELEVATION.

RANGE.	30°	40°	50°	60°	70°
500	7.3	8.8	10.5	12.7	16.0
600	8.0	9.7	11.5	13.9	17.5
700	8.7	10.5	12.5	15.0	18.9
800	9.2	11.2	13.3	16.1	20.2
900	9.8	11.9	14.1	17.0	21.5
1000	10.3	12.5	14.9	17.9	22.6
1100	10.8	13.1	15.6	18.8	23.7
1200	11.3	13.7	16.3	19.7	24.8
1300	11.8	14.2	17.0	20.5	25.8
1400	12.2	14.8	17.6	21.3	26.8
1500	12.7	15.3	18.2	22.0	27.7

After the above explanations, there will I trust be nothing more necessary, to render both the use and principle of this contrivance clearly understood; and I may therefore dismiss it, in the full confidence of its securing the support of the profession, if its merits should entitle it to their approval. The only objection I can at present anticipate lies in the circumstance, that, as much uncertainty must always prevail where the distance of the object fired at is not precisely known, it may be thought that any pains taken to regulate the range and elevation must be fruitlessly bestowed, as an easier and more certain method, would be to judge by an experimental trial. But it must be recollected that the experience gained in this way, perhaps at the cost of considerable time and trouble, will merely serve as a guide in the use of the same kind of ordnance, as that from which it is derived, and under the same conditions; and that if it be admitted, that the most eligible mode at present known for securing accuracy in practice, is that of waiting for the knowledge wrung from repeated failures, not only is the Artillery Officer rendered helpless in operations by night, when this auxiliary is denied him, and calculation cannot be avoided, but even in the most favourable case, the same guess-work process has to be repeated, both with every different species of ordnance in use, as well as on every occasion wherein any change in any one of the circum-

stances of charge or elevation, may become necessary. On the other hand, were a single shot fired from *any* piece as an experiment, during the day, and the distance ascertained by the Sliding Rule; and which, being checked as it would be by a double process, (being first given by the charge and elevation, and secondly by the time and elevation,) could not fail to be a near approximation to the truth; he would then be furnished with the power, by availing himself of its further aid at night, to adjust the exact elevations and charges for every other kind of piece in the battery, under whatever circumstances.

I could enumerate other occasions on which an Instrument such as has been described, must be felt to be a valuable acquisition to the Artillery Officer; but it is needless to enlarge upon what must be apparent to all who have felt the difficulty of calculating in the field. That the Parabolic theory has been less frequently resorted to than its importance would seem to demand, may be readily explained from the fact of its calculations being so troublesome and intricate, that, what with the difficulty of selecting the proper tables of practice, and the delay and chance of error occasioned by taking out and working the Logarithms, an Artillery Officer, when called upon to act in any emergency, is placed in a situation in which the very attempt at such a process would be absurd. When however these difficulties are completely removed, and when an instrument is put into his hands by which he may at any time, at a moment's notice, and by the very simplest process, obtain any and all his required knowledge at a glance; we may hope to see the connection between theory and practice established in their true relations, and that the clearing aside of this obstacle, may be the means of opening a way to further improvements.

August 10th, 1837.

N.B. The few Instruments which were sent out to India by myself, were manufactured by Mr. Thomas Morris, Mathematical Instrument Maker, of 11, Chester Street, Walcot Place, Lambeth, who is now in possession of patterns which will enable him to execute others to order. They were originally charged at £1 5s. each; but that sum being insufficient to leave a remunerating profit to the maker; and further improvements having added to their expense, their price, including a Case, and a copy of the "Description," has now been fixed at £2 2s. each.

Extract from the Madras Artillery Record vol. 1 p. 81

CAPTAIN SMITH'S INSTRUMENT.

A Gunner's sliding rule, an instrument intended to supersede the calculations now required in Gunnery, has been invented by Captain Smith of the Madras Engineers, and a comparison of its merit with actual Practice has been made by Lieutenant and Quarter Master Moore of the 2d Battalion Artillery, which proves the instrument to be very correct, and hence very useful.

Calculations on Captain Smith's sliding Gunners scale, compared with actual ranges, charges, times of flight,

and length of fuzes, ascertained from practice carried on at Saint Thomas's Mount with 8-inch and 10-inch Iron mortars. The object of this comparison being to discover whether, in the event of an Iron 10-inch Mortar giving a range equal to one, marked on one of the scales, the calculations on that scale could be applied in practice with those Mortars. The scales were constructed and the compilations made for the purpose of being used with Brass Mortars.

The sign + is prefixed in the column of remarks when either the charge, time of flight, or length of fuze, given by the sliding scale is in excess of the charge, time of flight, or length of fuze ascertained by actual practice; and the sign—when less.

On inspection of the Table, we see that the charges, time of flight, and length of fuze indicated by the sliding scale approach nearer to those used in actual practice, when they are applied to ranges under 600 yards, and that a greater difference is found to exist when the ranges are higher, but still to so trifling an extent as in no way to preclude the calculations on the scale from being advantageously adopted for practical purposes.

If Gunpowder by any future improvement in its manufacture, should be rendered capable of giving higher proof ranges than at present, the discrepancy between actual results and the calculations on the scale will be slightly increased, that is to say, the deficiency in the latter will be greater.

Captain Smith's Instrument was submitted to the Artillery Select Committee in November 1836, when they remarked as follows:—

The Committee can entertain but one opinion as to the ingenuity and talent displayed by Captain Smith in the construction of the Gunner's slide.

2d. It is seldom, however, that the Practical Artillerist can have occasion to refer to such instruments, and let them be ever so well contrived, they cannot with any prospect of permanent advantage be issued to the Service for general practical purposes: for, in the most scientifically constructed instrument, it is impossible to guard against the discrepancies, caused by the variations in the dimensions of Ordnance and Projectiles, and deteriorations which take place in gunpowder.

3d. Captain Smith's slide works remarkably well, yet, when necessary to consult authority, glancing the eye over Practice Tables, ready drawn out, would be infinitely easier, than working out the question on the slide.

4th. Written tables can be corrected, renewed, and placed in the Gunners hands at a trifling expense, whilst instruments are not only expensive, but once arranged, cannot be altered.

5th. The slides as at present constructed, will only

Gunner's sliding rule.

PRACTICE OF 1837

PROOF RANGE 1142.696 YARDS.

DISTANCE.	Charge by scale			Charge used.			Fuse by scale.		Fuse used.		Time of Flight by scale. sec.	Time of Flight ascertained. sec.	REMARKS.						
	lbs.	oz.	drs.	lbs.	oz.	drs.	lbs.	ths.	lbs.	ths.			Difference of charge.			Difference of Time.	Difference of Fuse.		
													lbs.	oz.	drs.	sec.	lbs.		
No. 1.—10 inch Mortar.																			
568 Yards.....	1	1	10	1	1	4	0	0	1	1	10.95	11.	-	0	0	-	0.75	-	0.1
770 ".....	1	1	7	1	1	12	0	0	1	1	12.75	12.	-	0	0	-	0.0	-	0.0
889 ".....	1	1	12	1	1	11	0	0	1	1	13.75	13	-	0	0	-	0.75	-	0.2
1013 ".....	1	1	14	1	1	8	0	0	1	1	14.25	14.16	-	0	0	-	0.416	-	0.2
1104 ".....	1	1	4	1	1	0	0	0	1	1	14.25	15	-	0	0	-	0.75	-	0.2
782 ".....	1	1	7	1	1	0	0	0	1	1	14.25	12	-	0	0	-	0.0	-	0.0
No. 2.—10 inch Mortar.																			
481 Yards.....	1	1	14	1	1	0	0	0	1	1	9.5	9.25	+	0	1	+	0.25	+	0.1
521 ".....	1	1	11	1	1	0	0	0	1	1	9.75	10	+	0	0	+	0.25	+	0.1
796 ".....	1	1	9	1	1	0	0	0	1	1	12.25	12.333	-	0	0	-	0.083	-	0.1
1122 ".....	1	1	15	1	1	0	0	0	1	1	14.5	15.25	-	0	0	-	0.75	-	0.1
1018 ".....	1	1	12	1	1	14	0	0	1	1	14	14.25	-	0	0	-	0.25	-	0.1
760 ".....	1	1	7	1	1	8	0	0	1	1	12	12.0625	-	0	1	-	0.0625	-	0.0
No. 3.—8 inch Mortar.																			
568 Yards.....	0	12	10	0	12	0	0	0	0	0	10.95	10.	+	0	0	+	0.25	+	0.0
655 ".....	0	13	9	0	13	4	0	0	0	0	11.	11.5	+	0	0	+	0.5	+	0.1
720 ".....	0	14	8	0	14	8	0	0	0	0	11.5	11.666	-	0	0	-	0.166	-	0.0
906 ".....	0	0	0	0	1	1	0	0	0	0	12.875	13.166	-	0	13	-	0.291	-	0.0
946 ".....	0	1	1	0	1	2	4	4	0	0	13.25	13.25	-	0	0	-	0.0	-	0.0
768 ".....	0	15	2	0	15	6	4	4	0	0	12.	12	-	0	0	-	0.0	-	0.0
1112 ".....	0	1	2	0	1	14	12	12	0	0	14.25	15	-	0	0	-	0.75	-	0.2
1226 ".....	0	1	3	0	1	6	0	0	0	0	15	15.5	-	0	0	-	0.5	-	0.1
No. 4.—8 inch Mortar.																			
660 Yards.....	0	12	9	0	12	4	2	2	0	0	11	11.333	+	0	0	+	0.333	+	0.1
770 ".....	0	14	14	0	15	2	2	2	0	0	12	12.333	-	0	0	-	0.333	-	0.0
996 ".....	0	1	2	0	1	4	4	4	0	0	12.5	13.0	-	0	0	-	0.0	-	0.0
1008 ".....	0	1	1	0	1	3	8	8	0	0	13.75	14.25	-	0	1	-	0.5	-	0.1
1136 ".....	0	1	4	0	1	4	2	2	0	0	14.5	15.	+	0	0	+	0.5	+	0.1
1267 ".....	0	1	6	0	1	0	0	0	0	0	15.25	16.75	+	0	0	+	0.5	+	0.0
No. 5.—8 inch Mortar.																			
564 Yards.....	0	12	10	0	12	0	0	0	0	0	10.95	11.	+	0	0	+	0.75	+	0.0
655 ".....	0	13	9	0	13	4	0	0	0	0	11.	11.	+	0	0	+	0.0	+	0.1
940 ".....	0	1	1	0	15	12	4	4	0	0	13.125	13	+	0	0	+	0.125	+	0.1
787 ".....	0	15	2	0	15	6	4	4	0	0	12.	12.75	-	0	0	-	0.75	-	0.0
1126 ".....	0	1	4	0	1	4	12	12	0	0	14.5	15.166	-	0	0	-	0.666	-	0.1
1210 ".....	0	1	6	0	1	6	0	0	0	0	15.	15.5	-	0	0	-	0.5	-	0.1

PRACTICE OF 1838.

PROOF RANGE 1161 YARDS.

DISTANCE.	Charge by scale			Charge used.			Fuse by scale.		Fuse used.		Time of Flight by scale. sec.	Time of Flight ascertained. sec.	REMARKS.						
	lbs.	oz.	drs.	lbs.	oz.	drs.	lbs.	ths.	lbs.	ths.			Difference of charge.			Difference of Time.	Difference of Fuse.		
													lbs.	oz.	drs.	sec.	lbs.		
No. 1.—10 inch Mortar.																			
594 Yards.....	1	1	12	1	1	4	10	10	1	1	10.5	10.5	-	0	0	-	0.0	-	0.1
612 ".....	1	1	4	1	1	5	0	0	1	1	10.5	11.25	-	0	0	-	0.75	-	0.1
778 ".....	1	1	14	1	1	8	0	0	1	1	12	12	-	0	0	-	0.0	-	0.1
1028 ".....	1	1	12	1	1	14	0	0	1	1	12.75	13.25	-	0	0	-	0.5	-	0.1
1142 ".....	1	1	15	1	1	1	0	0	1	1	14.5	14.833	-	0	0	-	0.333	-	0.1
1199 ".....	1	1	0	1	1	15	6	6	1	1	15	15.166	-	0	0	-	0.166	-	0.0
No. 2.—10 inch Mortar.																			
600.666 Yards.....	1	1	15	1	1	4	8	8	1	1	10.5	10.5	-	0	0	-	0.0	-	0.1
815 ".....	1	1	7	1	1	9	0	0	1	1	12.25	12.416	-	0	0	-	0.166	-	0.1
1010 ".....	1	1	12	1	1	14	0	0	1	1	12.5	13.083	-	0	0	-	0.583	-	0.1
1150.333 ".....	1	1	15	1	1	1	0	0	1	1	14.5	14.916	-	0	0	-	0.416	-	0.1
1204 ".....	1	1	0	1	1	15	2	2	0	0	15	15.25	-	0	0	-	0.25	-	0.0
No. 3.—8 inch Mortar.																			
570 Yards.....	0	12	3	0	12	12	12	12	1	1	10.25	10.333	-	0	0	-	0.083	-	0.0
614 ".....	0	15	12	0	13	4	4	4	0	0	10.75	11	-	0	0	-	0.25	-	0.1
824 ".....	0	0	0	0	1	0	0	0	0	0	12.25	12.416	-	0	0	-	0.166	-	0.0
785 ".....	0	14	12	0	15	12	4	4	0	0	12	12.25	-	0	0	-	0.0	-	0.0
1003 ".....	0	1	1	0	1	3	0	0	0	0	12.5	12.25	-	0	0	-	0.75	-	0.1
1177 ".....	0	1	1	0	1	5	8	8	0	0	12.5	14.25	-	0	0	-	0.75	-	0.1
1177 ".....	0	1	4	0	1	5	8	8	0	0	14.75	15.25	-	0	0	-	0.5	-	0.1
No. 4.—8 inch Mortar.																			
612.5 Yards.....	0	12	12	0	13	0	0	0	0	0	10.5	10.666	-	0	0	-	0.166	-	0.1
803.666 ".....	0	15	0	0	1	0	0	0	0	0	12.25	12.416	-	0	0	-	0.166	-	0.1
1032.666 ".....	0	1	2	0	1	3	8	8	0	0	12.5	13.833	-	0	0	-	0.333	-	0.1
1165 ".....	0	1	4	0	1	5	8	8	0	0	14.688	14.166	-	0	0	-	0.416	-	0.1
1165 ".....	0	1	4	0	1	5	8	8	0	0	14.688	15.25	-	0	0	-	0.416	-	0.1
No. 5.—8 inch Mortar.																			
561 Yards.....	0	12	6	0	12	4	4	4	0	0	10.25	10.5	-	0	0	-	0.25	-	0.0
816 ".....	0	15	2	0	1	0	0	0	0	0	12.25	12.416	-	0	0	-	0.166	-	0.1
1011 ".....	0	1	1	0	1	3	8	8	0	0	12.5	12.5	-	0	0	-	0.0	-	0.1
1178 ".....	0	1	10	0	1	5	0	0	0	0	14.75	15	-	0	0	-	0.25	-	0.1

serve for mortars, whilst the practice tables now in use, are constructed for all kinds of Ordnance.

6th. Captain Smith seems to think he can supply any want, or remedy any defects in the present instrument: so much ability has been shewn in the arrangement of the present one, as far as it goes, that the Committee would gladly see that Officer entrusted with its modification.

7th. If it should be thought advisable to introduce such instruments into the Service, the Committee would recommend an increase in the size, for it is with much difficulty that the numbers and some of the lines of demarcation can be read off on the present slide, and it should be made of metal, as ivory or wood is apt to warp in hot weather.

8th. The tables should be constructed for iron mortars, brass ones having become obsolete.

9th. In the present ivory slide, there is a mistake, copied from the tables in the Madras Gunner—viz. in the charges with powder of 1200 and 1400 yards proof, the largest charge for the 13 inch, is given to the strongest powder, from 500 yards upwards.*

Since the foregoing opinion was delivered I have had no opportunity, nor did the subject appear to be of sufficient importance to justify my putting forth any defence against the strictures which have been made upon this invention. I cannot however now publish them without saying a word or two in its behalf.

I must therefore observe in respect to the impossibility of guarding against the discrepancies caused by variations in the dimensions of ordnance and projectiles, and deteriorations of powder &c. that the sliding rule was merely intended as a substitute for *calculation*, and that whenever the latter has to be resorted to, (and that it occasionally must there is no question), the operation may be performed by its assistance with a very great saving of time and trouble. That discrepancies, more or less, may arise from the causes above mentioned, is quite certain, but it is also true that neither calculation nor tables could guard against them.—Their occurrence, therefore, is no argument against the use of the sliding rule, as a substitute for other modes of solving artillery problems; and the fact that it does give answers very closely corresponding with the results of actual practice, is a proof that they have not much practical influence upon its efficiency. In regard to the *facility* of solving questions by the rule, as compared with the use of tables, I can only say that I think that a little further acquaintance and familiarity with the use of the former,

* The same error will be found in the scales represented in plate I which are merely copies from those which were attached to the sliding rules.

would have completely altered the Committee's opinion in its favor. The question might be easily decided by a trial, and I cannot help entertaining the belief, that if 100 *mixed* artillery questions of all kinds, were proposed to two persons equally versed in the use of tables and of the sliding rule, the holder of the latter would be able to give the answers in much the shortest time.

The objection that the slide as at present constructed would only serve for mortars, is quite true, for the fact is, that the few rules which actually exist were merely made up as samples of what could be effected, and chiefly in order to illustrate the principle; and they were accordingly suited to the ordnance of which the data happened to be in my possession; but there would be no difficulty whatever in applying the same principle to every other description of ordnance; and it is proper to explain, that although specimens were given of the pattern according to which in my opinion a valuable instrument might be constructed for the use of the artillery service, it was by no means my intention to limit its construction to the particular form or dimensions adopted by myself, but to leave that and other points, to the better knowledge and practical experience of the scientific corps for whose use it was designed. I think that an increase of its size might perhaps be an improvement, and that other alterations also might be made with advantage.

Since the first part of this article was sent to press. I have received a letter from a distinguished officer of the Madras artillery, in which he makes some very valuable suggestions on these points, and amongst others proposes the substitution of card slips for those of ivory, whereby in addition to cheapness, the advantage would be gained of a facility in making any alteration or addition, in correspondence with the progress of knowledge and experiment. This modification, together with the omission of three of the lines, which are not frequently required on service, would tend to make it a simpler and cheaper instrument, and release it from all the objections above recorded. I am happy to appeal to so high an testimony as that of Major Anstruther C. B. to prove that part of them are not universally felt: he says, "I have always thought it a most valuable improvement on our old system of looking to a book for rules and tables of charges." "I will not rest till each mortar is supplied with one as a necessary accompaniment to the fuze-bench" These opinions, with similar testimony from other quarters, lead me to hope that the principle of this contrivance does afford the means of effecting a valuable simplification of the complicated process of reference necessary to meet all the varieties of detail in the ordinary practice of gunnery; and that in the hands of those so much better able than myself to give it the form and construction suited to make it of service in the field, it may hereafter be found to realise all my expectations.

MEMORANDUM ON TRACING MOUNTAIN PASSES—BY LIEUT. COLLYER.

Had I not seen it apparently so often neglected, I should have thought it unnecessary to premise, that before commencing the tracing of a road, a knowledge of the country must be acquired, every pass examined, and all possible information collected from the Inhabitants. In tracing a pass it is not always easy, indeed from the steepness of the sides of mountains generally very difficult and tedious, to use either a theodolite or a spirit level, and the most convenient instrument for the purpose is a gunners quadrant, fitted with a sight and cross wires, placed on a staff of a convenient height, with a spike at one end to go into the earth, and a hole at the other to receive the quadrant, which works on an universal joint; an assistant with another staff of the exact height of the instrument, when so fixed, precedes the person tracing the line; and moves it up or down as the case may be, to the required slope: a peg is then driven firmly into the ground where the instrument was placed. The tracer places his instrument where the assistant placed the staff, and the operation is repeated: by this means the line is at once traced and set out by pegs. After this a party opens a small pathway of a couple of feet in width; this whole operation should not cost more than 16 Rupees per mile.

In this way I have traced out many miles of road, the last, the new pass from Coimbatore to Mysore—called the "Binkenhully Ghaut:" this pass has been made 8 feet wide, and is 8 miles 173 yards in length; 6 miles 1233 yards of which are on a constant ascent (at various slopes the maximum 1 in 15 and the average 1 in 16.08) to the top of the ridge, which is 2204 feet above the foot of the pass; and the remaining 1 mile 700 yards at the same maximum slope descends into Binkenhully. From the foot to the top, the slope of the side of the hill averages 1 to $1\frac{1}{2}$ or $\frac{1}{3}$ Horizontal, and the remainder at 1 to 3 or 4 Horizontal. From the shortness of the spur upon which this road is made it was necessary, to get the above slopes, to make 24 zigzags, many of those were from necessity revetted; there are many mountain rills which have also been revetted and open inverted, drains constructed to carry off the water; and 3 considerable torrents which have been entirely built up with large stones and inverted drains—there being no other way of carrying the road across them; about 150 cubic yards of rock have been blasted, besides many cubic yards of large

boulders removed by levers &c. and in one place the road is built up for about $\frac{1}{2}$ of a mile. Open drains have been constructed where required. The revetments are built of stone, not set in mortar, as large as could be conveniently procured, $\frac{1}{2}$ of their height in thickness at bottom, with a batter of 1 or 2 inches to a foot. The blasting was paid for at the rate of 12 Annas per hole for every hole 1' 6" deep and $\frac{1}{2}$ inches in diameter, and 1 rupee if of 2 inches in diameter. The men furnished their own boring tools, and were supplied with powder. The quantity used was the cube of the line of least resistance in ounces, and the tamping, potters clay. I do not think there were any failures.

The workmen employed were Woders on daily hire. They received 2 Annas per diem, and the boys 1 Anna. They commenced work about 7 A. M. and left off about $\frac{1}{2}$ past 5 P. M. Those who worked well, and those who built the revetments got a trifle more. There was a Maistry, (one of their own head men, who was paid as the others, but merely looked on) and a cook, allowed for every 15 men, and some boys occasionally for bringing water. No work was ever done on Sundays, or on their own Feast days, which are few, but they were paid the same as if they had worked. They received one Anna per diem batta, for coming from their villages, and the same when they returned. The whole work, taken over all, including revetting, blasting, &c. has cost 1 Anna 7 Pie per cubic yard, the total outlay was somewhat under 2400 Rupees.

The Superintendence is not included, but as that consisted of Talook Peons, it is no additional item to the cost.

I have been thus particular, as I think it will serve as a guide to any one similarly employed, and give a tolerable idea of the probable expense of opening such a communication; on perhaps as difficult a ghaut, as to the hardness of soil, (being mostly decomposed rock, and so hard as to render it necessary to work during the rains) as is likely to be met with.

G. C. COLLYER,
ASST. CIVIL ENGINEER.

COIMBATORE, }
28th Sept. 1843. }

N. B. The average slope is actually 1 in 16.05 but it will be reduced to 16.08.

REPORT BY CAPTAIN E. LAWFORD ON THE IRRIGATION OF THE THIRD DIVISION.

CIVIL ENGINEER'S OFFICE,
THIRD DIVISION.

To,
The Secretary to the Board of Revenue, Department of public works.

Sir,

I have the honor to forward for submission to the Board of Revenue, copy of a communication addressed to Charles Cotton Esq. on the general state of irrigation in this Division, trusting that the information it contains, however imperfect, may be of use in directing attention to some principal objects, claiming the exertions of the Civil Engineers.

2. The wide extent of the Divisions, to which Bellary and Cuddapah were formerly attached, and the urgent importance of works in other quarters, precluded the possibility of that investigation of the wants, and capabilities of these central Districts, which is so greatly required, and hence, beyond the mere routine of ordinary inspections and repair, they remain an almost untrodden field.

3. It will not, I am sure, be considered as any reflection on my predecessors, (the last of whom exercised the functions of Civil Engineer over a tract of country comprising eight Collectorates), when I state that no detailed surveys of the rivers, nor plans of their irrigation, are on record; and until something of this kind is effected, each succeeding Officer will have to work out his knowledge at the same expense of time and labour, as those who have gone before him, from whose observation and experience, he can derive no benefit.

4. The inconvenience I have felt from the want of such guides to an acquaintance with my Division, has in great measure, influenced my present attempt to recommend to the consideration of the Board, the advantage of entering on a systematic examination of our chief rivers in these regions, and especially those two grand streams, which in fact are the only outlets for the waters of the extensive table land between the Cauvery, and Kistna.

5. These rivers, I need hardly specify as the Toombuddra, and Pennar, both of which, though under different circumstances, afford the fairest promise of success to energetic measures for developing their immense resources for irrigation.

6. I estimate the extent of surface drained by the Toombuddra and its affluents ere it reaches the first, and principal annicut at Wullavapoor, to be not less

than 7000 square miles: that of its greatest tributary (the Huggry) at about 8000, while the numerous streams of the Southern borders of the Nizam's territory, and those of the Northern frontier of Bellary, sweep over a range of fully 3000 miles more; so that this river carries out of Bellary District, the water of a region of 18,000 or probably 20,000 miles in superficial extent; and of this tract, a very large portion is deluged by the violent and protracted rains poured upon the Western borders and Mountains of Mysore.

7. Calculating the mean annual fall of rain, in this space, at the moderate average of 48 inches, and allowing one third or 16 inches for evaporation, absorption, &c. which, as the great body of water falls almost continuously upon a mountainous and undulating country, partly covered with forest, and almost destitute of tanks, will probably be a maximum, then it cannot be an exaggeration to say, that the quantity of water carried off annually by the Toombuddra exceeds 40,000 millions of cubic yards, which at 7000 yards per acre, (an average gathered from several calculations) would irrigate nearly 6,000,000 acres, or 9,000 square miles.

8. A similar amount results from a calculation, founded on a mean section, and velocity of the river, which for one hundred days in the year, may be considered to discharge 253 millions of yards per day, or 35,000 millions in the whole period; and assuredly more than 10,000 millions will flow off during the remainder of the year. During high freshes, I have seen the Toombuddra with a stream 800 yards broad, and an average depth of 5 yards, sweeping along at 5 miles an hour, and discharging not less than 600, millions of yards in one day.

9. The actual extent of irrigation on both banks of the Toombuddra, cannot exceed 20,000 acres, or about 30 square miles, demanding an aggregate supply of 140 millions of cubic yards of water.

10. The present number of main channels from the South, or right bank of the Toombuddra, is nine, but there appear to have been at a former period, three more, as the annicuts to which I have alluded in my letter to Mr Cotton at Moodalcatta, Soogoor, and Munchal, yet remain, though the channels are obliterated, which in cotton soil (prevalent near the sites of two of these works) would speedily be the case.

11. Whether the irrigation from these annicuts could be revived, I am quite unable to say, having never had an opportunity of giving them sufficient ex-

To,

C. R. COTTON ESQUIRE,
Member of the Board of Revenue.

SIR,

1. The long period, during which your communications of the 9th and 29th July last, have remained unanswered, has been owing chiefly to the hope I entertained of procuring from the Collectors of Bellary, and Cuddapah, certain statements regarding the principal works of irrigation in those Districts, from which to form an accurate opinion of their present and former condition.

2. My applications on this subject proving entirely unsuccessful, and failing to elicit any reply whatever, I shall proceed to offer such observations, as my own short experience, and limited means of information will allow.

3. The District of Bellary possesses but few tanks of considerable value, and a still smaller proportion are fed by streams of perennial supply.

4. The principal reservoir is that of Bookaputnum, formed by embanking the gorges of a range of hills, through which flows the river Chitravaty, a large and usually abundant stream, the surplus of which, after filling the extensive tank of Durmaveram, some miles lower down its course, supplies a number of small irrigating channels.

5. The Shinganinulla, and Anantapoor tanks, are the next in importance, but these depending on inferior streams, are very precarious in their returns.

6. The tank of Camlapoor is the only one accessible to the waters of the Toombuddra, which it receives in limited quantity, from the surplus of an extensive river-channel.

7. The following statement exhibits the value of the principal tanks in Bellary, the revenue being taken at the highest amount realized in the most favourable season, and exclusive of all deductions.

Tanks.	Highest net Reve- nue ex- clusive of Manium.	Circum- ference of Tanks when full.	
		M.	F.
1 Bookaputnum.....	22848	13	4
2 Shinganinulla.....	13248	11	5
3 Anantapoor.....	13002	8	2
4 Gurgee.....	9501	12	1
5 Durmaveram.....	7098	11	2
6 Canacul.....	8175	8	5
7 Darojee.....	7320	9	3
8 Dunaikenkerra.....	8586	5	5
9 Cotnoor.....	6384	7	1
10 Chinna Toombalum.....	6159	5	4
11 Yerratimroyencherroo.....	2700	8	5
12 Morabangul.....	5139	5	5
13 Kumbadoor.....	4515	8	1
14 Gooty.....	3822	6	1
15 Uggalee.....	5895	5	1
16 Moolakalade.....	4239	7	4
Total Rupees..	128631	0	0

8. The intrinsic condition of the tanks generally, except an one important particular, is superior to that in which they came into our possession, the personal attention and sound practical knowledge of the late Mr. Robertson having been for fifteen years bestowed on their improvement.

9. With few exceptions, the embankments are in excellent order, and the stone revetments, many of which have been rebuilt, are of very substantial construction.

10. But from the accumulation of silt, brought down by their supplying streams, the beds of most of these reservoirs have become so much raised, that they are no longer capable of retaining water sufficient for the irrigation of the lands formerly supplied by them; and although this cause of deterioration has been partially obviated by raising the embankments, yet such a remedy is not always applicable, from its involving the submersion of the lands of other villages.

11. A considerable proportion of land under some tanks has been rendered sterile, by the quantity of salt, or soda, which it now contains; a circumstance affecting chiefly the fields more remote from the reservoir, owing to the impurity contracted by the water in its passage to them.

12. Some loss of arable land appears to have been occasioned by the bursting of tanks, the effects of which, in sweeping off the rich soil, are often distinctly visible, though happily such accidents are now of rare occurrence.

13. Very few tanks, producing revenue on the cession of this District, have been suffered to fall into permanent ruin since that time; but there are many ancient bunds which were breached during the Native Government, and have never been restored.

14. The beds of some of these old tanks afford a very profitable dry cultivation, from the rich alluvium they contain; but of many the reconstruction appears advisable, as mere reservoirs for the use of cattle, especially in the black lands, where drought is often most severely felt.

15. Of late years, the restoration of wells and cattle tanks in the black land Talooks, had engaged much of Mr. Robertson's attention, and with very beneficial effects; extensive tracts of this rich soil having been in consequence brought under the plough, which must otherwise have remained utterly waste.

16. The absence of direct return from such reservoirs, has I believe proved an impediment to any considerable outlay on their repair; but no doubt can exist of their necessity, in lands so extremely destitute of water, as those now alluded to.

17. It is not from the mere quantity contained in their own beds, that these small tanks derive their chief value, but from the supplies they yield to springs,

from which wells, formed within their influence, are fed.

18. The river-channels of Bellary are of two classes, the first of which, issuing from the Toombuddra, are all maintained by annicuts, the second, and most numerous kind, are those drawn from the Pennar, Huggry, Chitravaty, and inferior streams, none of which are artificially raised.

19. In both cases irrigation is confined to very narrow limits on the banks of the rivers, but the Toombuddra Channels are certain and superabundant in their supply; while in the secondary channels the scarcity of water is often such, as to render the crops very precarious, and occasion serious quarrels among the ryots, whose labours under the most favourable circumstances, are unremitting, and severe.

20. I am not aware that any material change has taken place in the great Toombuddra channels, of which, owing to the comparatively small extent of dependent land, the aggregate net revenue, after all deductions for repairs, &c. is not more than 1,30,000 Rupees.

21. The annicuts constructed of large masses of uncemented stone, are maintained in efficiency; and the channels undergo an annual clearance, which preserves the regular flow of water, the yearly cost of these works being about 16,000 Rupees.

22. But in the revenue derived from secondary channels, a sensible decline has, I believe, been experienced within the last half century, owing apparently to the want of sufficient care to preserve the lands from the attacks of the river, and also from the overwhelming sands, drifted up by the high, and prevailing Westerly wind.

23. The banks of the Pennar and Huggry chiefly consist of soft loamy soil, readily yielding to the violent current of the river freshes, the annual encroachments of which on the fields are very perceptible; as well as the injuries thus occasioned to the channels, by being brought in close proximity to the bed of the stream, in which some have become entirely absorbed.

24. The enormous accumulation of sand on the East bank of the rivers, by which the channels are choked, and cultivation destroyed, is an evil, against which, though evidently progressive, no means of prevention have yet been attempted; and although the loss of revenue from this, and other causes, may be trifling in any particular locality, yet, from the numerous instances that have come under my observation, I am convinced the aggregate deterioration must be great, and the discouragement to cultivation serious.

25. The tanks of the Cuddapah District are much more numerous than in Bellary, but a few only are of great importance; of which the following account is believed to be tolerably accurate.

	Tanks.	Probable Revenue.
1	Cumbum.....	30,000
2	Budwail.....	20,000
3	Poremamla.....	10,000
4	Tippasamoodra.....	14,000
5	Wontimitta.....	8,000
6	Paut Cuddapah.....	10,000
7	Poly.....	4,000
8	Ootkoor.....	5,000
9	Mylapully.....	5,000
10	Owk.....	10,000
11	Pennagaloor.....	4,000
	Total Rupees..	120,000

26. The three first of these are exceedingly well situated, their bunds consisting in great part of low chains of hills, connected by artificial embankments, a very short extent of which is thus sufficient to produce a great surface and depth of water; but as none of the streams so intercepted, are very considerable, the supply, and consequently the revenue, of these fine reservoirs, is liable to much fluctuation.

27. A moderate number of tanks in Cuddapah depend on rivers, and are proportionately certain in their produce.

28. The tanks in this District have not received nearly the same attention, as those in Bellary, and their present condition generally is much inferior; the banks being worn, or washed down, and the facings dilapidated; the channels of supply, and works of outlet, being also in numerous instances, out of order.

29. This state of things, which has been repeatedly noticed by my predecessors, arises from the want of an adequate Maramut Establishment, of which Department, three Maistries are the only permanent servants allotted to the Collectorate.

30. The Tahsildars, and their Subordinates, consider tank duties as entirely secondary, and give them but little attention, for which a divided control affords them opportunity; while the temporary gomastahs, employed on Public works for six months in each year, are too frequently ignorant of the most common routine of the Department.

31. The consequence of this defective system is, that whilst in Bellary (although that District is but inadequately provided with efficient Maistries) the heaviest Monsoons are attended with the failure of perhaps three, or four tanks; in Cuddapah it is not unusual for ten times the number to burst during any season of generally heavy rains.

32. In Bellary, the breach of a tank is followed by careful enquiry into its cause, and such repair as to place it out of future danger; but in Cuddapah, it is

considered sufficient to give the reservoir present efficiency, by patching up the broken part, leaving the tank more liable than ever to a recurrence of the accident.

33. In Cuddapah, as in Bellary, the tanks are gradually losing their capacity, by the accumulation of silt in their beds.

34. Near the town of Cuddapah, I have noticed the people digging and removing the deposit for the purpose of manuring their lands; an excellent practice, which ought to be of universal adoption, but which can only co-exist with a higher profit on cultivation than is generally obtained.

35. The irrigating channels of Cuddapah are derived from the Pennar, Bahooda or Cheyair, Paupugnee, Chitravaty, Goonjinna, and other streams, which afford an abundant supply only during the rainy season; and the ordinary cultivation, being carried on under circumstances of difficulty and disadvantage, similar to those experienced in Bellary, has in like manner declined; though from the greater quantity of rain falling in the hilly, and woody portions of the former District, its drainage is far more copious than that of the latter.

36. The following Statement is believed to be authentic.

State of the works of irrigation in the Cuddapah District in Fusly 1845.

	In repair.	Out of repair.	Total.
Tanks.....	7340	1290	8630
Channels as follows.			
Channel from Pennar River..	14	5	19
Do. do. Paupugnee do.	83	12	95
Do. do. Gondecah do.	3	0	3
Do. do. Bahooda or Cheyair	137	34	171
Do. do. Suggelair do.	5	1	6
Do. do. Chetravaty do.	14	0	14
Do. do. Paularoo do.	4	0	4
Do. do. Jumpla do.	4	0	4
Do. do. Coomoodrooty do.	1	0	1
Do. do. Joranady do.	0	1	1
Do. do. Pinchanady do.	77	29	106
Do. do. Maundiva do.	76	13	89
Do. do. Coundainia do.	6	0	6
Do. do. Arjoona do.	23	3	26
Do. do. Gargaya do.	1	0	1
Total..	448	98	546
Channels from Springs &c....	927	134	1061
	1375	232	1607
Wells.....	55954	7834	63788
Annicuts.....	98	29	127
Total..	64767	9385	74152

37. In venturing to give official expression to my ideas on the prospects of improvement afforded by this Division, I am deeply sensible how scanty and superficial is the topographical knowledge, acquired within two years, and amidst a variety of incessant duties, of a tract of country extending over 25,000 square miles, containing several considerable rivers, and presenting much diversity of feature.

38. It shall be my endeavour to lay before you such views only, as have most strongly impressed themselves on my mind, and appear least liable to the imputation of a speculative, or visionary character.

39. The principal river within my range is the Toombuddra, the course of which, from its entrance into the Bellary District to the Kurnool frontier, is about 160 miles in length.

40. The advantages of irrigation from this stream, which divides the British from the Nizam's Territory, are shared between the two states, but I believe that the greater portion of water drawn from it, is on our side.

41. The source of the Toombuddra is among the Western Mountains, not far from that of the Cauvery, and it receives an extensive drainage from districts under the full influence of the South West Moonsoon; while in its course across the Peninsula, it is joined by smaller torrents, filled by the North East rains; so that judging from the volume and permanence of its stream, this river might be expected to have a very material effect on the irrigation, and revenues of the country.

42. But the fact is otherwise: the lands watered from the British side of the Toombuddra, yield some what less than a lac and a half of Rupees; those on the North bank might perhaps be valued at a lac more, making the total revenue derived from the River, 250,000 Rupees; a sum, moreover, which arises, I am informed, from a far higher assessment than the average of similar lands in the Southern Districts; and is consequently levied on a much less proportionate surface.

43. The limited extent of cultivation under the Toombuddra, is without doubt owing to the depth of the Channel, through which it flows with great impetuosity; and to the character of the ground adjoining its banks, which is in some parts rocky, uneven, and intersected by ravines, and in others falls rapidly towards the river.

44. Yet, notwithstanding these defects, the Toombuddra possesses features highly favourable to irrigation purposes; of which the advantage already taken, does not seem to be carried to its full extent.

45. The slope of its bed is considerable, as is proved by the velocity of the current; and it is traversed at intervals, by remarkable chains of rock, extending between islands, or stretching from bank to bank, so as to form, in a certain degree, natural dams; and it is in

such positions, that the ancient annicuts on this river, have, with astonishing judgment and skill, been established.

46. The Channels from these weirs are conducted in several instances along the sides of hills, and between rocks, which would appear almost to defy any such attempts; these results of Native ingenuity, and enterprize, being truly such, as to afford to us both example, and encouragement.

47. I have before observed, that no material decrease has taken place in cultivation from the Toombuddra; but there is strong reason for believing that its present extent may be enlarged, partly by the repairs of three ancient annicuts; which, having become disused before the District came into our possession, have never been restored to efficiency, nor can I ascertain that their capabilities have been sufficiently investigated.

48. The Royacalvah, the most productive of all the present Channels, actually flows for several miles through lands entirely under dry cultivation, which could at once be laid under water, if an increased supply were drawn from the river; a work of easy accomplishment, while much is at present wasted.

49. But the whole question, whether the waters of the Toombuddra may be applied more extensively to the irrigation of the Bellary District, can only be fairly answered, when that river is more thoroughly known, than the circumstances of the Engineer Department have yet allowed.

50. Second in importance is the Pennar, the sinuous course of which, extends for about 250 miles through both Districts, but deriving its entire supply from the Eastern side of the Peninsula; this river has by no means the abundant, or permanent stream of the Toombuddra.

51. Yet the extent of country drained by the Pennar, and its tributaries, cannot be less than 18,000 square miles, comprising a great part of Bellary, and very nearly the whole of Cuddapah; so that notwithstanding the dry state of its bed during the greater part of the year, the quantity of water carried off by the freshes must be very considerable.

52. I should estimate the aggregate amount of revenue derived from the numerous petty channels led from this river in the Bellary District, at about 80,000 Rupees; of which upwards of 60,000, are produced in the Yadakee, and Tarputtry Talooks, just before the Pennar enters Cuddapah; after which, it ceases to have more than a very trifling effect on irrigation, though its course within that District alone, cannot fall short of 100 miles.

53. The difficulties attending channel cultivation under the Pennar, and similar rivers, have already been noticed; and I think that any attempts at improvement should be directed in the first instance, ra-

ther to the removal of these disadvantages, which are heavily felt by the people; who would be better disposed to enter upon plans of extended cultivation, than can be expected while their whole energies are scarcely sufficient to maintain what they already possess.

54. The most effectual way of encouraging the present wet cultivation, and eventually augmenting its extent, would be by the construction of annicuts; not to throw off any additional channels, but to maintain permanent heads of water, or reservoirs, from which, those already in operation could at all seasons be supplied.

55. If example were needed to prove the benefit of such works, we possess it in the Toombuddra, the natural fall of which, would leave in its bed no more than a feeble rivulet after the last influence of the rains had passed; whereas the effect of the principal annicuts is sufficient to cause, in the dryest season, a depth, and extent of smooth water, which supplies the channels with a constant flow.

56. Such, I conceive, would be the case in the Pennar, especially if the water so retained, were devoted exclusively to present cultivation: the improvement would be attended with the happiest effect on the labours and means of the ryots, and prevent those serious disputes, now constantly occurring, and from which, even in recent years, loss of life has sometimes resulted.

57. The course of the Pennar affords some positions so singularly favourable to the construction of dams, that it is only wonderful they do not already exist; but for this, the former divided state of the country may perhaps account.

58. Through a part of Bellary, the river winds in a deep channel, through a rocky and undulating country, where its bed, traversed by masses of stone, is often not more than 150 yards in width, occasionally flanked by spurs from the hills, that would serve admirably as abutments for any work across the stream, which from this confinement emerges upon the level plains of Yadakee, where the most valuable channels are placed.

59. But the most striking feature of this river, is its passage through the hills at Gundicotta, where, joined by the Chitravaty, it rushes between perpendicular sand stone cliffs, 200 feet high, its own bed being from 120 to 150 yards across.

60. As the range in which this remarkable fissure exists, extends for about 30 miles, constituting a vast natural embankment, with no outlet besides this pass, for ten miles on either side, the formation of an annicut in that spot, would cause the river to swell into an extensive lake, without the necessity of any other artificial construction whatever.

61. Through two other chains of hills, and by passages resembling that at Gundicotta, the Pennar issues from Cuddapah into Nellore, in which District it is the principal support of irrigation.

62. It should here be observed, that the most splendid reservoirs of these Districts, and many of minor importance, are formed in a manner precisely similar to that now suggested, and that their influence upon springs is felt for many miles, and far beyond the limits of any cultivation from their own sluices; and it is also to be recollected, that tanks possessed of such natural advantages, are much less costly in their erection and maintenance, than those having the extended embankments which are required in a flat country, though this consideration would apply more to plans of increased cultivation, which, for the present, are not entertained.

63. In the formation of annicuts on the Pennar, I should adhere, as far as practicable, to the ancient style of construction prevalent on the Toombuddra, by building them of heavy masses of stone, laid without cement; such works answering sufficiently for the retention of the water, which at the same time, by its partial discharge through the interstices, carries off much of the sand that would otherwise accumulate above the dam, and thus also every part of the dependent cultivation receives a fair supply, of which it cannot easily be deprived, by undue appropriation.

64. Simultaneously with these works, the banks of the river should be secured, where necessary, from the destructive effects of sand, and water; and in such measures, with some encouragement, the ryots might be induced to co-operate, and by adopting the fascine revetments of Tanjore, protect their fields from the ravages of the stream.

65. The river Chitravaty, flowing from Mysore through the Southern limits of Bellary, fills the large tanks of Bookaputnum, and Durmaveram, and then rushes through a narrow valley, upon an open country, where, after supplying some inconsiderable channels, it falls into the Pennar, near Gundicotta.

66. This river is susceptible of improvements similar to those suggested for the Pennar, but to a less extent.

67. The Bahooda, or Cheyair, is formed by the confluence of several streams, draining the Southern Talooks of Cuddapah, which unite in a chain of hills, dividing the Roychoty, and Chitwail Talooks; and after winding for several miles in a deep valley, occupied entirely by its bed, the river bursts out upon a plain near Nundaloor, spreading to the breadth of a mile, and then again contracting its channel, passes through another valley, into the Pennar.

68. The value of irrigation from this river, within the short space occupied by the Nundaloor plain, cannot be less than 50,000 Rupees, but the lands are subject alternately to inundations, and scarcity of water, owing to the violence and rapidity of the stream, to break which, and preserve its flow for a longer period, would appear practicable, by constructing a series of

dams in the ravine through which the river passes with accelerated force.

69. The year 1804 was a season of unusual rains in the Balaghaut, and every part of the Ceded Districts bears some marks of the destructive freshes of that period; but in no place did the devastations equal their extent on this river, nor have the effects ever been recovered.

70. The Paupugnee, flowing from the South West of Cuddapah, enters the hills by a narrow valley near Vaimpully, and supplies a considerable number of Channels below that place, where, by the construction of a single annicut, an extensive sheet of water could be formed, to the great, and permanent benefit of the cultivation below.

71. The Huggry, or Vadavutty, rises in the Western Ghauts, and carries into Bellary a large portion of the drainage of Mysore, falling into the Toombuddra between Seeragoopah, and Rampoor. Although the supply of the river is abundant, being influenced by both Monsoons, yet its waters are but little employed in irrigation, though its rapid descent would probably render the formation of large channels a work of no great difficulty, especially by the aid of annicuts.

72. It would be of little use to enumerate the minor streams of these Districts, all of which, in their rapid slope, and other features, partake of the character of the larger rivers, and like them are capable of improvements that would greatly augment their utility.

73. The extreme uncertainty of the seasons in Bellary, greater than in most parts of Southern India, renders it of the highest importance to the permanence of the Revenue, and the welfare of the people, that increased efforts should be made to secure to the District, some of the prodigious quantity of water which passes through it from more favoured regions, but with a velocity which renders it comparatively valueless.

74. The Toombuddra, and Pennar, are unquestionably the main objects to which our attention should be directed, and on which judicious plans of improvement cannot be thrown away.

75. No public works on a grand scale have ever yet been undertaken within this Division; Mr. Robertson's works in Bellary having been confined to mere repairs of tanks, and channels, while latterly he made some efforts to improve their supply, by diverting the courses of hill torrents; but too often were the hopes he had formed defeated, and his expenditure rendered fruitless for many seasons, from the failure of local rains.

76. At the same time it must be remembered, that from the admirable order in which the late Principal Collector of Bellary has left most of the works of irrigation, the District is now in the best condition to receive plans of extensive improvement, while in Cud-

dapah our utmost efforts are often unavailing to secure the correct execution of ordinary repairs.

77. I cannot close these remarks without adverting to the difficulties likely to occur, in entering upon any great project of improvement.

78. I pass over the scantiness of the population, because such works as I propose, are intended in the first instance to benefit existing cultivation, which would give the ryots confidence in our ulterior plans, besides rendering them more capable of extending their labours.

79. But I allude chiefly to the opposition excited by any deviation, however beneficial, from established usages.

80. The absurd, and vexatious length, to which one community of Natives will often carry their hostility, to plans designed to benefit their neighbours, though unattended with any real detriment to themselves, has come repeatedly under my notice, and thwarted several minor projects; but as no great improvement, such as the formation of an annicut, tank, or channel, can be

effected without some interference with other lands, than those for the immediate advantage of which it is designed, I anticipate considerable trouble in undertaking such works, from the ignorance, and prejudices of the people.

81. The scarcity of workmen would perhaps be another obstruction to extended operations in this Division; but by careful management, and reasonable remuneration, this difficulty would probably be easily surmounted.

I have the honor to be

Sir,

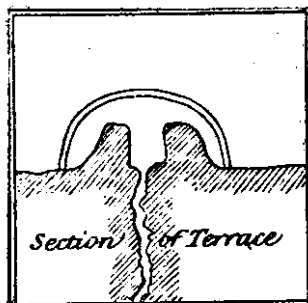
Your most obedient Servant,

(Signed) E. LAWFORD, LIEUTENANT.

Civil Engineer, Third Division.

Civil Engineer's Office,
Third Division,
BELLARY,
31st January, 1840.

Stoppage of Leaks.—The following ingenious, simple, and I believe highly effectual plan of overcoming those otherwise almost incorrigible things, large cracks upon the terraces of old buildings, has been communicated to me by my friend, Jas. Lawder, Esq., with whom it originated. These long fissures are often occasioned by the flexure of old beams, or by the very gradual subsidence of the walls of such antique mansions, and therefore the permanent cure of the leaks occasioned by them, is almost a hopeless undertaking; for as the fundamental cause and root of the mischief cannot be got at, any repair and stopping up of the leak, can only be temporary in its effects, and however carefully the crack may have been closed up, it after a



time gradually opens again, and the leak is found to be as bad as ever. Mr. Lawder's plan seems to be quite free from this objection, and to possess the great advantage, that when once done, it is done for ever. It is as follows. No attempt is made to fill up the crack itself, at all, but along the whole length of it, a ridge or little wall of 5 or 6 inches in height, is built on each side of it, firmly connected with the masonry of the terrace, and carefully plastered over, so as to do away with the possibility of any of the water accumulated on the top of the terrace ever getting into the crack and flowing down through it. Then a long semicircular pantile being made of sheet lead or copper, and merely laid over these two walls, so as to embrace and include them both, standing on the terrace, as shown in the annexed figure, the rain is effectually prevented from falling into the opening, and the leak is for ever stopped, even although the crack itself should widen very materially. As a cheaper substitute for the copper or sheet lead, Mr.

Lawder has used an arch turned in masonry, unconnected with the terrace, but occupying the same position as the metallic plate would, and he assures me that this plan has answered remarkably well.—Ed.

NOTES RESPECTING A SUBSCRIPTION BRIDGE RECENTLY BUILT ACROSS THE TAMBRAPOORNY IN THE TINNEVELLY DISTRICT.

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The following brief notes of the construction of the Ambasamoodrum bridge, are inserted principally on account of the valuable illustration they afford of the many difficulties which are inseparable from the construction of large public works in the interior, under the disadvantages of the employment of the agency of untutored and ignorant natives, and the anomalous and inefficient footing on which the executive Engineer department of the provinces is now established. The valuable details, herein given, will, it is presumed, be of the greatest assistance to young Officers hereafter charged with similar undertakings, by showing them how entirely different their labours are from the practice of Engineering in civilised countries, and how innumerable are the petty risks and causes of failure which have to be foreseen and guarded against in this barbarous land. For this reason, the history of the disasters attending the execution of this work has been thought more suitable for introduction into the present volume, than any account of the erection of the many other magnificent and useful structures of the like kind, which have of late years been raised in different parts of the presidency, and which, under more favourable circumstances, have less to record for the guidance and instruction of future Engineers.—Ed.

The Ambasamoodrum subscription Bridge was slightly alluded to in a paper on bridge-building printed in the first volume of the transactions of the Corps; and a suggestion has been made, that an account of its executive operations should be prepared for circulation in the second series of professional papers now being collected. Had I anticipated that a record of my employment, at so early a period of my service, would prove acceptable to my brother Officers, it would have been my endeavour, by more detailed notes, to have met in a fuller manner than I may now be able to do, the views expressed by the Editor of the former papers. With this apology for what may seem defective, I now beg leave to offer the following observations.

A good road, adorned by spacious avenues, formerly led through Madura, Strevilipootoor, and other large towns, to Cape Comorin, then, and still famous as a place of great resort for pilgrims and devotees.

This route passes near several wealthy Villages, inhabited by weavers and cloth merchants, and is not less adapted for facilitating the commercial prosperity and enterprize of the Country, than for the supposed spiritual advantages, which the Naik chiefs, to whom its construction is attributed, were chiefly anxious to secure. During the disturbed period, previous to the introduction of British authority, it had, however, fallen into decay; and has only recently been restored at the recommendation of the Sub Collector. The large trading towns of Ambasamoodrum and Culladacoorchy, are both situated on this road, but separated by the deep and rapid stream of the Tambrapoorny.

In the year 1838, a paper was circulated by the Sub Collector, Charles Bird, Esq., setting forth the advantages of a permanent bridge to connect these two towns, and inviting the Native Community at large, to

form a voluntary association for contributing the funds necessary for so desirable an undertaking. This paper, aided by the exertions of Soolochina Moodelliar, the influential and intelligent Naib Sheristadar, and its object being promoted by his liberal example of a handsome donation of 700 Rupees, had the effect of dispersing the apathy of the Indian character; and the proposal became so attractive in the eyes of the inhabitants, when they learnt that a suitable inscription on a granite pillar, would perpetuate the memory of the subscribers, that a sum of 20,000 Rupees was collected without difficulty.

The branches of the river Tambrapoorny rise in the Western Ghauts, and run as Mountain torrents in rocky and precipitous beds, till they unite, and forming a magnificent cascade, fall into a large basin at the foot of the Hills, near Paupanassum. Thence the river flows through a comparatively level country, which it irrigates by means of channels led from dams across it. At Ambasamoodrum, after a distance of 16 miles, the bed for the first time is found free from rock, and has a breadth of nearly 500 feet. The river is affected by both monsoons. In the south-west monsoon, the usual depth of the freshes is 12 feet, and in the north-east monsoon, the river has been known to attain a height of 20 feet. Thus, with the exception of 5 months in the year, it is always liable to freshes, and at no period is it actually dry.

The site for the intended work, was selected by Captain Faber, who prepared a plan (See plate II.) which allowed 9 elliptical arches, each of 45 feet 6 inches span, 2 feet thick at the crown, with a rise of 11 feet 6 inches, to rest on 8 piers and two abutments, with the streamward cutwaters faced with granite; the piers and abutments to be 12 feet high, the piers 7 feet 6 inches broad; the abutments 10 feet at the top and 12½ at base, with buttresses of 6 feet. The extrados to be bounded by

elliptic curves; the width of the arches 16 feet, and of the road way 14 feet, the piers and pilasters projecting 6 inches beyond the general surface. The cutwaters are triangular prisms extending outward 6 feet, and as high as the piers.

In acting upon this project, large rough stones were used for the foundations, which were about 8 feet deep, and rested upon rock; with the exception of the northern pier, which was built upon gravel, at a depth of 14 feet below the bed.

With the exceptions noticed, the whole work was constructed of bricks, and stone lime mortar, collected, made, and burnt near the spot. The writers personal superintendence commenced from the 21st February 1839, when the two abutments, and the 4 southern piers, had already been raised to their full height, and a fifth pier nearly completed. The works were rendered very tedious by the difficulty of drainage; a cut below the site, though always filled with a running stream, was not sufficient to keep the excavations dry; but by the help of piccottahs and Malabar Wheels* the water was kept sufficiently low to place the large stones, and fill up the interstices; the upper course only was laid in mortar. The daily rate of progress to the piers above water, depended upon the supply of cut stone, which was furnished by contract. The addition to their height averaged about $1\frac{1}{2}$ feet per day.

Dykes were thrown up to protect the new work, and the water was led as far as possible from the spot.

The construction of the centring for the first arch was commenced on the 28th of February, 1839, by building up the temporary pillars of brick in mud, 3 feet square, on which it was to be supported. The second centre was begun on the 2nd of March, both were completed by the 21st, and the arch work put in hand on the 2nd of April.

The centring made use of is delineated in Plate II. Figure 5.

In forming it, the upper exterior edges were first carefully fashioned to the correct semi-ellipse, by the use of pegs placed in the *foci*, and a line attached to them equal in length to the greater axis or span of the arch.

The space included between these external moulds, was next worked up to its proper surface, by loose bricks disposed cellularly, in order to diminish the weight, and plastered with tenacious clay. This coating was then floated, and corrected with the straight edge and level, till the correspondence with the outside guides was complete; lastly, a little sand was sprinkled over the whole surface, and in half a day, the mould was dried by the sun, and very hard.

The arch bricks were of various forms and dimensions. The moulds were prepared by Captain Faber, so as to suit the curve generally, and to form a complete bond for two alternating courses.

They were numbered from 1 to 4, and were laid as shown in Plate 3. Figures 4 and 5, in which may also be seen the form of the bricks, increasing in thickness towards the back, and bevelled to fit the curve. The key bricks (Nos. 5 and 6) were each 12 inches long, and 5 inches thick; No. 6 was placed above No. 5, the bottom of the latter being 4 inches broad, and the top of the former 5 inches, with a gradual slope up from one to the other; in driving them, they were placed with their breadth parallel to the road way, so that the pressure should not act in the direction of the weakest dimension.

The bricks thus moulded, though partaking generally of the character designed, were ill burned. They were rubbed down to the proper shape. In the first arch, the bond was scrupulously adhered to; and by putting sometimes a portion instead of a whole brick on the outside, the joints were made to break bond, so that scarcely any two were in the same plane.

In the arches which were built afterwards, the different numbers were laid in heaps on the work, and the bricklayers selected by the eye those which they required in each place, and which their former practice had taught them to choose with sufficient accuracy. A simple bond also was adopted, which saved time, though it caused a greater wastage, since the bricks were obliged to be cut to make them break joint.

While the arches proceeded, drains were worked in at the angles of the pilasters, or projecting faces above the piers; and when the work had advanced to within about 3 feet of the crown on each side, the courses were all gauged, and at length the key bricks, the sides of which were rather more inclined than they should have been, were driven tightly in, by means of heavy iron bars, the trowel being placed on the top of the bricks, lest the blow should split them.

To get the proper direction of the voussoirs, nails were driven into the mould at a foot apart, and a board being fixed along the axis of the ellipse, corresponding nails at distances previously calculated were driven into it. A line passed from one nail to the other served as a guide to the bricklayer.

The courses in the 5 feet of archwork nearest to the spring, were directed to a point in the transverse axis, at a distance of 6 feet 6 inches [which was a near approximate radius of curvature to this portion of the ellipse (See Plate III. Figure 4.)

Malabar Wheels.—This useful and simple little auxiliary to the baler, is so little used, that a few words descriptive of its form and application, may not be unwelcome.—The wheel consists of six boards, radiating from a central axis and strengthened by intermediate struts. The wheel works in a water tight case, shaped like a quadrant, described by a radius a little longer than the floatboards; and this case is fitted into the embankment containing the water to be drained.—A reference to Plate III. figure 7, will show how the rotation of the wheel, which is turned by hand, causes the discharge required.

On the 12th of April, the spandril arch over the first pier was constructed, and immediately uncentred.

The thickness of this little arch was 15 inches, and it formed a semi-circle of 3 feet 3 inches inner radius. Its length was 14 feet, so that the spandril walls, which were 2 feet thick, closed the openings by 1 foot, and bonded into the surface one foot. To perfect this connection both ways, projecting bricks were left in the alternate courses, as shown in Plate III. Figure 6. Over the large arches also, projecting bricks were left, to connect them with the side walls.

Eleven days after the keying of the south arch, the process of uncentring was begun, but with such ignorance and want of thought, that the outside edges were completely disengaged from their moulds and supports, whilst the intermediate space rested on the stuffing. This occurred during the brief half hour that there was no European superintendence. In consequence, two large exterior portions, having separated from the mass of the arch, fell bodily outwards, and the whole arch had to be taken down and rebuilt.

This unforeseen accident, suggested the subsequent use of exterior timber cramps, with transverse straps (See Plate III. Figure 3,) which effectually checked any lateral movement. Similar precautions would seem to form a very desirable portion of all Indian bridge centres—After this, the upper parts of all the centres were removed, and built up again; the beams over the pillars having been placed on wedges playing on iron rollers, the lower portion of the wedge having a small catch, (See plate III. Figure 2) it was intended that this should be sawn off, before striking, and the wedges moved with a line fixed in the hole, and the rafters were cut to allow them to close together in sinking.

On the 22d of May, when I returned from a temporary absence, the south arch, or No. 1. was found again nearly completed; but during the illness of the head maistry, his deputy had constructed the mould, and it was so misshapen as to be nearly flat for a considerable space towards the crown. This unhappy malformation, combined with the after sinking, caused the curve to bulge downwards, slightly, rendering this arch less pleasing to the eye than any of the others. It was keyed on the 24th of May. The 2d arch was completed on the 25th, and the 3d on the 31st of the same month.

The freshes having now begun, though as yet moderate, it was considered advisable to draw the works to a close for the season. The temporary pillars of the 4th centring had been built of brick in chunam, to a height of 12 feet, they were now further protected by a front and rear wall stretched from pier to pier, and the exposed part of the mould was protected by plaster, so that this centring, which was intended to remain during the freshes, might not be injured

by the water. A sufficient portion of the arch No. 4 was built up to form a counter thrust to No. 3.

The next object being to strike the three finished arches, this was now set about in a different manner, in order to quiet the fears of the workmen, none of whom had ever seen so large an arch before. The bricks were taken out with the hand, from below, at small intervals, so as to leave the arch supported, as it were, upon a great number of little pillars, instead of one solid stuffing. This process engaged them three days, and on the fourth, the men standing on the scaffolding at the sides, knocked away these supports with long sticks, headed with iron points and hooks. In this manner, the south arch was successfully struck on the 4th of June, and the workmen, now beginning to put confidence in this method, it was thought inadvisable, in striking the other centres, to use the wedges above described, and in like manner they were also successfully struck. While the centring of the second arch was being removed, the water suddenly rose and saturated the brick and mud pillars; on the night of the 6th and on the morning of the 7th of July, only two rows of pillars remained, which were speedily removed, and the arch took its bearings satisfactorily; the 3d arch was struck on the 10th. These arches were allowed from the date of keying 11, 13, and 10 days respectively, and their subsidence at the crown was about 6 inches.

From this stage of the undertaking, I was absent in the Madura District until the 10th of March, 1840.

In September and October 1839, the period intervening between the monsoons, the works were, by the order of the Civil Engineer, continued under the direction of the Tahsildar and maistry; and by them the remainder of 4th arch, and the 5th, and 6th, were turned; also a part of No. 7, as counter thrust to the latter.

It was hoped, that after the completion of the three southern arches, the close imitation for which native bricklayers and maistries are remarkable, would have been sufficient to ensure a safe prosecution of the work; and that the exaggerated view so generally taken by the natives, of the difficulty of Bridge building, would have given way, and no longer served as an obstacle to the construction of similar works for the general benefit; but this hope was disappointed.

The maistries attempted to strike Numbers 4 and 5, simultaneously; but, through some mismanagement, the arches fell, and the whole of the piers having been calculated to support equilibrated arches, and unable to resist the horizontal thrust, were partly pushed over.

Thus the counter thrust to No. 3 being removed by the fall of No. 4, its pier was pushed out, and the arch fell. The same occurred to No. 2, but No. 1 remained standing, as shewn in Figure 6, Plate II: perhaps

because it had been longer built; or it may have been sufficiently supported by the mass of masonry remaining over the pier. No. 6, and a portion of No. 7 remained on their centrings.

The works were in this state, when the then acting civil Engineer, Lieutenant Best, first inspected them, on the 26th of November 1839, and reported that the 2d, 3d, 4th, and 5th arches had fallen.—The separation of the arches took effect in nearly vertical planes. The piers were left standing, and above each of them remained a portion of the arches which it supported.

On the 5th of December 1839, Lieutenant Best again visited the work, and the water in the river having fallen, he found that the 3d pier was cracked horizontally, about 2 feet above its foundation, and moved towards the North $\frac{1}{4}$ of an inch. Soon afterwards I rejoined the work, and having tested the 2d pier with the plumb, it also was found to be $\frac{1}{4}$ inch out of the perpendicular. Minutely examining the foot, a horizontal crack was discovered close to the foundation. The whole body of masonry had moved Northward nearly $\frac{1}{4}$ of an inch, thus showing that the fall of the 2d and 3d arches depended upon the same cause, and that the counter thrust having been removed by the fall of the 4th arch, the perpendicularity of the 2d and 3d piers was destroyed by the horizontal thrust, and the piers, being pushed outwards, permitted the downfall of the arch in mass.

Lieutenant Best immediately gave orders for rebuilding the 3d pier, and removing the broken masses of masonry, the remains of the arches. He also directed, in order to save time, that the haunches of the arches should be built to the height of 4 feet, without centring. This, from the inclination of the voussoirs, was done easily enough.

The advantage was afterwards felt, when the works were pressed for time. These portions of archwork became hard before the rest, and when the centrings were struck, we did not observe the vertical cracks which had always previously showed themselves at the angles of the pilaster over the pier, and at which the separation was found to commence in the arches that fell. We noticed, however, that the junction between the old and new masonry of the arch was prominently visible before the plaster was applied, and even afterwards to a practised eye. This may have arisen from the unyielding nature of the part that had long been dry, compared with the rest, and perhaps the difficulty of exactly fitting the mould to the work already done, contributed to this result.

In the next diary of Lieutenant Best, he fixes the least time for the arches to remain, reckoning from the date of keying, to be 20 days, and observes "indeed, it is, in my opinion, advisable that the centrings of brick arches of large dimensions should remain as long as

they can, without preventing the river from flowing; that is until the season of the freshes."

"It might be useful to slacken the centrings a little, in order to allow the bricks to close in and compress the mortar, but this should be done immediately the arch is completed; and with this view, part of the centrings will be supported upon wedges, driving in which will effect this object without weakening the support of the arch during the period allowed for the masonry to consolidate, which I have above fixed at a minimum of 20 days." Lieutenant Best at the same time directed that the centrings should be made as shown in Plate III. Figure. I.

The difference of the behaviour of the arches struck after 12 days, and those struck after 20 days, has shown the value of Lieutenant Best's remarks.

The 6th arch which had remained on its centre more than 6 months, did not subside at all, when the centre was removed, but when the weight of the superstructure was added, it sunk 2 inches.

With regard to the fall of arches 4 and 5, the accounts of the tahsildar, maistry, and the marammut superintendent, differ so much, that it is next to impossible to assign the true cause.

It appears, however, that gauging the latter courses was omitted, so that by the side of the key brick, a space of an inch or more was left to be filled up with fragments and chunam.

This may help to account for the accident.

The disaster which has been described as taking place, the moment that the Talook authorities were left to their own resources, indicates one of the greatest difficulties that projectors of public works have to contend with, in South India. It is not possible to say what particular precautions were omitted, or to what error in workmanship the accident is to be attributed; but the broad fact is obvious, that processes had been shown for building an arch that would stand. From ignorance of the value of each precaution, and of the tendency of each arrangement carried into effect before their eyes, it will have been noticed that the moment European superintendance was withdrawn, not only did failure occur in the operations conducted by the native servants of the Talook, but those previously brought to a successful termination, were involved in the general overthrow.

The subsequent operations of the bridge were carried on without accident or interruption.

The arches were commenced from the North side, and continuing the same numeration as before, the 9th or North arch was keyed on the 6th of March, and No. 2 pier, which has been described as out of the perpendicular and cracked at the bottom, was taken down and rebuilt.

In the archwork, 16 bricklayers were daily employed on each arch, till towards the latter courses, when the space became too confined, and their number was reduced.

The work, when the thickness was between 2 feet and 2 feet 6 inches, averaged about 6 feet a day, measured along the curve of the intrados. Each foot also, so measured, contained $5\frac{1}{2}$ courses, and each course 110 bricks, where the thickness of arch is 2 feet. This makes nearly 4000 bricks per day for 16 workmen, at 250 each. In keying, 24 key bricks occupied 6 feet in length across the arch, and took 4 men 55 minutes to drive.

The following table shows the subsidence of the arches, and the dates of their being keyed, and their Centring struck.

No. of Arches	Date of Keying	Date of Striking	Interval	Subsidence Measured 12 hours after Striking		Measured after Completion of Superstructure
				Crown Sunk inches	Haunch Rose Inches	
9	6th March 1840	28th Mar. 1840	22d days	3	14	$4\frac{1}{2}$
8	13th do.	2d April 1840	20	2	$\frac{1}{2}$	$4\frac{1}{2}$
7	14th do.	4th do.	21	$2\frac{1}{2}$	$\frac{1}{2}$	$4\frac{1}{2}$
6	9th Oct. 1839	10th do.	184		None	2
5	6th April 1840	28th do.	22	$2\frac{1}{2}$	$\frac{1}{2}$	4
4	16th do.	6th May 1840	23	$2\frac{1}{2}$	$\frac{1}{2}$	4
3	28th do.	18th do.	24	$1\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{2}$
2	29th do.	19th do.	20		—	$3\frac{1}{2}$

On inspection, the plan will readily show the difficulty of removing the stuffing between an immovable frame, and an enormous weight of superincumbent masonry; and indeed the utmost vigilance of supervision was required during the whole process.

On commencing the operation, a few clever bricklayers were employed, working from below, in gently loosening and removing every third course of bricks in the direction of the breadth, as well as of the length of the bridge; This having been done, the next thing was to clear out an opening over each transverse beam, because if that stuffing were left to the last, the weight thrown upon it would have been enormous, and the pillar would have been so jammed that its removal would have been difficult.

The final supports were left in the middle of the bays, by which arrangement the elasticity of the palmiras, of which wood the timber parts of the centring chiefly consisted, permitted a certain degree of adaptation to the change of shape, which the curve was preparing to assume.

At the same time that the stuffing over the beams was removed, a space was also freed, about 4 feet wide, beneath the middle of the arch, and the solid portions which now remained were similarly sub-divided, so as to allot the greatest number of supports to the parts of the arch which pressed with the greatest weight.

It had previously been remarked, that directly after the application of the keys, the whole ellipse endeavoured so far to take its bearings, as to be lifted off its mould near the haunch, and in this manner separate itself from its centring for a distance of one sixth of the semi-ellipse; or in other words, that the two up-risings amounted together to one-third of the length of the total curve, leaving only two-thirds of the arch insistent upon the mould.

The part of the centring thus shown to be unnecessary was therefore removed at any convenient period, and good deal of time was gained in the whole archway.

This appears one great advantage of the *arche surbaissée* and is not obtained in any segmental curve.

It should be remarked, that this partial self striking was observed by M. Perronet, and described in a very able memoir on centring and uncentring large arches which that famous bridge Architect read before the Royal Academy at Paris.

The proportion which he lays down also corresponds precisely with the measurements given above, and which were taken before meeting with M. Perronet's report.

By attention to the preliminary expedients already detailed, the support was so much diminished (although left so disposed as not to disturb the arch) that on the day of striking, less than an hour's work sufficed to complete the operation; 14 men being employed, 7 on either side, to each of whom, a particular task was assigned.

In striking the Northern arch, the fears of the workmen were so great, that they hesitated to knock away the supports to the outer edges, and the arch had time to sink between them, as it were, and a longitudinal crack appeared from below, but did not extend far into the masonry, and was not at all visible on the extrados; see exaggerated sketch Plate III. Figure 3, after the work people had gained confidence by success, this did not again happen.

It may not be uninteresting to remark, that the perusal of Captain Smith's valuable experiments upon the advantage of an increased proportion of Jagghery in mortar, led to a greatly augmented use of that auxiliary in the latter part of the operations just described, and that a series of experiments conducted by the author of these Notes, fully corroborated the results arrived at by Captain Smith.

Fig. 1.

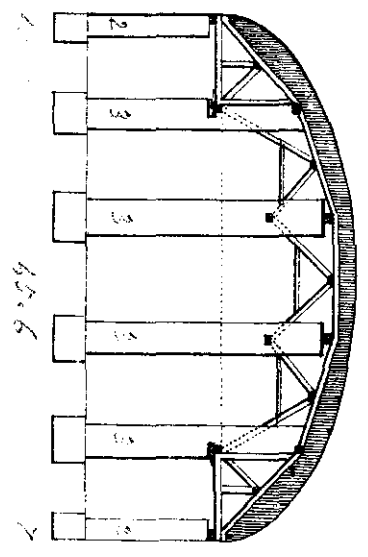


Fig. 2.

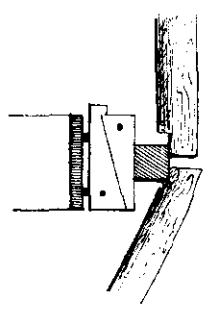


Fig. 3.

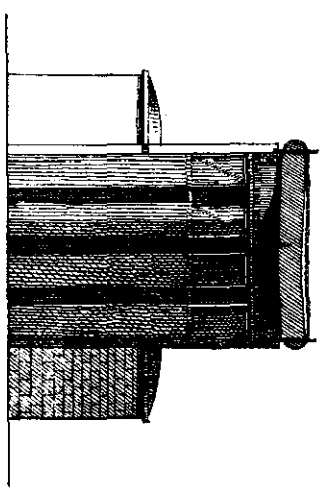


Fig. 4.

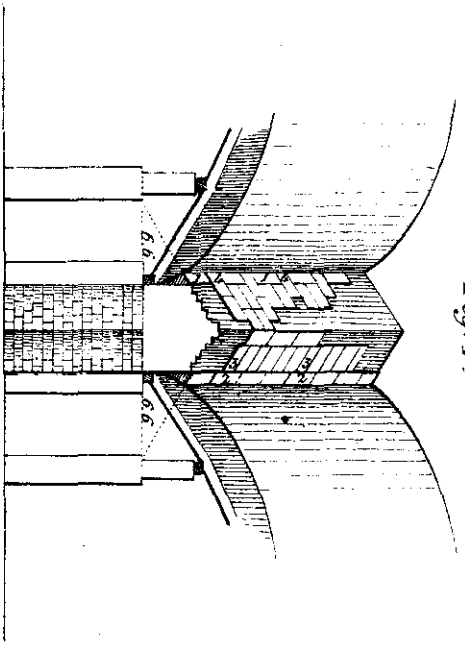


Fig. 5.

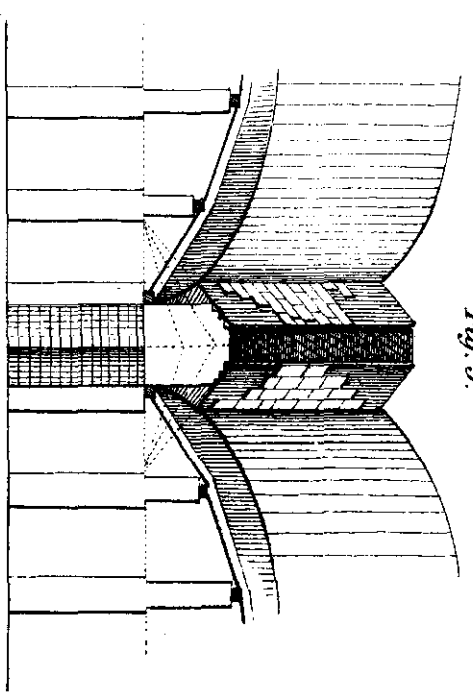


Fig. 6.

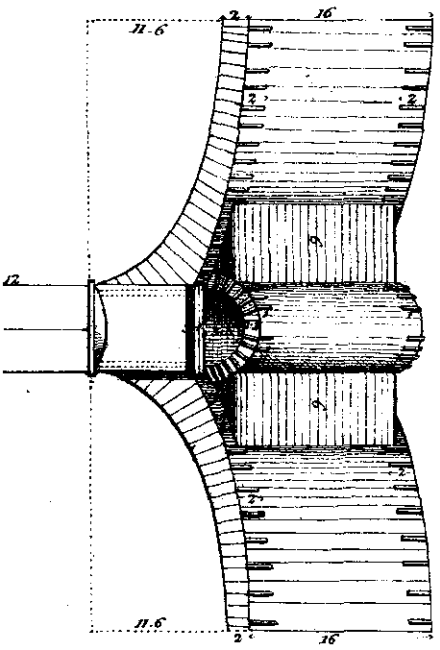
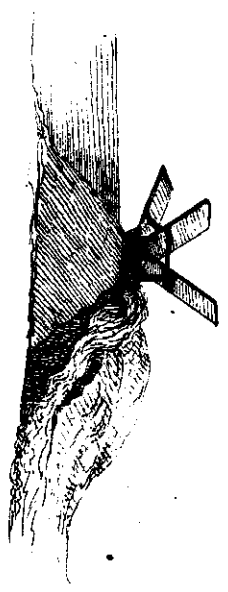


Fig. 7.



In the desire rather than the expectation of contributing to the practical knowledge of Bridge building in India, many minute and probably tedious details have been entered into. The remaining operations of placing the superstructure and filling in the road way may therefore be briefly passed over by the mention of their completion in a few days after the uncentring of the arches.

Notwithstanding the accidents that befell the work (and they teach very clearly how indispensable European superintendance is) its cost, 18000 Rupees, was only 2000 Rupees more than the original estimate.

The Bridge was opened for general use before the first freshes of the year 1840 came down the river; and the public are in the full enjoyment of the convenience obtained by their own liberality, guided usefully as it was by the Revenue Authorities of the Government.

A very pleasing consequence of this success is the spirit of self confidence and enterprize which has been diffused throughout the neighbourhood, and which showed itself in the alacrity with which a scheme was organised for bridging another river by joint contribution, at an expected outlay of 2000 Rupees.

A yet more remarkable result of the undertaking described in this paper, is the munificent proposal on the part of the same liberal minded Native Gentleman, Soolochina Moodelliar, to whose influence and example so much of the success of the Ambasamoodrum Bridge was attributable, to build at his own sole and unassisted cost, a handsome Bridge across the Tambrapoorny, between Palamcottah and Tinnevely.

This proposal, which concerns no less an outlay than 40,000 Rupees, is yet more striking, because the private estate of the projector of this noble work is by no means large. A contribution of not less than a third of his

patrimonial inheritance, for the general benefit of the community, entitles Soolochina Moodelliar to a very high place indeed amongst the benefactors of the Public, whether in this or any other country.

It is most encouraging to notice, how effectual a little judicious management has been, in giving a stimulus to the Native character, and in developing an activity and liberality which, perhaps unjustly, or too hastily, have been supposed foreign to the inhabitants of India.

It cannot fail to strike the attention, with what simple appliances, and in how short a period, a few village bricklayers, who never saw a similar work before, succeeded in carrying the subscription bridge into effect; and the general want of public works of this nature seems not less extraordinary than mortifying, when the ease of supplying the deficiencies is dwelt upon.

Climate alone holds out many advantages for bridge building. The facility of obtaining excellent and cheap materials, saves all anxiety regarding one of the most important considerations; and the economy of workmanship is very remarkable, when compared with the rates of labour elsewhere.

The actual condition of the country, however, with its imperfect communications, and general want of bridges, would make it appear that hitherto the establishment of public works had not been sufficiently noticed, and dwelt upon, to make the progress of improvement so rapid as the wants of India, her contribution to English wealth, and regard to our own reputation might have fully warranted us to expect; and all must agree in this hope, that this deficiency, a source of common surprize and regret, will be gradually removed by the orders of aliberal and enlightened Government.

ACCOUNT OF THE METHOD OF CLOSING THE NAVIGLIO GRANDE AND MUZZA, (CHANNELS OF NAVIGATION AND IRRIGATION IN LOMBARDY) A TRANSLATED EXTRACT FROM AN APPENDIX TO A TREATISE ON THE CORROSION OF RIVERS, BY BERNARDINO FERRARI OF MILAN.—BY CAPTAIN S. BEST.

The following note describes the cavallettoni or *horses* used in some parts of Italy, for temporarily closing the heads of the channels. These nearly resemble what are called "modussil" in Tanjore and other places, where they are used to protect the banks of rivers from the effect of corroding currents.

In Tinnevely and in the Cauvery in the Coimbatore District, I formerly proposed to construct "wagganies" or "jetties," to divert injurious currents, in a manner similar to that which Ferrari describes; and I think that the introduction of this plan to the notice of our brother Officers, may at any rate supply them with a useful hint in their management of large rivers.

The first things required are frames, called *horses*, each formed of three beams or poles of oak, or green elm, or other heavy wood. They may be either of equal length all three, or two (*the legs*) of equal length, and the third (*the tail*) much longer than the others.—These poles are fastened together at the top by strong bands of withes. The two *legs* are then spread out, till their distance apart at the foot is equal to half their height; and the *tail* is made to incline, so that the *legs* may be vertical; three horizontal bars at half the height well nailed together retain them in this position, and are called the *fringe*.—The horses should be so high, that when set up, all the *fringes* may be at one level, and just above the surface of the water.

The depth of water at different parts having been previously ascertained, in order to proportion to it the size of the *horses*, they are carried in boats and placed so that the *legs* may be vertical in the direction intended for the temporary dam, and so that a *leg* of each be placed in succession close behind that previously fixed. After they are placed, a planking is laid on all the *fringes*, and loaded with stones to render the whole firm.—The two bars of the *fringe* that unite the *legs* with the *tail* are made long, in order that the planking may be continued behind the *tail*, and that there may be more space to place the weight and stones on; and to strengthen this planking still more, underneath the *fringe* are placed other pieces of plank nailed together.—Long beams of split pine, straight and strong, are then placed in front and below the *fringe*, well nailed and tied

together, and as much below the surface of the water as is possible.—Other pieces are then placed as struts, which are fastened to the *head* of one *horse* and the *legs* of the next, above the *fringe*; and also others to the *tail*, so that each *leg* has one strut, and each *tail* two.—The extreme *horses* are fastened to the bank in some convenient manner.

Next, are required fascines, made cylindric, and too strong to bend with the force of the current, and so long that they exceed by two feet the depth of the water.—These are placed vertically, being sustained by other bars placed below water, and which, without being fastened, are kept in their places by the pressure of the water.

The work must begin where the current is strongest, and must be done quickly, all necessary preparation should be made beforehand.

Small bundles of green brushwood, previously filled with stones, must be placed after the fascines, to form an edging, at the foot, and then a quantity of gravel and sand should be thrown on, out of the boats.

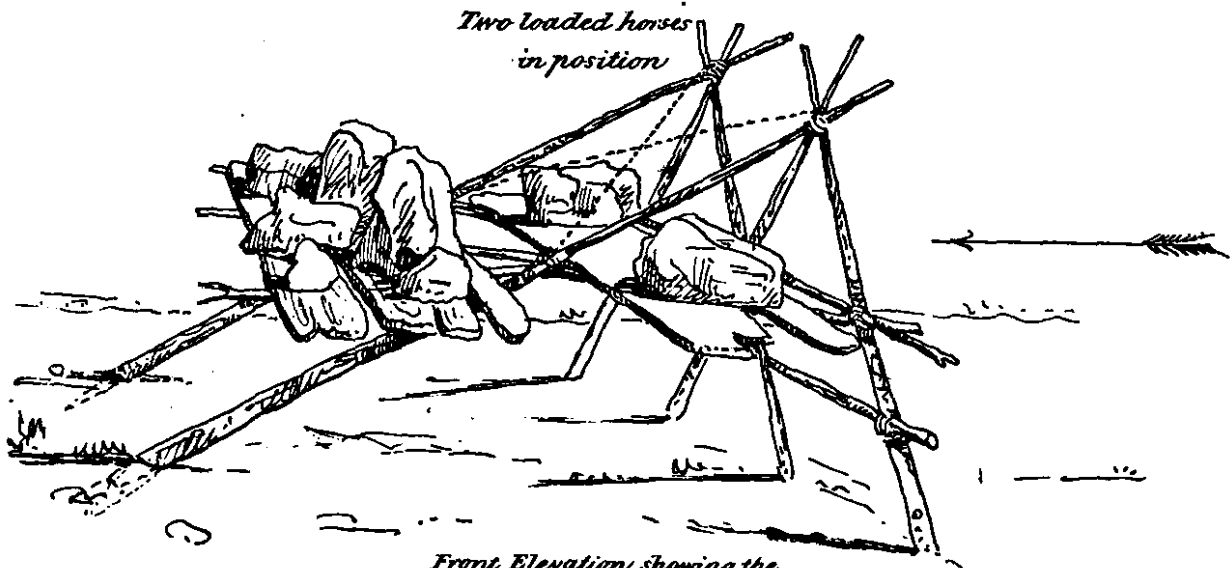
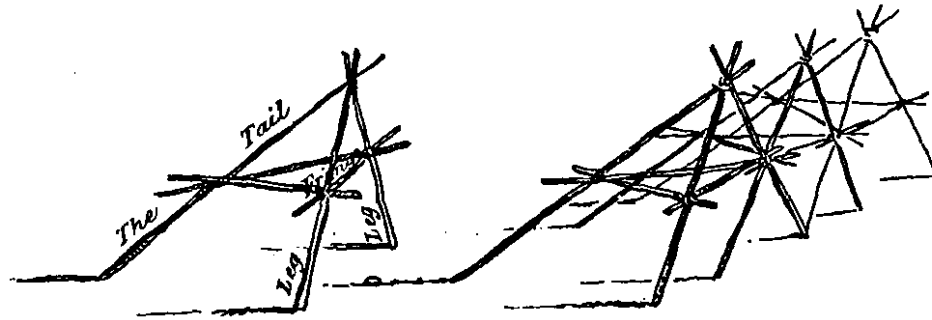
Finally, having sewed together enough cloth, in width to correspond with the height of the fascines, it is rolled on cylinders, and being put into boats, some of the men standing on the planking take one end of a roller, and others in the boats hold it lower down; and thus the cloth is unwound, and immediately nailed above to the bars of the *fringe*; made to spread downwards with poles &c. kept down by means of stones thrown on it, and covered with another stratum of sand and gravel at the foot. One length of cloth is placed after another, taking care that the ends lap over one another a yard or so; and terminating with a turn towards the bank, where it is fastened.

This kind of temporary dam is easy to erect or take away, and very strong, if weighted in proportion to the size and strength of the current.—It is useful and fit to be adopted in all situations, except in torrents and in rivers that are subject to sudden irruption of large bodies of water.

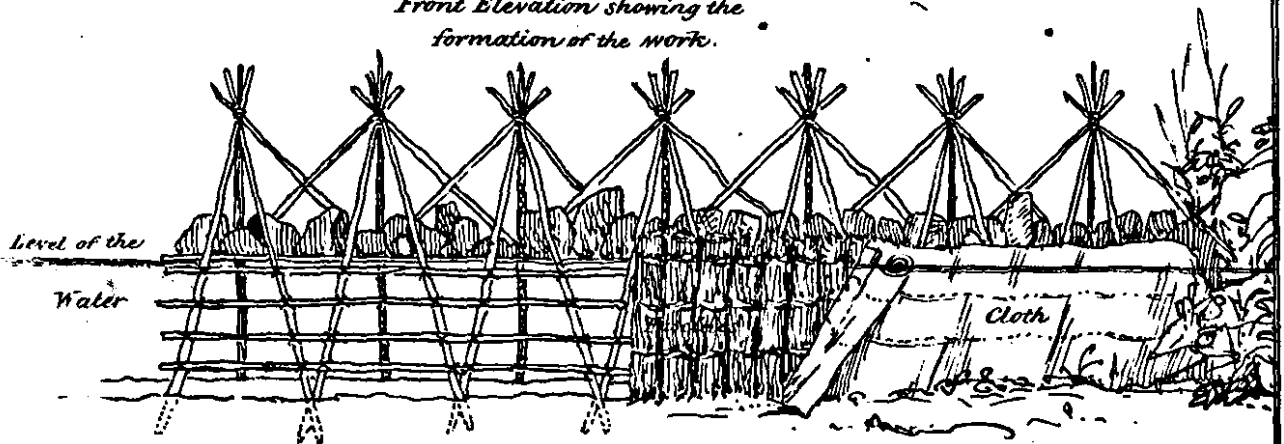
The accompanying drawings given in Plate IV. further explain the construction of it.

*Method adopted in Italy for diverting
Currents by a sea.*

Pl. IV.



*Front Elevation showing the
formation of the work.*



REPORT UPON A DEFECT IN THE SYSTEM OF THE INDIAN CURRENCY, TOGETHER WITH
A SUGGESTION FOR ITS REMOVAL—BY CAPTAIN J. T. SMITH F. R. S.

I have taken the liberty of inserting this paper, in the hopes of attracting some attention to a subject which appears to me very important to the success of the attempt to establish an uniform and sound monetary system throughout India. While so great difficulty and distress are felt in every province for want of the circulating medium, and the necessary facilities for exchange are so scantily supplied, one cannot help feeling impatient for the removal of a cause which greatly impedes the attainment of the desired object, in respect to that part which so materially affects the poorer classes.

As it is the interest of the numerous shroffs who gain their bread by selling the means of exchange, to keep up a scarcity of the smaller Coins, and no hindrance exists to prevent their doing so, as regards the small silver coins, it cannot be expected that that branch of the currency should ever prosper; and it must cease to be surprising that even after the great expence, which has been incurred by Government, in the fabrication of these pieces, and the issue of millions of them during former years there should still be nearly as great a scarcity as before. Ed.

Fort St. George,
Mint 17th March, 1843.

No. 188.

From Captain J. T. Smith Engineers Mint Master.

To

J. Orr	} Esqrs. Mint Committee.
J. F. Thomas	
A. J. Cherry	

Gentlemen,

1st. I have the honour to lay before you the accompanying facts and circumstances in connection with the coinage of the fractional parts of the rupee, to which my attention has been drawn by the very great scarcity of small silver coins which is now felt, and the efforts which are found necessary to replenish this branch of the currency; at present nearly destitute of this auxiliary of exchange, although a few years since amply supplied, a fact unaccountable by reference to the comparatively short interval which has elapsed between the cessation of the operations of this Mint in 1836, and the present recommencement of the fabrication of small coins.

2d. From its great importance to the prosperity of the country, I have felt it to be a duty to bring the subject under your consideration, and I trust that this circumstance will also plead as my apology for trespassing upon your attention by the observations which I have ventured to make upon it.

3d. The Government of India have fixed the Rupee as the standard of value, and have accordingly assigned the limits of deviation within which coins used for payments shall be considered as legal tender—The necessity of a regulation on this point is very obvious, to prevent the injury and wrong which might otherwise be done by the transfer of large sums by means of coins materially short of their proper value; but the same necessity does not apply to all silver pieces, and particularly not

to the very small fractional coins, which are not intended for, and rarely are used for effecting large payments, and seldom indeed perform any other office than their legitimate one, of filling up the minor parts of such payments which are too small to be liquidated by the principal standard coins themselves.

4th. For this reason, in most countries, the coins of the smallest worth are considered subsidiary to those which constitute the standard or measure of value; and while they are on the one hand excluded from the privilege of being offered as legal tender for indefinitely large sums, they are frequently, to a greater or less extent, made to take the character of "tokens," of which the essential property is that the intrinsic value is not necessarily equal to the nominal rate at which they are put into circulation.

5th. In England, the standard of value and legal tender for indefinitely large sums is the gold money, and the subordinate silver coins are essentially constituted of the nature of "tokens," their intrinsic value being less than the nominal rate at which they are issued for circulation—The same applies also to the copper currency, the pieces of which are also "tokens."

6th. In America, the standard of value is the dollar, and this coin together with the half and quarter dollar is established by law as legal tender for any sums whatever, being at the same time restricted within narrow

limits of deviation from the exact standard of accuracy : but the smaller silver coins, the *dime*, and $\frac{1}{2}$ *dime*, are only legal tender for sums less than a dollar, and they are purposely made to take the character of tokens, being of less value than their denominations, as compared with the dollar.

7th. In India, the principle above referred to has been acted upon in regard to the copper coins, which are altogether of the nature of tokens, but no principle has yet been laid down in regard to the fractional silver coins, which are now issued for the first time as parts of the uniform monetary system of India ; and it appears necessary that the subject should be taken into consideration on account of the reasons which will be hereafter given.

8th. The expences of the coinage of silver are defrayed by a seignorage of 2 per cent upon all bullion made over to the Mint, and were no other coins than rupees fabricated, it is possible that the sum realised by that charge might be sufficient—Taking every thing into consideration, however, it is not more than sufficient, and it cannot be said that even in these coins the Honorable Company realise any profit—Under the most favorable circumstances any one of their Mints may be capable of executing rupee pieces at an expence very considerably less than the rate of charge above specified, but on the average of all circumstances the cost is certainly more,* and if the same rigour in estimation were used which it would be necessary for private speculators to apply to secure themselves from loss, it would perhaps be found to be considerably so.

9th. But whatever may be the case with regard to the integral coins, there cannot be the least doubt but that the fractional pieces are issued at a very considerable sacrifice to the State. It is difficult to fix precisely what the fair average cost of each ought to be stated at. It will be however evident, when it is considered that the cost of fabrication is in great degree proportioned to the number, or tale of pieces, that the rate upon the centage of *value* must be very materially higher in regard to the small coins. If the fabrication of 100 rupee pieces cost 2 rupees, that of a hundred double anna pieces may indeed be less, and perhaps short of 1 rupee ; but their value being only one eighth that of the former, the expence of fabrication upon the centage of value would, even at that calculation, amount to four times that of the former or 8 per cent.

10. This estimate may probably be in excess of the actual charges of any one of the Honorable Company's Mints under the most favorable circumstances of manufacture, but by no means so in regard to the average of all the conditions and circumstances under which the small coins may be required by the Financial exigencies of the State—At one period the cost of executing the

small coins, including single anna pieces, was stated to be at Madras as much as 21 per cent upon their value, and although it is to be hoped that the circumstances may never again occur which gave rise to so high a charge ; still, occasions may frequently arise at all the Mints, when the rates of manufacture may be caused to exceed the usual average, as in the instance referred to.

11th. A similar calculation applied to the *single anna* pieces would exhibit a rate of charge very much higher, but enough has been already stated to show, that in the issue of all such coins, for the manufacture of which the Government receive 2 per cent, and pay 5 or 6, a very considerable loss must be encountered. This circumstance, together with the very great difficulty and impediment to the despatch of business created by the minute adjustment in weight of such multitudes of small coins, cannot but operate more or less to dispose the Officers of the different Mints to be averse to executing them ; whilst the merchants on the other hand, whose individual views are not governed by any consideration as to the public convenience, rarely (I believe never) call for them, on account of the difficulty of counting on transfer so many separate pieces.

12th. While these obstacles oppose the introduction of the subsidiary coins, the interests and convenience of the mercantile community, and particularly the poorer classes, loudly demand their issue ; and in some parts of the country it is the opinion of those persons most acquainted with financial subjects, that an extensive circulation of them is highly desirable. It is therefore of great importance to consider whether the difficulties and loss which now oppose the introduction of this branch of the currency could not be diminished ; and still more so, whether some means ought not to be adopted to prevent them from being encountered, as it will be shortly seen they partly are, *in vain*.

13th. When a currency is established which in any degree partakes of the nature of tokens, the difference between the intrinsic value and the nominal rate operates as a bar to its exportation ; for it is evident that no foreign merchant will receive his balance in coins of that description at the rates at which they are current in exchange, the value in all other countries being estimated by the intrinsic worth of the metal, and by that only—Thus the *silver* currency of England being circulated at a nominal rate of 6 per cent over and above its intrinsic value, is secured both from being exported and from being melted down, either operation being attended by a loss to that extent. But when no such difference exists, and the coins of both large and small denominations are equally true to the standard, it is evident that an equal benefit is derived by the exportation or melting of either, and it may with certainty be concluded, that if it be not substantially the interest of the merchant or broker to export or melt one species of coin in preference to the other, none will be found to

* From later information I am induced to think that this statement requires correction, and that the larger coins may perhaps be executed at a less rate than the seignorage at all the Mints.

take the trouble to discriminate between them, however great may be the loss to the State, or the inconvenience to the Public, from their not doing so.

14th. Hence it may be inferred, that the pains which are taken in adjusting the small coins with so much accuracy to their equivalent values, as compared with the standard rupee, have no other effect than that of defeating the very purpose of their execution, and entailing a fruitless and never ending loss upon the Government, in continually replacing coins subject to constant exportation or destruction; whilst it ought not to escape notice also, that even if these elaborate endeavours had not this fatal tendency in the manner above explained, the whole trouble thus bestowed in the attempt to regulate the small coins upon an equality with standard must upon another account be necessarily thrown away, since even if issued of the utmost exactness, it is impossible to maintain them so, it being well known that the wear and loss by weight of small coins is incomparably greater than that of the larger ones, a fact which discloses another cause for their speedy removal from circulation, owing to their liability to early condemnation on account of deviation from standard.

15th. Upon every account it is desirable that the subsidiary coins should be maintained in circulation, because their express office and duty is the facilitating of payments, and the convenience of commerce: were it for no other reason it would be desirable that they should be guarded from exportation; but when in addition to this, we take into consideration the very great difficulty with which they can be replaced, and the loss which is unavoidably met with in doing so, the imposition of some check upon their removal or destruction seems to be imperatively called for.

16th. It is further to be observed, that were the smaller coins, from the quarter rupee downwards, made professedly subsidiary or representative of the standard rupee, and at the same time of a somewhat inferior comparative value, instead of being as at present proportional equivalents, there would cease to be the necessity which now exists for that elaborate pains which is required to adjust them within the proportional degree of proximity to the standard. Were they confessedly in part but "tokens" the use and benefit of such an exact conformity to precision would obviously cease, and a very considerable expence and great impediment to the despatch of business would be done away with, the only effect of which appears to be realising a purpose not intended by them, nor desirable, and which it is impossible for them permanently to fulfil, viz. that of being fit for the transfer of large payments without loss, and at the same time equally suitable for export or the crucible.

17th. From the above facts it appears, that whilst the Government incur a great loss and difficulty, in supplying the subsidiary branch of the currency, there is no check whatever to prevent this sacrifice being wholly thrown away, in consequence of the exportation or melting down of the pieces which it is so difficult to replace, in common with others.* I would therefore beg to suggest, that with the view to prevent this evil, the inferior denominations, from the quarter rupee inclusive downwards, be, like the silver coins in reference to the gold in England, and like the silver dime and half dime in reference to the dollars in America, separated into a distinct class, as a subsidiary or representative currency, and that their intrinsic values be made less than the rate or denomination at which they circulate, by taking off from their weights whatever quantity may be deemed most advisable. The result of this step would be, that whereas there is now no obstacle to prevent the exportation or melting down of the large, and small coins indiscriminately, it would hereafter be done at a loss in respect to those coins in particular which it is most difficult to replace, and which it is most important to retain in circulation; while at the same time, by the difference between the intrinsic and nominal value, the Government would realise an additional profit, which would go towards meeting the great comparative out-lay with which they are charged in the fabrication of these pieces.†

18th. This additional profit, however, it must be observed, would not constitute any extra tax upon the gains of the merchant, or seignorage upon the price of the bullion, which would be received at the usual deduction of 2 per cent, the surplus being realised only in event of its being issued in that species of coin which requires the protection of a discriminating duty, and taken out of the pieces.

19th. It next becomes a question to what extent this proposition, if acceded to, ought to be carried, the decision of which must be left to the higher authorities, but it may be useful to mention that in respect to their fabrication, great facility in the despatch of business and saving of expence would be attained by dispensing with the examination of, and remedy for *individual* pieces, and by ordering them to be tested in mass, as the silver coins in England are by the pound; and that it would be proper that the limit of deviation for wear should be much greater than at present. By way of suggestion I would propose the weights to be adjusted as follows, quarter Rupee 42 grains $\frac{1}{8}$ Rupee 21 grains $\frac{1}{16}$ 10 $\frac{1}{2}$ grains by which arrangement the difference would be fixed at about 7 per cent: and that the limit of deviation from exactness be extended to 10 per cent in regard to small coins, provided they be not clipped or in any other way defaced.

* It is perhaps not generally known that a profitable trade is kept up by the export of the very small coins from this Presidency to the Eastern and other Islands.

† It was not considered necessary to enlarge upon this point in support of a measure, the recommendations in favor of which were quite of a distinct character; but it might have been added that by applying this principle to the inferior currency of the whole of this vast empire a profit would be gained of not less than two or three lacs of rupees per annum.—Ed.

20th. As I am aware that various objections to the proposition which is above advanced may occur to those who have not very attentively considered the subject, I feel it to be necessary to anticipate and reply to such as have occurred to me, in order to obviate the risk of their being urged in the absence of a statement of the reasons by which they may be controverted.

1st. That as the small coins are chiefly used by the poorer classes, the deduction from the value of the fractional pieces will inflict an injury upon them, by raising the price of commodities, owing to their being rated in a currency of inferior value.

2dly. That it would cause a loss to retail dealers, by the accumulation in their hands of pieces of less intrinsic value than they profess to be.

3dly. That the defect in the intrinsic value of the small coins will give rise to a shroffage, and thus inflict a burden on the poor.

21st. The first of these objections, namely the injury which would be inflicted upon the poor by the rise in the price of provisions &c. is founded upon the misconception that intrinsic value is essential to a subsidiary currency; but the error of this supposition has long been demonstrated, and it is now fully admitted by all who are well informed upon the subject, that subsidiary coins may circulate at any arbitrary rates, within the limits of the State wherein they are issued, and without any effect upon the standard of value or the prices of commodities. It is only when about to be withdrawn from internal circulation that the loss of the intrinsic value is felt, and this very loss is desirable as a bar to their removal. Were the above explanation otherwise than correct, a much greater evil than what is apprehended in the above objection would have been already inflicted by the subsidiary copper currency, the intrinsic worth of metal in which is 50 per cent less than the denominative value, yet this currency is already very largely circulated without any such evil having been experienced.

22d. The second objection, regarding the loss which retail dealers would suffer, is the statement of an evil which cannot ensue—The evil in fact is not the consequence of a deficiency of intrinsic value alone, but of a combination of that cause with the fact of an excessive issue—and even when these two circumstances do concur, no loss is sustained except on the supposed occurrence of a third, viz. the sudden repudiation of the currency. Losses of this kind may have been sustained when a representative currency of greatly inferior value has been left to be provided at the discretion of private individuals, who had an interest in its excessive issue, but can never occur when the regulation of the currency is put under the management of the officers of Government. Nor is it to be supposed, that even if an excess of the subsidiary coins did exist, and any particular part of the currency

which had been issued by the state were recalled, the Government would insist upon the loss being sustained by the accidental holders, the gain upon issue having been realised by themselves.

23d. The third objection, that the proposed measure would give rise to a batta, or premium upon the exchange of coins, is equally without foundation with the other two. Shroffage, which is unavoidable, (apart from imposition,) arises from the necessity of a charge being made for the exchange of pieces, one for another, to reimburse the party who undertakes the task of managing the business, for his time and trouble in doing so; and is therefore merely a consequence of the necessity for money changers, which necessity will exist as long as the inferior traders are so poor as to possess but little cash, and the supply of coins of all kinds is not abundant.

24th. The charge may indeed become excessive, and the premium upon exchange be a serious grievance to the poorer classes, whenever the comparative supplies of large and small coins are very disproportionate, and there is a great deficiency of either, especially the latter; but this is an inconvenience obviously occasioned by causes totally irrespective of the intrinsic worth of the pieces, and to be remedied solely by care in their distribution.

25th. The abuse of shroffage, or that which is fraudulent, arises from the shroffs taking advantage of the ignorance of the community, when many various coins from different native and other Mints are in circulation; and this abuse can in no way be remedied more speedily than by a perseverance in the enlightened measures now in progress for the general introduction of a uniform system of coins throughout the whole country. When there are no coins but those whose appearance and worth are familiar to the public, imposition will be impossible.

26th. In regard to the removal of the evil which ensues from the necessary employment of shroffs at all, and the injurious effects of a deficiency of small coins, it may be observed that in this respect the proposition now brought forward will be of the greatest service; for by ensuring the certainty that all the smaller coins once thrown into circulation shall remain within it, some reasonable hope may be entertained that, in the course of time, the continual issues may at last bring about a sufficient abundance; but such an expectation cannot be held at present, when we are certain that no obstacle impedes their removal or destruction, and we find it to be the fact that vast quantities do disappear from the circulation, so that it is next to impossible to maintain an abundant supply.

27th. No impediment to the introduction of the proposed measure can arise from the previous issue of small coins of full intrinsic worth. The latter are certain to be selected on all occasions when small coins are re-

quired to be melted or sent abroad, and will assuredly disappear from circulation; if they did not do so, they would be no obstacle to the reception of the new coins of a trifle less intrinsic value, the same being made equally legal tender in exchange for a rupee.

28 It is also to be observed, that hereafter, whenever the circumstances of the country may be such as to require gold to be the standard of value, the introduction of the present measure will not be felt to have created any obstacle. The rate of the gold coins must necessarily be then so fixed, as that the rupee should be over rated, and that all the silver coins should become subsidiary; but it will be no inconvenience that the smaller coins will be by the same arrangement rather the most overrated; and the only consequence which will ensue therefrom will be, that the same advantages will continue to be realised from the change which are now expected from its immediate adoption.

29 I cannot refrain from adding, that if any alteration in the system of the inferior coins be determined upon it is highly desirable their forms should be also changed. Unless there be some good reason to support the present patterns of small coins, they are certainly most objectionable. The reason for making rupee pieces very thin and of large surface was, I presume, that of preventing their being drilled and plugged with lead &c. &c. The thinness of rupees adds to the difficulty and cost of fabrication, but if they be secured by it from fraudulent debasement, that advantage is a sufficient compensation—Now if a rupee at its present thickness be safe from such attempts, a coin of smaller diameter, at the same thickness would be more so. A half rupee of the form now executed, being thinner, much more so, and the present quarter rupee “a fortiori” still less liable. By the application of the proportions of the larger coins to the minute pieces, however, evils have been introduced which are of great consequence. As above stated, had the half, one fourth, and one eighth rupees, been fabricated of the same thickness as the rupee, they would have been more difficult to drill, and much less likely to be attempted, but they would on the other hand be more easily and cheaply fabricated; and not only from possessing a smaller surface, but also from receiving a bolder impression, would wear less and last very much longer than those now executed will do.

Memorandum on the Mint Master's Proposal to separate the small currency into a distinct class, as a subsidiary or representative currency, and that the intrinsic value be made less than the rate or denomination at which the coins circulate.

I have no doubt that this is correct in principle—such small currency has no influence, or ought to have none, on the foreign exchanges; nor can it affect largely the debtor and creditor transactions of the country. Its sole legitimate use, is to increase the facilities of the every day petty transactions of life, and for this end, it is obviously of importance that a sufficient amount should be kept in circulation. But as each individual holds only a small amount in his own hands, and he neither receives nor pays his debts in this small coin, nor is any obligation to any extent discharged by it, it is of little moment to the individual, whether the intrinsic value of the coins is a few per cent more or less; whilst to the Government, as the issuers and

30th. The thickness of the present 2 anna blank before stamping is about the 1-36th part of an inch, that of the 1 anna, if a similar solid, will be 1-45th. Out of these thin films has the metal for the relief of the head on the obverse, and the letters on the back, to be raised. As it may be imagined, any thing like a bold and durable impression is impossible; and in consequence, the coins though pretty looking on first issue, will very soon be deprived of their marks and become unserviceable.

31st. In respect to them, the extreme degree to which the sheet of metal is reduced before they are cut out, greatly adds to the labour of preparation, and the difficulty of attaining exactness; and it also tends, by increasing their surface, and diminishing the depth of impression, on the one hand to augment the rapidity of wear, and on the other to diminish their fitness to endure it.

32d. With reference to these considerations I would not propose any change in the form or dimensions of the principal or standard coins, nor even in the quarter rupee pieces, excepting the reduction of weight; but I would strongly recommend that, in addition to the alteration of weight on all the inferior coins, the sizes of the double and single annas be changed from the prescribed similarity to the rupee piece, to one of greater solidity and smaller surface; and I would suggest that the diameters should be, of the 2 anna coins $4\frac{3}{4}$ tenths, and of the 1 anna coins $3\frac{3}{4}$ tenths; which particular dimensions are selected because they would be such as to enable the pieces to be cut from the refuse straps of the half and quarter rupees, a circumstance which would considerably promote the facility and economy of their fabrication.

33d. Should your Committee be of opinion that the subject brought forward in this paper is of sufficient importance to make a reference thereupon desirable, I have the honor to request that you will be so good as to forward copies of it to Government, with the view to their being transmitted to the Honorable Court of Directors, or to the Supreme Government, or both, as you may think most expedient.

Fort St. George, } I have the honor to be,
Mint, } Gentlemen,
17th March, 1843. } Your most obedient servant,
J. T. Smith Mint Master.

providers of the currency, its intrinsic value is an object of considerable moment. It is no less an object also to Government, for the general convenience, to keep the country well supplied with this small currency, which it appears it cannot do, whilst its relative intrinsic value is as high as that of the Rupee. I would strongly advise, therefore, the adoption of the Mint Master's proposition. I think the ratio of depreciation suggested by him of 10 per Cent for this representative, or Token currency, an advisable one. This change can inflict no loss on any one, whilst its effects in keeping the small currency in circulation, will be a public benefit.

22d March.

(Signed) J. F. T.

MEMORANDUM ON THE USE OF GRANITE IN THE BELLARY DISTRICT.
BY CAPTAIN E. LAWFORD.

Considering the general diffusion of granitic rocks through a great part of Southern India, and the excellence of the materials they afford for architectural purposes, it may appear remarkable that their use should have been almost exclusively limited either to the rough work of facings to tanks, and wells, or to the expensive construction of pagodas, choultries &c. which are formed entirely of stone, cut from the solid rock, without any regard to expence. It is I believe only within a limited range, that dwelling houses, and other ordinary buildings are commonly constructed of granite, and the traveller is greatly struck with the neat, and substantial appearance of many towns in the Bellary District, as contrasted with the mud built huts of other parts of the country.

I am aware that in the Carnatic, as well as Mysore, the use of granite in the foundations of brick buildings is not uncommon; but I have never seen the art of raising walls of good granite masonry, at moderate cost, so generally practised, as in certain portions of the Balaghaut.

In the town and station of Bellary granite has, from an early period, been employed in the construction of buildings, and long experience having proved its advantage and economy, a few notes of the method of quarrying and applying the stone, may not be altogether uninteresting, or useless.

In speaking of granite, I would be understood to refer not merely to the rock, which in strict geological language is so designated, for I have ascertained that gneiss, and sienite, under their different modification, are alike applicable to every purpose of building, and that they admit of being quarried by the same means. The whole of these rocks, whether stratified or not, have the property of splitting into laminæ, concentric with the bed or mass from which they are derived, although not always with an equal degree of facility.

The application of heat will in almost all cases detach a portion of stone from the surface of the rock, sometimes in thin plates suitable for flags, and in other cases in thick masses, well adapted for building stones; gneiss being the best rock for the former, while granite or sienite may be considered preferable for the latter purpose.

In quarrying granite for ordinary building purposes, the rock is, according to a common expression "burned," that is, a fire is maintained on the surface until the upper part is by the heat sufficiently expanded to detach itself from the mass. It has been stated by travellers, and especially Dr. Benza, that when the rock is thus heated, the separation is produced by throwing cold water on the stone, and thus suddenly contracting it, but this is never done in any of the quarries that I have visited.

The first point is to select as clear and extensive a surface of rock as possible, on which heavy logs of wood are laid, and kept in a state of ignition for about two hours. The rock is then struck with a crowbar, to ascertain from the sound if a crack has been made, and when this is found to be the case, a large heap of light fuel, such as the thorny branches of the mimosa, which is very abundant in the plains of Bellary, is burned for about the same period, or less, according to circumstances, when the upper lamina, before partially detached, may be expected to separate decidedly from the rock; its disjunction being marked by a sound, which guides the workmen in removing the ashes.

They then insert wedges into the crevice, driving them as far as possible, and throwing heavy weights on the surface, break the stone into pieces of the required size, the small stone and splinter, which come off at the same time being very useful as rubble.

The time occupied in this operation varies according to the character of the rock, and the thickness of stone required: it is also greatly influenced by atmospheric temperature, being much less in hot than in cold, or wet weather.

The weights used for breaking the stone are boulders of trap or greenstone, obtained from the dykes of that rock which traverse the country: these are extremely heavy, and are thrown down with the utmost force.

Sometimes the workmen find a rock that resists their utmost efforts, and as they term it "will not burn," though I have never been able to discover any reason for the difficulty arising from mineralogical structure, or other peculiarity. Trap rock is sometimes broken up or quarried by fire, but with more difficulty than granite, and is far less applicable to ordinary building purposes, as it usually breaks only in irregular blocks, and not in slabs. In fact all rocks of globular shape and contracted surface, in which form trap commonly occurs, are far more difficult to work upon than those of a smooth and flat character.

When flags for flooring, or other purposes are required, the rock is first heated and partially separated: a line of holes a few inches apart is then chiselled according to the intended dimensions, and the flags are separated by steel wedges being inserted in these holes, and forcibly struck by a hammer, in the same manner as the rock is cut in every part of the country, when the aid of fire is not employed.

In quarrying flags of any length, uniform thickness cannot be depended on, one end of a stone may be 3 inches, and the other from 6 to 8 inches in depth. Much depends on the character of the rock, and on the carefulness and skill of the workmen. Thin laminæ are occasionally separated, measuring ten or twelve feet square, but as the brittleness of the stone is greatly increased by burning, such slabs are of little or no use.—

The size of building stones varies according to the nature of the work in which they are to be employed. For facings to tanks or wells, the stones ordinarily average 18 inches square, and 12 in thickness, though I have known some quarries produce slabs of 3 feet in length and from 18 to 24 inches thick: but this is seldom practicable at moderate expence, from the quantity of fuel required to heat the rock to such a depth.

For the walls of large buildings 2 feet thick, the best size of stone is about 10 or 12 inches by 5 or 6 inches thick; dimensions somewhat less are applicable to the ordinary breadth of wall, which is 18 inches, and for very common works, a third, and inferior size is made use of.

The prices of these stones at Bellary are as follows, and include the carriage from the quarry to almost every part of the Station.

	R.	A.	P.	R.	A.	P.
Tank stones per 1000.	20	0	0			
Building stones. {	First sort 4 per cubic foot.	4	0	0		
	Second sort 6 per do. do.	2	8	0		
	Third sort 9 per or 10 do.	2	0	0		

Flooring flags are usually 18 inches square and cost 5 Rupees per hundred, which includes only the expence of burning and carriage; the cutting forming a separate charge of nearly equal amount

The splinter or rubble broken off with the stone is left at the quarry, and though very useful in building is not appropriated or sold by the quarriers, but is free to any one who wishes to remove it.

In using granite for building walls, the first operation is to chip off all projecting edges, for which purpose one mason is constantly employed with a hammer, for every two occupied in building. The outer stones being first laid, the middle space is filled in with one of suitable size, and the joints with small rubble; over each course a layer of cement (whether mortar, or clay) is spread in a state sufficiently fluid to find its way into the interstices; considerable skill is required for fitting the stones properly, and avoiding open joints, and in this respect the Native builders of the District have a great advantage over the Carnatic bricklayers who have settled at Bellary, as the former are able to run up a stone wall with as much ease and dispatch, as the low country people can one of brick.

The use of stone is not confined to walls; for columns, and cornices are also constructed of this material, the former requiring much care in the selection and adjust-

ment of the materials. Cornice stones are thin slabs, which answer exceedingly well for exterior work, but are less adapted for the interior of buildings than bricks, owing to the feebler adhesion of the plaster, and to its liability to peel off.

It is seldom that stone buildings for ordinary purposes are constructed throughout with chunam, and there is of course much less difference between the cohesion of lime cement, and that of clay, in stone than in brick masonry. But it is dangerous to omit a coping of chunam work to all stone walls, as they are otherwise very liable to be penetrated by the wet, and to split to their foundations.

Native builders rarely, if ever, employ thorough stones or binders, a precaution which I was always careful to adopt in Public Buildings, especially at the angles.

The Estimates for Public Works at Bellary have for some time been calculated at the following rates, which are in ordinary cases found sufficient,—

	R.	A.	P.
Stone in chunam per Cubic foot.	0	1	0
Stone in clay. Do.	0	0	8

Flooring flags are generally about 18 inches square, and should be as little in excess of 3 inches thick as possible, in order to diminish the expence of trimming their sides, and fitting them to each other. The surface may receive as much smoothing from the stone cutter's chisel, as the nature of the building may seem to render necessary, but by taking the slabs from a fine quarry of gneiss, I have been able to construct an excellent floor almost without any after cutting, and of course at small expence.

The quarriers of Bellary are the Wuddurs, or Tank diggers, and belong to the same class as are employed in rough stone work all over the country. They are a laborious and useful people, but much addicted to intoxication, and extremely troublesome when employed, often receiving advances for stone, and selling the material to other parties. Their gains are very great, and they would soon become rich, but for their dissipated habits. As it is however, these people in the town of Bellary are very much better off in every respect than their brethren employed in the District, who barely earn their subsistence.

The stone cutters are altogether a different class, and are not confined to any particular caste, some being Hindoos and others Mussulmans.

**MEMORANDUM OF THE METHOD ADOPTED BY THE BELGIAN ENGINEERS TO STOP
A BREACH IN A DAM NEAR ANTWERP, BY CAPTAIN S. BEST.**

In August 1837, during a short stay at Antwerp, I had opportunities of seeing the process adopted in filling up a large breach in the river dyke opposite the citadel. This dyke was formed in order to protect the low lands (called the Polders) on the border of the Scheldt, from the inundation of that river; but in 1832 was cut through by the Dutch during the siege of the citadel, in order to inundate the country (Polders), and thus, while they prevented trenches being made by the beseigers on the left bank of the river, to afford a passage for their gun-boats out of shot or danger from the works commanding the river below and near Antwerp, then in possession of the Belgians.

The Belgian Engineer Officers very politely gave me such information as I asked for regarding the work, and kindly shewed me their plans, from which the accompanying figures were sketched.

After the siege was over, various measures were undertaken to repair the mischief caused by the breach in the dyke, and to recover the inundated lands. In the first place a new dyke (vide Fig 1) was made, enclosing the breach and a considerable portion of the Polder near it, with the intention of letting the water off from the rest of the Polder by means of sluices *à clapet* fixed in the new dyke, and opening into the river at low water. It was expected that the hollow near the breach would silt up, and intended to let it do so, before regaining the land between it and the new dyke. This dyke was however breached; and likewise another made for the same purpose. It was then determined at once to close the breach itself, and a contract for doing so was made with some Dutch Engineers under the supervision of the Department of *Ponts et Chaussées*.

A large temporary dam (vide Fig 2) was made on the bed of the Polder, joining the old and new dyke, and enclosing a large tract, perhaps $\frac{1}{2}$ a square mile. Afterwards, the work at the breach itself was commenced; but before my visit, part of the repairs had been again washed away on a stormy day. In order to prevent further damage and loss of labour, the work was at this time going on very actively.

The temporary dyke above water had been formed of two banks of fascine platforms, between which was heaped up a bank of clay. The dyke at the breach (vide Fig 3) was being formed nearly in the same manner; the chief difference consisting in the latter being under water, so that the platforms could only be *sunk* into their proper situations, which consequently depended in some degree, on accident. In the other case, being above water, the platforms were placed regularly.

Each platform (the size varying according to the

space it is destined to fill, (vide Fig 2) consists of two tiers of saucissons placed at 1 metre apart—the second being above and at right angles to the first. Each tier is made fast, where it crosses, to those above and below it. Over the saucissons is laid a layer of reeds or straw; and over these, fascines in two layers crossing at right angles; each head of a fascine resting on the saucisson below it. Two more tiers of saucissons are then placed above the fascinage in the same form as at bottom, and pickets are driven through the whole at every corner of a square of 2 metres side; two rows 1 metre apart being driven in, round the edges of the platform. Some bundles of pickets are driven in here and there in order to lash ropes to for guiding the platforms, when they are to be moved or sunk.

The fascines and saucissons are reckoned to be $\frac{1}{2}$ metre in diameter. A few withes are twisted in among the pickets so as to form a small hurdle like side, which serves at the same time to keep all fast and to contain the stones with which the platforms are sunk.

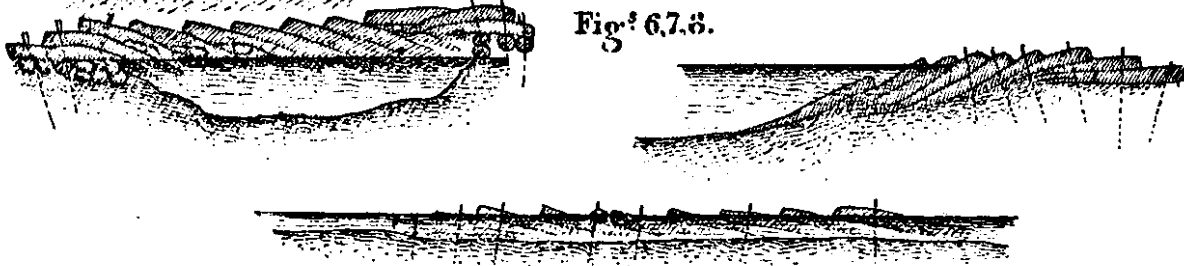
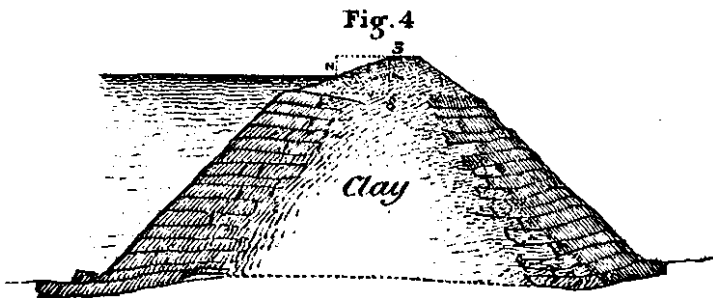
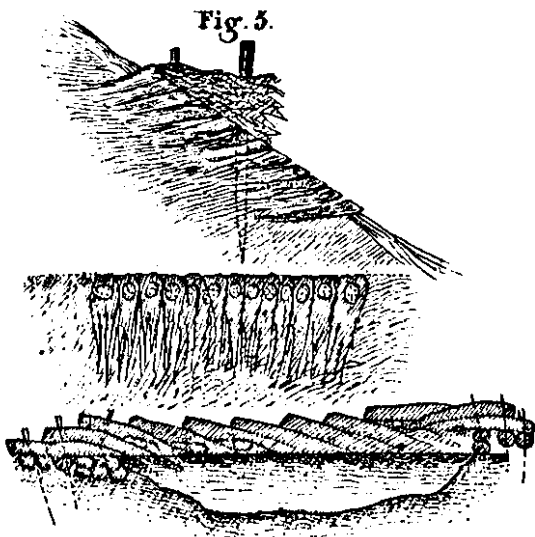
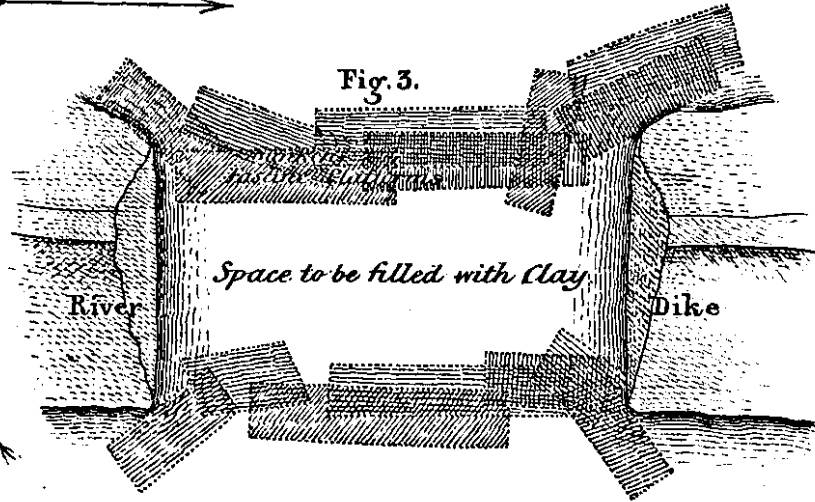
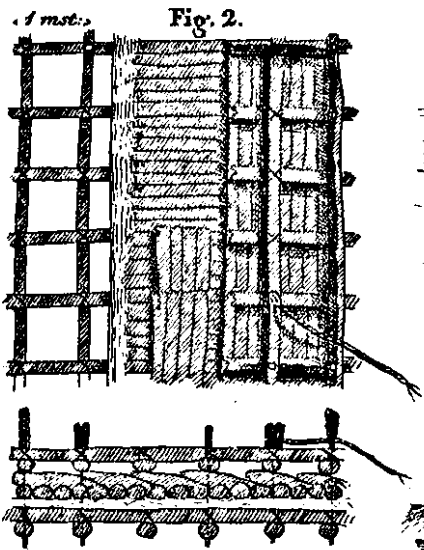
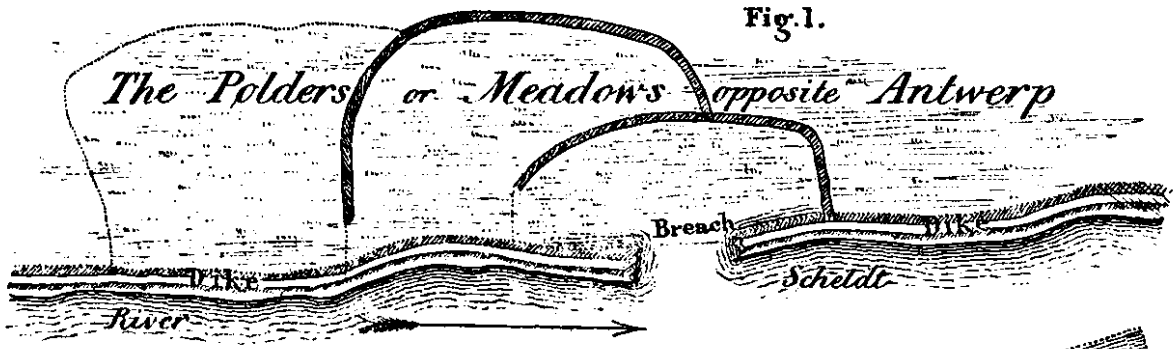
The breach, if under water, is sounded with poles; and vertical sections made before and in the rear part of it, where the two lines of platforms are to be.

The platforms are then floated over into their positions by boats from which they are sunk with stones, (Fig 3) and as they are quite flexible, they form a tolerable barrier to the stream during subsequent operations; the upstream bank of platforms diminishing the flow of water, and the down stream bank preventing the clay between from being washed away. Each platform with the earth and stones thrown on it is calculated to be 1 metre deep; and about 1 cubic metre (2000 lbs.) of stones is required for every 7 metres square of platform. A platform 18 by 6 metres will therefore easily sustain 50 men or 7500 lbs. The clay is very tenacious, it is cut in cubes of 8 inches, and thrown in so as to form in itself a perfect bank, free from admixture of any kind; the fascine work on each side forming for it a revetment, but not interfering with the clay bank, excepting so much as may serve to bond the two together.

At the breach, the dimensions of the bank were to be as follows (vide Fig 4).

For 2 metres above, and 2 metres below the usual high water mark, the bank was to be entirely of clay. Its thickness at top 3 metres; the slope towards the polder $1\frac{1}{2}$ base for 1 perpendicular, and towards the river 3 for 1.

Below this, the bank was to have slopes of 45° on each side—the centre part (entirely of clay) 8 metres thick at top; and the sides of fascine platforms as above described.



The following are data employed at the work.

A platform $50 \times 11 \times 0.60 = 330$ cubic metres can be made with hard work by 40 men in 5 hours.

	Francs.
1 Cubic metre of clay including carriage in boats for 9 miles.	2. 75
(The clay and stones were measured by observing the depth to which the boats that brought them were immersed.)	
Extra carriage by barrows at one relay of } 30 metres.	0. 36
and for each additional 30 metres distance.	0. 16
1000 Bundles of straw each weighing 3.5 kilogr.	280. 0
1000 Pickets each 1.20. metre long and 0.12. to 0.14 circumference.	280. 0
1000 Hurdles $2\frac{1}{2}$ metres long and 0.08. metres wide.	280. 0
1000 Fascines.	110. 0
1000 Bundles of reeds 2 metres long and $\frac{1}{2}$ circumference.	120. 0
(The wood found by Government.)	
The pay of a fascine maker per day of 11 working hours.	2. 5
The pay of a dyker.	2. 2
1 Square metre of revetment.	1. 40

Part of the dykes are revetted with reeds laid up and (vide Figure 5.) down the slope of the bank, straw being laid across horizontally, and forced in on each side of the bundles of reeds with an instrument made for the purpose ; so that a horizontal section or plan of the front revetment of a bank would be as represented in figure 5 the circles representing sections through the bundles of reeds, the curved lines the straw, winding round them. Over this, at every metre or half metre up the slope, a line of pickets being driven in, a low hurdle is formed by twisting withes between them so as to keep the reeds and straw down to the bank.

Ingenious methods of forming dykes with fascine (vide Figures 6,7,& 8) work are practised in the Polders. Where there are small ditches to cross, large pickets are driven in near the brink and made to sustain a few lines of fascines in the direction of the ditch ; these again serve to support others laid across the ditch ; these again others parallel to the ditch ; each tier being advanced towards the middle line of the ditch and finally pegged down, the ditch is gradually filled up. In nearly the same manner, beginning on dry land, a wide stream may be crossed with fascines and pickets ; and bad ground may be made to bear a weight without sinking, by laying down fascines on it, the head of each line of fascines lying over the centre of those laid down behind it.

REPORT TO THE BOARD OF REVENUE ON THE SUBJECT OF THE IRRIGATION DEPARTMENT, BY CAPTAIN A. COTTON.

To
The Secretary to the Board of Revenue
in the Department of P. W.

SIR,

1. In reply to your letter on the subject of the Tank Department, I have the honor now to offer the following as the results of what experience I have had in the matter. I propose confining myself chiefly to the consideration of the amount of expenditure necessary to keep up the Irrigation works, and not to enter upon the details of the application of that sum minutely; first because I concur with the Civil Engineer of the 3d Division in the views he holds on that subject, and which he has laid before the Board; and secondly because the amount of expenditure required has, so far as I am aware, never yet been thoroughly examined and determined upon sound grounds. This is a very remarkable circumstance, for it is the fundamental question; and till it is really answered with some correctness, all attempts, to make the Department efficient by a careful arrangement of the details must inevitably fail, there will be either a wasteful expenditure, or an inadequate one.

2. This question has been under my consideration for many years, and I have long been anxious to see it most thoroughly examined, being fully satisfied that in the management of the Carnatic, its irrigation, if not the very first point to be attended to, is at least one of first rate importance; and I must say that after being about 9 years employed in this line, I can come to no other conclusion than that the importance of the subject has been throughout altogether misapprehended. Since some time before my arrival in the country, it has indeed been pretty regularly advancing in the degree of attention which it has received, but after all, I have no hesitation in saying, that I feel assured, that it is a subject which requires a much more systematic arrangement than it has ever yet been deemed worthy of. I am sorry that I have not had more experience in the Department, and that I am not able to treat the subject as it ought to be treated, but perhaps what I can say, being the result of some years experience, and of my having taken a real interest in the country, may be considered worthy of some attention.

3. The fundamental questions in this enquiry I consider to be these.

1st. What are the value of the works that belong to the Tank Department, that is, not only the first cost, but also their annual value to the country, if in good order.

2d. What amount is absolutely necessary to keep them in an efficient state.

3d. What amount may be advantageously expended in new works, or improving old ones.

Out of the first of these questions arises the following, Has the actual expenditure hitherto been in excess or less than the sum really required?

And out of the 3d.

What have been the results of the attempts at improvements already made?

4. In answer to the first question it will be seen by the accompanying statement of the Nunjay Revenue of the Districts of the Carnatic up to Fusly 1244, that the average Nunjay Jamabundy of the 5 years preceding that Fusly, omitting Tanjore, and adding 3 Lacs for Chingleput, which has been omitted in the statement, was about 85 Lacs; the total Land Revenue nearly 190 Lacs; and the total of collections including extra sources 242 Lacs. That is, the Nunjay Revenue was more than two-fifths of the total Land Revenue, and about $\frac{1}{2}$ of the total collections.

5. The statements do not contain a separate account of the Nunjay Revenue of Tanjore, but the Revenue of the dry lands of that District is very small, and the total Nunjay Revenue of the Carnatic, including Tanjore, for the average of the years above mentioned, was about 118 Lacs; that of the total Land Revenue 226 Lacs; and the grand total collections 288 Lacs; or the Nunjay Revenue was more than half of the total Land Revenue, and about two fifths of the total collections. But I must here observe, that the Irrigation works in general are so far from being in good order, that the Revenue actually derived from them at present, is by no means the full measure of their value. In proof of this I give the following comparison of the Nunjay Revenue of 5 Districts, for four Fuslies beginning from 1232; and that of four Fuslies beginning from 1241 omitting Fusly 1242 because it was a year of extraordinary failure of crops from want of rain.

Fuslies.	North west.	South East.	Madura.	Tinnevely.	Trichinopoly.	Remarks.
1232....	16,44,000 0 0	12,41,000 0 0	4,20,000 0 0	12,26,000 0 0	8,00,001 0 0	
1233....	15,12,000 0 0	12,16,000 0 0	3,65,000 0 0	11,84,000 0 0	8,10,000 0 0	
1234....	15,64,000 0 0	12,43,000 0 0	4,17,000 0 0	11,25,000 0 0	8,45,000 0 0	
1235....	14,45,000 0 0	12,51,000 0 0	4,41,000 0 0	11,65,000 0 0	8,37,000 0 0	
Total..	61,65,000 0 0	49,51,000 0 0	16,43,000 0 0	47,00,000 0 0	33,00,002 0 0	
Average.	15,41,000 0 0	12,38,000 0 0	4,11,000 0 0	11,70,000 0 0	8,25,000 0 0	
1241....	13,32,000 0 0	10,44,000 0 0	4,00,000 0 0	*8,26,000 0 0	7,91,000 0 0	*Not taken into
1243....	11,84,000 0 0	10,12,000 0 0	4,37,000 0 0	11,23,000 0 0	8,00,004 0 0	the average as be-
1244....	12,37,000 0 0	11,10,000 0 0	4,62,000 0 0	11,32,000 0 0	8,00,003 0 0	ing an Extraordi-
1245....	11,27,000 0 0	10,20,000 0 0	5,00,000 0 0	10,65,000 0 0	8,00,002 0 0	nary season.
Total..	48,80,000 0 0	41,76,000 0 0	17,99,000 0 0	33,10,000 0 0	32,00,000 0 0	
Average.	12,20,000 0 0	10,44,000 0 0	4,60,000 0 0	11,00,003 0 0	8,00,000 0 0	

6. From this it appears that the Nunjay Revenue has very greatly fallen off in some of the Districts even within the last ten years; in Arcot $\frac{1}{2}$ in South Arcot $\frac{1}{2}$ though in two of its Talooks by attention to irrigation it had greatly increased, and in Tinnevely $\frac{1}{10}$. In Trichinopoly it has not fallen off of late years, in my opinion, because it has been so vigilantly attended to by the present Collector, but I have no doubt that it has fallen off since it has been under the Company's management. In Madura it has rather increased of late years chiefly I believe from the same cause, and in Tanjore it has increased also from the same cause, leading to its obtaining a much more liberal expenditure and much more of the attention of the Tank Department Officers. Excepting the last, I think that in every tank district the revenue is now much below what it would be if the works were in good order, so far as I can judge from what I have seen of the multitude of Tanks and Channels that now only produce $\frac{2}{3}$, $\frac{1}{2}$, or even $\frac{1}{4}$ of the Ayacut Revenue. I should judge that (omitting Tanjore the works of which are in the main in good order) the remaining districts, which now yield about 85 Lacs, would yield at least 120 Lacs, making with Tanjore 158 Lacs as the annual Revenue of works of irrigation under the charge of Government in this Presidency: and taking the Revenue at 40 per cent upon the crop, the annual value of the gross produce of these works is about 382 Lacs. To this must be added rent free lands, probably about 8 per cent, and it makes a total of 413 Lacs of property per annum, entirely dependent upon the state of the works of irrigation.

7. As to the original cost of the works, I can only judge very rudely that the returns in Revenue to Government are on an average 20 per cent upon the outlay, which would make their first cost 825 Lacs of Rupees, allowing for the rent free lands. This is not however a point of much consequence.

8. The answer to the first question then is as follows:

1st. The original cost of the Irrigation works may be about 825 Lacs of Rupees.

2d. The annual value of the crop dependent upon them if in good order about 413 Lacs.

3d. The annual Revenue to Government in that case would be about 165 Lacs.

4th. The present actual Revenue is 118 Lacs.

5th. The present total value of the annual crop dependent upon them, about 320 Lacs, including the rent free lands and taking the Revenue at 40 per cent of the produce.

9. I will now consider the 2d question viz: What annual sum is absolutely necessary to keep them in an efficient state? So little has this point been considered, that I know of no data whatever having been prepared at any time, which would enable us directly to answer this question. I believe that if a question was asked respecting the grounds on which the present annual expenditure has been fixed, there is no person whatever who could assign any reason for it, whether drawn from the annual account of property dependent upon the works, or from the experience of past years showing how far the sums expended had been sufficient or insufficient to prevent the Revenue from falling off. No

annual statement showing the increase or diminution of Nunjay Revenue, with reports showing how far that increase or diminution was owing to the state of the Irrigation works, how far to the failure of rains, how far to the state of the assessment &c., are ever prepared; so that this most important subject is never brought into a clear point of view; I can only therefore give my own judgment upon it, formed from a consideration of the other question mentioned as dependent upon this; viz. Has the sum actually expended been in excess of, or less than, the sum annually required? I have not the least doubt myself that the expenditure has been totally inadequate.

I judge first, from the innumerable instances of works in a defective state, which have come under my own observation. So generally indeed have I found the works in a defective state, that I believe I may say that nearly all the Tanks in the country, and nearly all the Channels also, excepting those of Tanjore, and the very large ones of other Districts, water less lands than they once did, many only $\frac{1}{4}$, and very great numbers from $\frac{1}{4}$ to $\frac{2}{3}$, and the actual Revenue derived from several Districts some years ago compared with the present, fully supports me in this opinion. By the statement above given it appears, that the Nunjay Revenue of N. Arcot is 3 Lacs below what it was 10 years ago, out of 15 Lacs; in South Arcot 2 Lacs out of 12; and in Tinnevely $\frac{2}{3}$ Lac out of 11 $\frac{1}{4}$. But the falling off in the Nunjay Revenue, has I believe been going on for a long series of years. I cannot obtain accounts of the Nunjay Revenue for more than a few years, because there are no returns of it distinct from the other items of Revenue; however that it has been falling off of late years is the principal point that it is necessary to ascertain at present, and that this is the case in several districts is shown by the above Statement. This question indeed arises; Is this deficiency owing to the defective state of the Public works or to other causes? To this I can only reply, that from what I have seen I have no doubt it is owing to that cause, and I believe that it will be generally allowed to be so by the Revenue Officers and Engineers who have been employed in the Irrigated Districts.

10. The two Southern Talooks of South Arcot are an instance of diminished Revenue, which having come under my own observation I can say with certainty is solely owing to the neglected state of the Irrigation works; and as very nearly the whole of the lands of these Talooks were once actually watered, the total collection of Land Revenue shows very distinctly the degree of order in which the Irrigation works have been kept up, from the time of the Company's taking charge; but it must be observed that these Talooks are said once to have yielded 4 or 5 Lacs, and I believe they would now yield that if properly taken care of. (See Appendix.)

11. The Province of Tanjore requires distinct notice, as being a remarkable exception to the general state of the Carnatic, in respect of its Nunjay Revenue. In this there has been no less an increase than nearly 40 per cent of gross produce in 30 years, as shown by the statement C. of the Appendix. In this it will be observed,

1st. That there has upon the whole been a constant increase of produce.

2nd. That the regularity of the produce has been increased in an extraordinary degree, in so much that while the variations in the produce of different individual years in the first period of five, were as great as from 100 to 57, these variations had so much decreased of late years, that in the last five the greatest variation was only from 100 to 95½. This is perhaps the best test of all for the state and effect of the Irrigation works, both because the very object of them is to obviate the effects of the irregularity of the seasons, so that the crops may not be drowned in very wet ones, or withered in very dry ones, and also because it is an effect which is most clearly to be attributed to that cause.

12 The general improvement in the state of this district has been doubtless owing to its having had a succession of very able men as Collectors, on account of its great importance; but I am sure that it is in consequence of their being really able men, that they have considered the Irrigation of the Districts worthy of their utmost care; and they have consequently not allowed the works to get out of order, either for want of necessary expenditure, or of the attention of the Officers of the Tank Department. To return to the question under consideration, in general the expenditure is allowed to be quite inadequate; some of the Revenue Officers indeed say that the amount of the bills is quite sufficient, if it was really and judiciously expended, but even these who are of this opinion I believe, consider that an increase of the Inspecting Department is absolutely necessary to see that the money is not wasted.

13 I will now consider what inference can be drawn by comparing the expenditure with the value of the property to be secured, upon the general principles applicable to such works. The average expenditure of the last 6 years in the Tank Department, including Civil Buildings, is about 5,80,000 rupees and deducting ¼ alac for the latter works, there will be expended upon works of Irrigation annually Rs. 530000
Allowances of Officers Surveyors &c. 100000

Total. 6,30,000

Total amount of Revenue dependent upon these works at present. 118,00,000

Upon which the expences of the Tank Department are more than 5 per cent. But allowing the Revenue of these works if in good order to be. 165,00,000

It makes the expences of the Tank Department to be upon that sum less than 4 per cent, and taking the total value of gross produce under these works to be at present. 320,00,000

The expences of the Tank Department are upon the total annual amount of property about 2 per cent.

and if the original cost of the works was. 825,00,000

The annual expenditure is upon it less than ¾ per cent.

14. Upon this Statement it appears to me impossible to come to any other conclusion upon general principles, than that the expenditure must be inadequate; it cannot

I think amount to more than ¾ per cent upon the first cost of the works. In England, Canals and such works in which water is retained, require an annual outlay of 3 or 4 per cent, or from 4 to 6 times as much as is allowed in this country. There is thus an agreement between the conclusions to be drawn from this calculation, from the diminished Revenue, and the observations I have myself made, and I think I may say from the general opinion of the Revenue and Engineer Officers.

15. I could give innumerable instances of particular works which have fallen into decay from the inadequacy of the Tank Department, but I will only mention the following.

A tract of land in the very centre of Tanjore was deprived of its water by an alteration which took place in the bed of the river that supplied it; it was several years before the Engineers could find an opportunity of properly investigating the case, the work in the Division being so entirely beyond the powers of the Officers to get through. At last it was taken in hand; the average loss had been to Government about 26,000 Rupees per annum for 6 years, the total loss of property not less than 60,000 Rupees per annum; the lands were not saleable, the Merassidars were entirely ruined, and most of the Ryots had gone to other villages. About 28,000 Rupees were expended in rectifying the evil, and the lands now are fully watered, and saleable at 150 Rupees a Vaylie or 30 Rupees a Cawnie. In this case, therefore, there was an annual loss of property nearly 8 times as great as the sum required to restore the works, and in 6 years property to the amount of about 8½ Lacs of Rupees had been lost for want of an expenditure of 28,000 Rupees, and an Officer to plan and conduct the work.

16. The second is that of the Southern Talooks of South Arcot, above quoted, and upon which I have so often remarked in various reports. In 1827, I was called from the other end of the Division, 250 Miles distant, to look at the great Channel called the Vuddvaur by which they are irrigated.

This important work had been so utterly neglected, that I found it filled up with mud to a depth of about 2 yards; the Talooks were almost ruined, and many of the people had emigrated. An Estimate was prepared and sanctioned, but from the impossibility of Engineer Officers attending to the work, as it ought to be attended to, I found on being re-appointed to that District 8 years afterwards, that only a part of the work had been executed, and the Revenue had continued to fall off till in 1831 it was only 1,18,000 Rupees. Whereas it had once been 2,20,000 while under the Company's Government, and I believe as much as 5 or 6 Lacs at an earlier period. In the course of 6 years, by an expenditure of about 1½ Lacs of Rupees, the Revenue has been increased to 2,58,000 in Fusly 1246, exclusive of the Jaghere resumed in 1241, and yielding in 1246 nearly 49,000 Rupees; and there is every reason to expect that it will continue to advance. I have just heard that there is an estimated increase of 20,000 Rupees in this season over the last, in one of the Talooks alone.

17. A judgment may also be formed respecting the adequacy of the present arrangement, by simply considering the extent of country and value of the property

in each Division and the number of persons forming the Inspecting Department. In the 3d Division the annual Revenue of the work is

In Tanjore.	33,00,000
„ South Arcot.	9,00,000
„ Trichinopoly.	8,00,000
	<hr/>
Total Rs.	50,00,000

The total value of annual produce about 135 Lacs. The total value of the works themselves perhaps about 270 Lacs. The extent of country is, from North to South, 200 Miles and East to West, 140 Miles. For the inspection of the works spread over this surface there are at present 3 Officers (one of whom is quite in-experienced) one experienced Surveyor, and one Apprentice. When it is considered that the Officers must generally take their Office people with them, and consequently can get very little business done if moving at more than the rate of ten miles per day, it must be evident that only a very small part of the expenditure can be checked by the Inspecting Department; which is indeed the fact.

18. Concluding then, that both the present expenditure upon the repairs themselves, and also the number of persons in the Inspecting Department are quite inadequate, it remains to consider what amount would be adequate. I don't know how to judge of this with any certainty, but I think if the expenditure was at once increased from $\frac{2}{3}$ to $1\frac{1}{2}$ per cent upon the supposed value of the works, there could be no possible room for fear that the sum would be needlessly great, even were the works now generally in a fair state of repair, but as the works are so very generally in want of extensive repairs (see Appendix D.) I am satisfied that a sum double the amount of the present expenditure would be most economically laid out for some years; indeed I feel sure, that if it is desirable to bring the same extent of land under effective irrigation, as has been so at times within the last 30 years, it cannot be done with less than an annual expenditure of that sum viz. 12 Lacs of Rupees at the very least for some years to come.

19. In urging this point I beg the attention of the Board to the abundant returns obtained from the expenditure in Tanjore, according to the statement above given, and also those in the 2 Southern Talooks of South Arcot. It is more than probable, that to persons who are not intimately acquainted with the state of the irrigated lands of the Carnatic, it will appear quite impossible that such enormous sums in Revenue may be lost or secured by so small a proportional expenditure, but I cannot but think that if these statements are closely examined and considered, it will be impossible to avoid the conviction that the returns from money spent in securing the irrigation, are far greater than almost any other works could yield, or than almost any persons have supposed. Nor is it in the least surprising that it should be the case; that where the present means of raising food are so wretchedly bad that $\frac{2}{3}$ of the population must be employed upon it, any plan that will very greatly facilitate its production should produce such apparently vast results. I know that there are still

numberless works which if put into an efficient state, would most amply repay the outlay. I would further urge an extended expenditure, not only on the ground of Policy, but also of justice; the lands that are watered by Government works, are bought and sold in dependence upon the faith of Government, that it will keep up a vigilant attention to those works; there are at this moment multitudes of estates that are of one fourth or one half the value that they once were, owing to the decayed state of the Irrigation works. None but those who have been much in actual contact with the people of the Carnatic, can believe the extent of loss to which land owners have quietly submitted from this cause. Those who have seen, as I have, miles of valuable land, which within 10 or 20 years were excellent property, actually over-run with jungle and really unsaleable from the failure of the irrigation works, can only be astonished that violent disturbances have not followed from it. When I visited the Southern Talooks of South Arcot in 1826, and again in 1833, and also the tract above-mentioned in the very centre of Tanjore, the whole body of Merassidars came to my tent and complained bitterly of the state of ruin into which they had fallen; and there could be no possibility of doubt about the state of the case, for the fields were covered with jungle, which had been some years before valuable paddy-land, and which are now again covered with grain, and the causes were equally obvious. In one case the main Channel had literally been allowed to fill up to the extent of 6 feet, as above stated, so that it had only 2 feet of water in it when it ought to have had 8; and in the other the bed of the river had lowered about 3 feet, so as to leave the lands formerly watered by it so much above its level as to deprive them of their supply. In both these cases the fault was in the total inadequacy of the Inspecting Department, and of the expenditure.

20. But besides the direct loss to Government and the country, arising from the want of a sufficient number of Officers to prepare the Estimates &c., another consequence of so confined a Department is, that what is done, must be done without sufficient local knowledge, for no Officer can ever remain so long at any one work, as to enable him to form any thing like a proper acquaintance with its circumstances; for want of which he is continually in danger of making serious mistakes in his plans. I can say from my own experience that this is constantly the case. In the instance of the Vudavaur Channel in South Arcot, a former Engineer Officer recommended a large head Sluice to be constructed in order to prevent the Veranum Tank (which it fills) from being breached by too great a supply of water; when I visited the work first, the people earnestly begged to have it destroyed, declaring that it had done much harm by obstructing the flow of the water. From want of a sufficient knowledge of the work in particular, and the Civil Engineer duties generally, I was quite unable to judge in the case, but it appeared to me to be advisable to remove some of the cross stones, which could do no harm, and I therefore did so. Before I could again visit the work, I was succeeded by another Officer, equally in-experienced, and equally unacquainted with the localities; he however upon further inves

tigation of the case, destroyed the Sluice, with the exception of the Wing walls; since I have returned to the Division, I have had occasion to examine the works much more thoroughly, and have satisfied myself that the Sluice was no protection to the Tank at all, which is endangered not by the water it gets from the Vuddavaur, but by the floods in the Vellaur, which come into the Tank from another direction; so that the Tank was burst in ten or twelve places in 1827 while the Sluice was still in good order: and again, that as it was of no use, so neither did it do any harm, and there was nothing gained by destroying it. This case seems to me suited to show, that unless the number of Officers and Surveyors in the Department are sufficiently numerous, to secure the Divisions being under the charge of an Officer who has previously had some experience, and who has also been long enough in it to obtain some considerable personal acquaintance with the individual works, it will be impossible to get the works efficiently managed.

21. As I have remarked above, it will probably be very difficult for many persons to bring themselves to believe the extent of loss that has been incurred by the grievous misapprehension of the importance of this question. I have been compelled to believe it myself by proofs which left no room for doubt. The loss by actual diminution of Revenue in the 2 Talooks of South Arcot in 30 years, has been certainly not less than 26 Lacs of Rupees; and no reason can be assigned why it ought not to have increased under the circumstances of peace and orderly Government which they have enjoyed. The Revenue is said to have once been 4 or 5 Lacs, and I feel assured that it ought now to be near 5 Lacs. If they had been managed properly for 30 years, I have no doubt that the Revenue would by this time have been at least $4\frac{1}{2}$ Lacs, and in that case the Revenue of the 30 years would have been about 100 Lacs instead of 56 Lacs; a sum saved in the management of 2 Talooks sufficient to have covered one-fourth of the cost of the whole Tank expenses of the Carnatic for 30 years, at the rate of expenditure allowed of late. That this is not a preposterous calculation, seems to me to be indisputably shown by the improvement of the Revenue since the year 1832, as shown in the statement (Appendix B.)

22. In the year 1836 the whole cost of the Lower Annicut is included, but certainly not more than one-fourth of that sum should be charged to these Talooks, because by far the greater part of the benefit derived from it fell to Tanjore.* The total sum expended upon the Talooks in 6 years may therefore be reckoned at about $1\frac{1}{2}$ Lacs, and the Revenue has been increased from 118,000 to 258,000, per annum, though only a small part of the benefits that the improved state of the irrigation works will produce has yet been realized; as it is of course only by degrees that the lands will again be brought into full cultivation.

* For this reason; owing to the depth of the bed of the Colleroon below that of the Vuddavaur the latter was not supplied until there was a great superabundance of water in the Colleroon, and but for this Annicut, that superabundance must have been allowed to pass the Upper Annicut and therefore be taken from Tanjore, so that the construction of the lower Annicut actually throws that quantity into Tanjore, besides what the S. Rajah Voikal supplies from the lower Annicut itself.

23. In the general statement of Revenue, Appendix A. the returns of the first 20 years do not correctly distinguish between the Nunjay and Poonjay Revenue, but to persons acquainted with the country, the column containing the total land Revenue of each year is a sufficient proof of the astonishing diminution of the Revenue from Nunjay lands. Even in the last 20 years omitting Tanjore the land Revenue of the watered Districts was in the average of 5 years terminating with

Fusly 1214.	214	Lacs.
Do. 1219.	216	Do.
Do. 1224.	203	Do.
Do. 1229.	215	Do.

since which it has regularly declined in 15 years to $189\frac{1}{2}$ Lacs, being a falling off in that period of $26\frac{1}{2}$ Lacs per Annum, more than 4 times the whole cost of the Tank Department at present. I believe it will generally be allowed that this diminution has not by any means occurred principally, if at all, in the dry land (the fact probably is that there has been an increase in the Poonjay cultivation, generally, as there certainly has in some Talooks.) But in proof that it has not, but that it is on the Nunjay land that the loss has been sustained, I will bring forward those Districts in which the Nunjay Revenue is stated separately. In Nellore it is only stated for the last 8 years, in which indeed it was pretty regular; in Bellary it is stated for 13 years, in the first 11 of which it had not much declined, and in the last 2 it had increased, the restoration of the Tanks having been most vigorously taken up by Government, and a much more liberal expenditure allowed. In Cuddapah also, from the time it began to recover from the effect of the decennial lease till 1244, a period of 12 years, it had not very materially declined, but in those Districts the Tanks were in so bad a state previously, that they could scarcely decline much. In North Arcot it has declined in 13 years from about $15\frac{1}{2}$ Lacs to about 12, or to little more than three fourths. In South Arcot it declined from 9,90,000 in 1234 and 10,80,000 in 1235 and 11,50,000, in 1236 to 8,70,000 in 1241, being 8 years; in 1242, it was only 7,50,000 which was an extraordinary year of drought; in the two following years it improved owing to the expenditure in the two Southern Talooks above stated. In Salem the falling off has not been great, it may be considered as having fallen from about 8 Lacs to $7\frac{1}{2}$ Lacs in ten years. In Trichinopoly it had fallen about $\frac{1}{2}$ a Lac in 13 years: In Tinnevely it had fallen nearly 2 Lacs, the average of 5 years terminating in 1229, having been 11,40,000, and of the same period terminating in 1244, (but omitting 1241 an extraordinary season) 9,45,000. In Madura it was pretty regular for a period of ten years up to 1244. In Coimbatore it has been quite regular: this District requires some remark. The works in it consist chiefly of noble Channels of from 30 to 50 Miles long, supplied by very solid annicuts across rivers filled by the South-West Monsoon, and they are an excellent proof of the superiority of works construction on a large scale: the expense of keeping them in order according to calculations I made some years ago is very insignificant: they afford also a strong proof of the value of irrigation, from the rivers supplied by the South-West Monsoon. While the rest of the Revenue from

want of rain and other causes has miserably declined, and the District has suffered most severely for 7 years, the Nunjay revenue has not in the least diminished.

It thus appears that in most of the districts there has been an actual, and in many a very considerable falling off, even during the short period of which we have any returns; and as the irrigation has undoubtedly been better attended to for the last 10 years than it was 20 years ago, we cannot be mistaken in concluding that it had been declining previous to the period of the returns, and when to this is added the consideration that almost all the Districts when they came under our charge had been in such a state of confusion for some time, that all the public works were in a very dilapidated state (and the comparison is made with their revenue while in that state) the sad effects of the neglect of the irrigation must be most palpable; for it is certain that instead of the revenue having declined, had the Tanks, &c. been put into a state of repair, it would have very greatly increased. In Appendix D., is a statement of the cultivation and revenue under Tanks in a part of the South Arcot district, which may be taken as a specimen of the Carnatic generally.

24. The total average land revenue of 5 years terminating in 1229 was 215 Lacs, the average of the succeeding 15 years up to 1244 was 197 Lacs; had the revenue kept up to the former amount, there would have been collected above what has been realized, 18 Lacs per annum, or 270 Lacs in 15 years. I believe the whole of this loss has been sustained in the Nunjay lands, but allowing it to be only $\frac{2}{3}$ of it, it amounts to 200 Lacs. I will venture to say, that had the Tank Department been on an efficient footing, not only would this have been saved, but the revenue would have greatly increased, so that I cannot reckon the loss at less than 300 Lacs in 15 years, or 20 Lacs a year, which I feel equally assured would have been saved by an increase in the expenditure averaging 8 Lacs a year, or 120 Lacs in the 15 years. The total collections of land revenue for 30 years viz., from Fusly 1215 (about which time the Districts appear to have got over the extreme state of depression they had been in during the anarchy that preceded the Company's Government) to 1244, both inclusive, were 6222 Lacs, making an average of 207 Lacs per Annum; the average of the 5 years ending Fusly 1219 (the first portion of this period) was 216 Lacs, making the average of the period of 30 years 9 Lacs less than the average at the beginning of that period and, as the average of the last 5 years was only 189 $\frac{1}{2}$ Lacs, the revenue had fallen no less than 26 $\frac{1}{2}$ Lacs per Annum in 25 years.

25. I must here observe, that in taking the averages, I have omitted those seasons which were evidently extraordinary ones, such as that of Fusly 1242, which is therefore not included in the average of the last five years. Had it been, the deficiency would have appeared much greater. It seems to me, that using this precaution, the average of periods of five years affords a very fair ground for judging. I have also stated all the sums in round numbers, that the statement might be clearer,

taking care however not to omit any sums of sufficient amount to affect the general conclusions.

26. In all these statements I have omitted Tanjore, because the circumstances of that District are as striking a proof of the good results of a liberal system in the management of the Irrigation, as the other Districts are of the opposite. I do not mean to say indeed that the other Districts would have afforded as great a result as this does, had the irrigation been equally well managed; because it is notorious that it has natural capabilities far beyond the Tank Districts; but still it is very encouraging, and to my mind proves that every district in the Carnatic would have been actually improved instead of declining in revenue, and also in prosperity, if the irrigation works had been kept in order, tho' not in the same proportion to the amount expended. At all events, it is not in any view possible to conceive, that there can be any ground for supposing, that all the other Districts should have actually declined, and in a great degree, while this has been most rapidly improving, had these works been equally well attended to; nor do I think there can be the least doubt, that had the Tanjore works been as much neglected as those of other Districts, it would have suffered more than they have, notwithstanding all that could have been done for it in other points of management. Neither do I pretend that all its improvement has arisen solely from its Collectors having been careful and judicious in their attention to the Public works. I allow that a very great part of that Improvement has arisen from the able management of it in other respects, or rather I should say, that it is from the two combined, that its present prosperity has arisen; for good revenue management would have availed it little, if the irrigation had been neglected, and but little could be effected by supplying the greatest abundance of water, where it was unaccompanied by a vigorous and lively system of revenue management, and a moderate and well regulated assessment. The following statement shows the comparative results in Tanjore and in the other 11 Irrigated Districts.

	In Tanjore.	In other 11 Districts.
Average total land Revenue of 5 years terminating Fusly 1214.	26,20,000	2,14,10,000
Do. of 5 years terminating 1244.	36,00,000	1,89,50,000
Decrease in 11 Districts.....		24,60,000
Increase in Tanjore.....	9,80,000	
Average total land revenue of 5 years terminating Fusly 1214.	26,20,000	2,14,10,000
Do. of following 30 years terminating Fusly 1244.	33,60,000	207,00,000
Average decline in 11 Districts.....		7,10,000
Do. Increase in Tanjore.	7,40,000	
Total loss in 30 years in 11 Districts.		2,13,10,000
Total gain in 30 years in Tanjore.	222,00,000	

27. I cannot omit here to remark upon the amount of the extra sources of revenue; not that I think they affect the present question, but to show why I think they do not, lest it should be supposed that as they have increased in all the Districts, it is because some how or other, the money that used to be paid in the form of land revenue, is now derived from these things, which form the luxuries of the middling and lower classes. This merely shows the more equal distribution of pro-

perty than formerly: and it is supported by two facts vizt., the impoverished state of almost all the families that were once possessed of great property (at least in this part of the country), which is notoriously the case; and 2dly the almost complete annihilation of the foreign trade in the ports of Porto Novo and Nagore; from which it appears certain, that the property which was once (as it will naturally be under a weak and unprincipled Government) concentrated in the hands of a few, while the great body of the people are in abject poverty, has under the strong and upright Government of the Company, become diffused thro' the great body of the people, and consequently that a great portion of what once went to support foreign trade, which supplies the luxuries of the very rich, now goes to the purchase of those articles of home produce, which form the luxuries of the great body of the people. I conclude therefore, that notwithstanding this increase in the Extra revenue, there has been a real diminution of Nunjay produce, and so of revenue, to the extent stated, under 30 years of perfect peace, under a strong orderly and upright Government, and without any one natural cause that can possibly account for it: a thing which perhaps never occurred in any age or country before. I think it will be generally allowed that there has been nothing in the Revenue arrangements which can satisfactorily account for it; those parts of the country which are chiefly under native revenue management such as the Zemindaries, not being included in these Districts.

28. Supposing it to be considered as allowed, that the loss in revenue, from not keeping up the irrigation works, has been enormous, and far beyond what the expenditure would have been, to have kept them in an efficient state, I will now consider the 3d Question, what might be expended, beyond what is necessary to keep the present works in good order, and what (must I not add) probably would have been done, even under a Native Government, had it been favoured with the prodigious advantages we have had, from continued peace and such an extent of Country under one authority as would allow of works being executed upon a noble scale; so as to include great tracts within the influence of individual works or sets of works, which would have many and great advantages over a multitude of small unconnected schemes. Had any thing approaching to what might be called an energetic system of proceeding in the irrigation question been followed up, who can estimate what might have been the state of the Carnatic at this time.

29. Had a hundredth part of the time, labour, and money, that has been lost by droughts, or expended in trying to obviate the effects of scarcities, been expended in providing against them, very much might have been effected. It is undoubted, that in the worst year that ever occurred, enough water has been allowed to flow into the sea to have irrigated ten times as much grain as would have supplied the whole population. The Carnatic, I acknowledge, is like England and every other country, not very able to support a large population, if nothing is done to provide water

when naturally it would be deficient, and to carry it off when naturally it would be in excess; but I am fully assured that there is no reason whatever why it should not be one of the most populous and fertile countries in the world, if the energies of its Government were exerted as they must be, to render any country whatever what it is capable of. The present state of Tanjore will answer for the rest of the country; the one grand difference between that and the other Districts is, that it is supplied with water. It is often supposed that it has great advantages in point of soil, but this is a mistake, the great proportion of land is by no means of particularly good quality; the proof of which is, that in general, if it is not irrigated, it is not worth cultivating for dry grains: what enables it to bear its crop is the fertilizing effect of the water. There are certainly in the other Districts tracts of rocky ground, but they bear a small proportion to the lands which are of a quality equal on the average to those of Tanjore. What was the state of Tanjore itself 30 years ago, as shewn by the returns of gross produce? (Appendix B.) It varied in different years so much as to be sometimes nearly double what it was in others; a variation as great as, I believe, if not greater than, in any other Districts; and for this reason, that if the main freshes failed, or exceeded in any considerable degree, the whole year was lost; whereas in the other Districts dependent upon the local rains, they often get rain enough to secure them a crop in another part of the year, tho' they may have failed at the regular season. What has now made the crop of Tanjore so much more certain than it was is, that there has been no change of the seasons, nothing but the same thing which is wanted in other Districts, arrangements for securing the water better in deficient seasons, and getting rid of it better in excessive ones. I have before observed that the supply of water is ample throughout the Carnatic. If there is any doubt about this, let it be observed how much water runs into the sea by the Pennar in Nellore the Pallaur the Poniaur in South Arcot, the Vellaur the Colleroon the Vygay and the Tambrapoorney, not in severe freshes, but in moderate ones; undoubtedly more than enough to water the whole Carnatic. There are at this moment passing to the sea by the Colleroon at least 100 million cubic yards of water per day, sufficient for a crop of Paddy in 8000 Cawnies; in a good fresh sufficient water for a crop on 30,000 Cawnies runs to waste daily. In a moderate season enough is lost to water certainly at least a million Cawnies, or a tract double the extent of Tanjore, which would provide grain for about $2\frac{1}{2}$ millions of people.

30. It would doubtless cost more to lead the same quantity of water through other districts than it does to distribute it over Tanjore, but this is the only difference; and still it would most amply repay for the cost of the necessary works, so far as I have been able to ascertain by enquiry. I estimate the value of water as follows; on an average the value of the gross produce of a Cawny of Paddy in one crop, may be reckoned at 20 Rs., the expence of cultivation at 5, and the Revenue at 10 Rs.; the quantity of water required for it

may be estimated at 12000 cubic yards and allowing a portion of this to be supplied by the local rains, a supply of 10,000 cubic yards secured by means of artificial works, will generally be sufficient. This water so supplied will almost certainly secure a Revenue of 1 Rupee per 1000 cubic yards, besides about $\frac{1}{4}$ Rupee net profit to the land owner. To compare this calculation with actual results on a large scale, I find that Tanjore receives in an average season 6,600 million cubic yards of water, but this includes a considerable quantity which is not required, viz. during the high freshes, and also during the local rains, when a great proportion flows into the sea. About 5000 millions may be actually used, the Revenue from which would be, if the rent free lands were included, about 40 Lacs; this gives rather more than 1,200 cubic yards per 1 Rupee of Revenue. This is sufficiently correct for our present purpose; As for the expense at which a certain quantity of water may be brought upon the lands, I judge from the cost of works now in use, and from the general experience I have had in the Irrigation, that there are yet openings for undertakings to a very great extent, by which water may be obtained at the rate of 500 cubic yards per annum for 1 Rupee of outlay in entirely new undertakings; and hence $2\frac{1}{2}$ Rupees expended on new Irrigation works would secure a Revenue of 1 Rupee; but as the same portion of the population if employed on Poonjay land would pay to Government, as far as I can ascertain, about 2-5ths of the Revenue that they would if employed on wet lands, the advantage to Government would be only 3-5ths of the whole Nunjay Revenue, or 3-5ths Rupee for $2\frac{1}{2}$ Rupees, of cost, or about 1 Rupee per annum for 4 of capital expended, or 25 per cent. This result I am well assured is under the mark. In the case of the Coleroon Annicuts, I reckon, that certainly not less than 2000 millions of cubic yards have been added to our annual supply of water for the irrigation below the Head of Seringam, in Trichinopoly, South Arcot and Tanjore, and this has been obtained at a cost of about 3,00,000 Rs., including a considerable sum for some small works which yet remain to be executed; this gives not much less than 7000 cubic yards per Rupee, but it is quite an extraordinary case, and the returns cannot probably be less than cent. per cent. on a series of ordinary years; not taking into calculation their effects in extraordinary seasons, such as that of last year. There are however cases somewhat similar to this, where water may be obtained at a less cost than 1 Rupee for 500 cubic yards as above calculated, such as those in which advantage is taken of works already constructed, the usefulness of which may be increased by some additional subordinate works, as for instance enlarging the channels from an annicut and adding a tank, in order to store up the water of the high freshes; where this can be done, as it may in many places, the main work being already constructed, the additional ones may be completed at a smaller cost in proportion to the water to be obtained, than in an entirely new undertaking. Another case in which the effects of a certain expenditure will be greater than I have stated it, is where channel or Tank Irrigation has been so extended, as to

cause a frequent loss of the crop, as in the Ambaravutty and Noel cultivation in Coimbatore, and more or less in most other places. In those circumstances the main part of the supply for the crop is already obtained, and a small addition that can be kept in readiness, is all that is required, I may therefore say without hesitation that there is much room yet for such additional works as would yield 50 per cent. in actual returns of Revenue to Government.

31. I will now merely notice a few situations where new works may be undertaken with advantage. It is evident that the first expenditure should be made upon those rivers that continue the most constant and certain supply of water, and upon those tracts where there is already extensive cultivation but which is not well secured in its supply of water.—The Cauvery and its feeders, as being supplied by both Monsoons, is of course the most important river of the Carnatic, and 2ndly, the Pallaur as passing through the next greatest extent of country; the Cauvery is also the first to be attended to, because so little has yet been done to it, while much smaller rivers and those wholly dependent upon the more precarious supplies of the North East Monsoon, are overloaded with annicuts. There was not one in use on the Cauvery below the Ghauts previous to the construction of those in 1836; there is an ancient one near the Ghauts, but it is partially ruined, and it is not certain that it was ever made use of. The high freshes of this noble river are therefore entirely lost still, excepting that the Veranum Tank and one or two small ones, get a portion of their supply from it. For the annicuts not having any other tanks attached to them only secure the water of the moderate freshes.

32. The first new undertaking that I would mention is one that I examined into with some care in 1828, viz: the construction of large reservoirs in the Neilgherries and Delki Hills, for securing the cultivation of the Bawany and Ambaravutty, and assisting that of the Cauvery. I did myself the honor of reporting particularly upon this project in 1829, but the plan was not supported by the Board. I do not hesitate now to mention it again, because I trust that the time has arrived for distinguishing between those things that are merely new, and those that are in themselves really visionary. I have stated in my report, that the fine basins with narrow outlets that are found on the hills, the certainty of the supply of water, and the extent of the cultivation in the low country subject to occasional deficiency of water, offer peculiar advantages which might easily be secured. As the Board have my report, I need not enter further into the details of this plan.

33. The 2nd undertaking that should be noticed, and which has been often partially brought to the notice of the Board, is the restoration of the Ponairy in Trichinopoly. This reservoir seems to have extended 30 miles in length, and its river channel, which was apparently 50 miles long, filled besides, many smaller tanks. There seems to me to be almost every inducement to restore this Reservoir; and at the same time I think the work may be so planned as to form one of the most complete under-

takings that could be executed in the Carnatic. I have not yet had time to investigate the case by any means completely, but so far as my knowledge of it goes, it appears that the best plan would be to lead off a large channel from the upper annicut, carrying it on as high a level as possible, so as to take it thro' the middle of the Arrialore and Ulodiar polium Talooks, cultivating much land immediately from the channel, filling almost every tank in those Talooks (which are now dependent upon the local rains and by far the greater part of which are now almost unproductive) securing a great portion of the water of the various jungle streams crossed by it, and discharging itself into the Ponairy; at its head must be a Lock, and from the Ponairy to the head of the Vudavaur in South Arcot, which is only a few miles distant, a cut should be made with another Lock, so as to complete the water communication to the Porto Novo Canal. The advantages of this undertaking would then be,

1st. In the high freshes of the Cauvery a large body of water which at present runs to the sea would be stored up in the Ponairy and other tanks against the time of the low freshes; that is during July, August, and November, the water would be obtained to be used in September, October, December, January, and February.

2nd. During the moderate freshes, when there is much more water than we can use for the present cultivation, a portion of it would be conveyed to a vast extent of lands watered immediately from the channel, as well as to those under the Tanks for immediate use. Since this was proposed a canal is ordered to unite the Cauvery and Coleroon at the lower annicut, which makes this navigation complete.

3d. There would be a most complete water communication from the upper part of the Cauvery to Porto Novo, which would be navigable for about 7 months in the year, and for boats drawing not more than a foot perhaps for 9 months.

4th. A portion of water during the dangerous freshes would be led off from the river, and thus what at present is worse than useless, would become very valuable. Every tank that is constructed to be filled during the high freshes, is a step towards relieving the country from damage by floods—The main branch of this channel might also be carried across the Vellaur into South Arcot, conveying the water of the high freshes of July and August into innumerable tanks, at present dependent upon the North-East monsoon.

34. The use of the upper annicut would in this way be greatly extended. The two talooks of Arrialore and Ulodiar polium contain a vast extent of excellent lands for irrigation, and I am assured that the population is pressing hard upon the present cultivation. The people are most anxious for these works, and it is stated that since it has been known that they are in contemplation many have been endeavouring to secure a right by purchase or otherwise to the lands likely to be watered. This is such a plan as I have long wished to see executed; all the present river channels either from the

smallness of their capacity and extent, or from their having too great a fall, merely water a narrow strip of ground near the river, but not one at present in use leads the water out fairly upon the general level of the country, so as to command a broad tract. In Coimbatore there are channels 50 miles long, but they have a fall of no less than 6 feet in a mile, and there are no channels from the Cauvery of more than 20 or 30 miles long. The total fall of the river from the upper annicut to that point which is opposite to the Ponairy, is about 180 feet, being 65 miles; hence if the channel has a fall of 1 foot per mile which is the fall of the Vudavaur it would at the end be 115 feet above the level of the river, and this, according to the information I have, is much more than the highest level of the ground in Ulodiar polium between the Cauvery and Vellaur, so that the whole of the lands of that tract might be commanded by the channel. These two Talooks might thus be made almost as productive in proportion to their extent as Tanjore, and they would have greatly the advantage over it in respect of floods. I would strongly recommend this being immediately taken in hand, but it cannot be done properly without additional Officers and Surveyors, unless almost all other business of the Department is stopped in the Division.

35. The 3d Work I would mention, is to carry the waters from the lower annicut across the Vellaur at the North end of the Veranum tank into the Bowanygherry Talook, filling the great tanks called Wallajah and Paroomal yairy (yielding I believe near 50,000, Rupees Revenue, if filled with water) and others, and terminating at Cuddalore. This is not a very extensive work but it would I should think be extremely productive. The great object of course is to find means of storing up the water of the high freshes, which the new annicuts have placed at our disposal, and wherever there is a large reservoir we should make use of it for this purpose if possible.

36. The 4th improvement which I have good reasons to believe would be of great utility, and abundantly answer, is one that has been talked of for a great many years, but never thoroughly investigated, viz. the restoration of the Neringapet annicut across the Cauvery 15 or 20 miles above Bowany, and nearly due west of Salem. This is a very old work about 400 yards long, and though breached, a great deal of it is still standing. I have not seen it myself, but have had an account of it from several persons, I have been however also informed by an Officer of the department, that a few miles higher up there is a good situation for leading off a channel without constructing an annicut. Next to the restoration of the Ponairy, this appears to me the best part of the country in which to construct an extensive tank, for securing a further portion of the high freshes of the Cauvery. A very large channel should be led off from the East bank to convey water to the first site where an extensive tank could be constructed, and I conclude that somewhere in that neighbourhood a large valley could be found fit for the purpose. A channel

The Ayacut of the Paroomal yairy alone is about 18,000 Rs. It now waters land yielding 6000 Rs.

100 yards broad would convey about 10 million cubic yards per day during the high freshes, and if the tank was 15 miles long, 3 broad, and 10 yards deep in the deepest part, it would contain about 500 million cubic yards, and would probably be filled every season, and supply water for a complete crop on 40,000 cawnies; the value of it, however, would in effect be much greater than the revenue of that extent of land, for it would be used to complete the supply on lands already cultivated, at those times when the river was too low, and hence it would (with the supply to be received from the river during a great part of the season) secure an extent of cultivation of 3 or 4 times that amount. At present the cultivation every where is limited by the height of the water in the low freshes, thus in a river channel which when the river is high, conveys water enough for 10,000 cawnies perhaps only 5000 will be cultivated, because that is the utmost limit to which they can expect a sufficiency of water during the low freshes, so that if there is water enough for 10,000 cawnies on 60 days in the year, and only enough for 5000 on 60 more, half the water during the 60 days is lost, and allowed to run to waste. But if there was a tank to provide only for the times of scarcity, the cultivation might immediately be extended. This is, however, besides securing the present cultivation, some of which is lost almost every year, and when the freshes are more irregular than ordinary, very great remissions are made. Thus, last year there was probably one-ninth of the main crop of Tanjore lost, which, if such a tank as that now proposed had existed, would have nearly all been saved, and it would have in that one year produced about 4 Lacs of Rupees in revenue, besides so greatly relieving the distress of the Southern Districts, by furnishing an additional supply of grain to the extent of perhaps 20 Lacs of Cullums. This would have been in Tanjore alone, besides the other Cauvery cultivation. The effect of such a work in diminishing the danger of breaches in Tanjore &c., would also probably be as good as if a Lac of Rupees was laid out on the Coleroon and Cauvery embankments. It would lower the rivers nearly a foot in a severe fresh. I think it probable that a channel from this annicut might be led on a sufficiently high level, to carry water over the ridge which separates the feeders of the Vellaur from those of the Cauvery, between the latter river and Salem, in which case it might be turned into the former river and conveyed along its channel thro' the Ahtoor pass, and when clear of the hills, it might be turned by an annicut into a channel which would lead North-East through the North-West parts of South Arcot, and across the Pallavaur near Conjeveram, thus carrying another supply from the Cauvery into the very heart of the Carnatic, on a higher level than those mentioned in the preceding proposals.

The 5th improvement I would propose, should be a more extended use of the Pallaur. That great river in one day sometimes pours into the sea I should suppose as much as 200 millions of cubic yards, while there are within a few miles of its banks, lacs of cawnies of good land perfectly waste, and on the lands that are cultivated

the crops are continually lost for want of water. Probably the best works for that tract of country would consist of one annicut across the Pallavaur, as far to the Westward as the nature of the country would admit, that is near the mouth of the Amboor Valley, with a large Rajah Voykal leading from each end of it, and extending 50 or 60 miles to the Eastward, with small channels leading to the innumerable tanks already existing there, and another annicut lower down, perhaps near Arcot, with similar main and branch channels extending quite to the coast; when all the present cultivation had thus been provided for, advantage might be taken of every suitable situation for the construction of additional reservoirs. By this means the country between the Ghauts and Madras might be incalculably improved.

I shall not here say any thing of the 1st Division, as I am only speaking from report, but it is well known that there are at least as fine openings for improved irrigation there as in the others.

I have mentioned these as instances of what might be done to make the Carnatic a fully cultivated and populated country, and I do not doubt in the least that were these plans followed out, even the climate would be greatly altered. Extended cultivation, accompanied as it would be by extended planting, would greatly diminish the severity of the hot winds, as in North America the climate has been wonderfully improved by clearing and draining the country.

Before concluding this part of the subject, I must remark upon the state of the population. I have been greatly disappointed in being unable to obtain from any person to whom I have spoken on the subject, any thing like a certain opinion as to the rate at which it is increasing; all say that the returns are so inaccurate that they cannot be depended upon so much as to enable us to judge what addition there has really been in a certain number of years.

However all seem to agree 1st that the returns are a tolerable approximation to the real number of people; and 2dly that it is considerably on the increase. In the Towns of Madras and Trichinopoly it seems to be fully ascertained that the population has greatly increased, and I suppose that this certainly indicates an increase in the rural districts. If this point is allowed, the question is, how is the additional population to be provided with grain food, by means of wet or of dry cultivation. Supposing for instance that the population of the 12 Districts is 9 millions, and that it is increasing at the rate of 1 per Cent per Annum, which from what information I can obtain seems certainly within the mark, there is an annual increase of 90,000 persons to be provided for, or within the next 11 years, 1 million. These would require 125,000 Cawnies of Nunjay cultivation to supply them with food. Probably the quantity of Nunjay has been decreasing in about that proportion, during the last 25 years. If while the population has been increasing, the Nunjay cultivation has been decreasing, can it be a matter of surprize that every bad season causes such dreadful scarcities. Surely it is desirable at least that provision should be made for the

increasing population by means of irrigated lands, otherwise their food must be supplied from Poonjay land, and it must therefore be extremely uncertain. But besides increasing the Nunjay cultivation up to what it once was, and providing for the additional population in the same way, why should not every effort be made to substitute Nunjay for Poonjay. Every step that is taken towards this end, both diminishes the danger of scarcities, and greatly increases the comforts of the people, for perhaps one half the number of persons are required to raise a certain quantity of food on wet land, as are required on dry, and the remainder will of necessity be employed in manufactures. While the country is mainly dependent upon a system of cultivation so precarious, that four fifths of the whole population must be employed in raising food, it is impossible that the great body of the people can be well clothed, or supplied with other comforts. Nor can the population itself increase rapidly; there can be no doubt that the scarcities and even famines that are so often experienced in the Presidency, must seriously check the population. I conclude the actual number of deaths by famine in the last fifteen years must be very great, from the accounts I have had from eye-witnesses.

I should on the whole recommend most earnestly that arrangements should be made—First. For the partial or complete restoration of the present works, not however without carefully comparing the probable re-

sults of each individual case, with those of new works on a more extended scale. Where it can be done without direct injustice to individuals, it would certainly be better to construct new works on a large scale, that would yield 30 per cent, than restore old and small ones that would yield an increase 40 per cent upon the required outlay; on account of the great advantage of having rather a few works of magnitude to watch over than a multitude of small ones. It is also very possible, that in some cases where extensive works are constructed, the cultivators under small works still partially in a state of repair, might be induced to remove to the lands watered by the new works. I do not however see how the present works, however imperfect and poorly supplied, can be allowed still further to deteriorate, without some distinct and equitable arrangement being made with the Ryots.

Second.—For the construction of new works either to water new land, or to secure the supply to lands already cultivated as Nunjay.

For the last question, as to what encouragement we have in respect of new works, from the results of those already executed; I would refer chiefly to the reports which the Board have received respecting the Colleroon annicuts; perhaps the following statement will show still more clearly the effects of the lower annicut than my former report.

Statement of height and quantity of water at the Grand Annicut.

	Average of 20 years.				Fuly 1241.				Fuly 1246.			
	Height.			Quantity.	Height.			Quantity.	Height.			Quantity.
	C.	I.		Millions.	C.	I.		Millions.	C.	I.		Millions.
June.....	2	8½	below.	150	1	4	below.	607	2	3½	below.	173
July.....	0	1½	above.	1200	0	11	Do.	907	0	6½	above.	1360
August.....	0	9½	Do.	1500	0	8	above.	1316	0	9	Do.	1400
September.....	0	4	below	1100	0	3½	below.	1078	0	6	Do.	1360
October.....	0	1½	Do.	1200	0	3½	above.	1233	1	18	below.	300
November.....	0	10½	Do.	900	0	10	below.	852	2	2½	Do.	173
December.....	1	12½	Do.	300	1	4	Do	694	3	5½	Do.	13
January.....	2	13	Do.	75	2	11	Do.	72	3	12	Do.	3
February.....	3	8½	Do.	3½	3	5	Do.	14	3	17½	Do.	2
Total of last 6 months	2478½				2865				491			

The measurements are cubits and inches above and below the crown of the Grand Annicut.

From this it appears that the year 1241 when the Revenue was at its lowest in Munnargoody and Chelumbaram (see appendix) the supply of water in the Cauvery for the whole year was above the average, and that the supply of 1246, (the year the annicut was built) was very greatly below the average, and nearly as low as in the worst year of which we have any records.

Height of water at Grand Annicut in the four last months of the season of cultivation.

	Average of 20 year		Fuly 1241.		Fuly 1246		Worst of 25 years.	
	C.	I.	C.	I.	C.	I.	C.	I.
October.....	0	1½	0	3½	1	13	1	10
November...	0	10½	0	10	2	2½	2	2
December....	2	13	1	4	3	6½	2	15
January.....	1	12½	2	11	3	12	3	12
Average of 4 last months	3	37½	3	28	9	33½	8	39
of crop.....	1	4½	1	2½	2	31	2	10

All below the crown of the Grand Annicut.

43. Again taking the averages of the four last months of the cultivating season, October, November, December, and January, it appears that 1241 was above an average year, and that 1246 was so much worse than any previous season of which we have any record, that the supply in the Augunda Cauvery could not have been one half of what it was in the worst year since 1812, being 25 years. For it must be observed, that the above heights show the quantity of water in the Cauvery at the grand Annicut, which up to 1246 was always in moderate freshes from ½ to ⅓ of the whole supply of the Augunda Cauvery; but in 1246 by means of the upper annicut almost all the water was thrown into the Cauvery, and in the latter months none at all was allowed to pass that work into the Colleroon; thus by means of the new works, the whole of the water in the Augunda Cauvery was distributed to Tanjore and Trichinopoly; and the South Arcot Talooks were so much better supplied from the drainage water of the bed of the Colleroon

alone than they had been in 1241 by more than an average supply in that river, that they produced a Revenue of Rupees 25,8000, while in 1241 they produced only 11,8,500, being an excess of Rupees 1,39,700 in these two Talooks alone. When it is also considered that there was a very great failure of the rains in this part of the country last year, and that the cultivation commenced within a few months after the Annicut was sanctioned, so that scarcely any thing had been done to improve the distribution, I trust it will appear indisputable that the results of these works are perfectly satisfactory, and by no means below what I estimated them at in my reports, that they amount to nearly a certainty, that the irrigation of these Talooks will be secured in future, and that they only require to be properly attended to, and such minor works as may be necessary for the distribution and draining, executed, in order to ensure after a time a revenue equal to what it is said formerly to have been, viz, 4 or 5 Lacs or more, for there is yet a very great extent of land unwatered, though every part of the Talook is below the level at which we can obtain water.*

* I have obtained statements of lands capable of being watered in Chellumbrum alone which would yield an additional Revenue of Rupees 1,00,000 besides much other lands.

in the river was less than half of the worst of the preceding 25 years, the Revenue exceeded that of the best year of the first 30 years of the Company's management by 18000 Rupees, yet there is an estimated increase this season of 35000† Rupees upon last year, making already a total of 53000 Rupees above the best year of the first 30 years.

+ Increased cultivation. } 46,000
Estimated cul- } 35,000
tivate. }
tuna. }

44. With respect to the results in Tanjore and Trichinopoly, I do not yet see the least reason for thinking my former view of the last years returns incorrect, excepting that I understand the Revenue exceeded that of the preceding by 2 Lacs, instead of falling short of it as stated. Thus far, I think there can be no possibility of doubt, viz, that the whole cost of the works was much more than repaid within 15 months from the commencement of their construction, almost every month of this year has been below the average in the supply of water in the Agunda Cauvery, yet the district has been plentifully supplied with water, without any intermission of consequence from the beginning of the season up to this time, which has never been known before I believe, and the accounts I have

* The increase of cultivation this year above the last is 2000 Vaylics, in Revenue 80,000 Rupees, besides the saving of crops on land previously watered.

got from the District are most satisfactory.* These results are I think abundantly sufficient to afford encouragement, to proceed with such works, as respects the actual returns in Revenue to Government; but I believe the increase in the value of property to individuals is also at least proportionately great: in Trichinopoly, I have ascertained that the value of the lands in Seringam has actually doubled, and I am informed that the same is the case in Munnargoody and Chellumbrum; in Tanjore also, I am assured that the price of

land has greatly increased, so that when it is considered that as much as 5,60,000 Cawnies of land are affected by the Annicuts, the saleable price of which is perhaps 800 Lacs, it does not seem too much, to suppose that they have been the means of causing an increase of private property to the extent of no less a sum than 50 Lacs.

45 If this has been effected with our present means, we may surely without the least doubt expect, that when after a time the Divisions are in charge of men of experience, and local knowledge, and something like real system is introduced into the Department, such a state of things may be established as respects irrigation and communications, as will make the Carnatic altogether different from what it now is.

46 I beg to apologize for the unreasonable length of this paper, but it is not easy to know what to omit in a case which I am confident affects the welfare of the country essentially, and I must yet make some remarks on the other branch of the duties of the Department, viz, the communications; though as I have before had the honor of forwarding a report on that subject, there does not remain much to be said by me here. I should first observe, that I have not seen reason upon further consideration and experience to alter my views of that question, (as stated in the above mentioned paper) as to the indisputable superiority of Rail roads on every account in this country; but at that time, I by no means expected that there would be so great a traffick as I have since seen reason to expect. This, so far alters the case, as to make it in my opinion a matter beyond all doubt, that a single Rail way will pay most abundantly on any of the great lines, and in some, I think it may even be advisable to lay a double line.

47 The principal point which appears at present to require consideration is, whether upon the whole it is better to repair the present roads at a comparatively moderate expense, or to make Rail roads at a much greater. This seems to me capable of a very easy solution. I take it for granted, that it will be allowed that capital can be obtained at 5 or 6 per cent, to almost any extent. If so, the question seems to be reduced to this point, upon which kind of communications would it make the best return? That which will yield most, must of course be the best for the country. Now the utmost that can be done by means of common roads, will not reduce the expense of carriage one half, probably not one fourth, or in other words, it would not produce such effects as to enable the Government to levy a toll worth metioning, so that the capital must be either paid out of the taxes, or borrowed, and the interest form a permanent charge upon the Treasury. This would certainly be better than leaving the communications as they are now, but what will be the effect if Rail roads are constructed? The expense of transport will be reduced, at least as much as to one twelfth of what it now is: on the Red Hill Rail road, one Bullock drew eighteen times as much as on a common road. Then supposing the present traffick on any line to be equal to 100 Tons per day. (see Appendix E.)

The present daily cost will be per mile.	
	RS. A. P.
at 2½ Annas per ton.....	15 10 0
Or per annum about.....	5,700 0 0
Deduct $\frac{1}{4}$, for the expence of draught with Rail road.	475 0 0
	5,225 0 0
Sum remaining to cover the interest of capital, expense of management, repairs &c.	
Interest.....	5½ per cent.
Repairs.....	2 ”
Management.....	2½ ”
	10 ”
If the first cost is 6000 Rupees	
The annual outlay will be	600 0 0
Net annual income	4625 0 0

or 76 per cent.

And supposing that the first cost should be 3 times as great as above estimated, or 18,000 Rupees per mile, which will probably be beyond what any person will think a single line would cost, then

	Rupees.
The annual outlay will be.....	1800
Receipts deducting draught	5225
	4425
Net returns upon 18,000 Rupees or 19 per cent	3425

48 This is the total advantage to be gained by it supposing the rate of carriage to be the same as at present, in what proportions it may be advisable to divide this between the Government and the public, is a separate question. Thus, to make common roads so much money must be expended by Government, and so much annual expense incurred, and no direct returns whatever can be realized. Railroads will not only literally cost nothing, because the capital can be obtained for asking for it, and the Railroads will pay the Interest but will yield a large Revenue besides. Before any thing can be done of any consequence in improving the common roads, the state of the Treasury and of taxation must be carefully considered; if Railroads are to be constructed, nothing is required but to begin upon them at once; the less surplus Revenue there is and the more severe the taxation, the more adviseable at once to commence upon these works. If once this important principle of using the public capital upon public works is recognized and acted upon, there will no longer be any limit to the power of Government to improve the Country. It has already been extensively brought into action in America. If a Government does not make full use of the confidence which it has established in its subjects by acting upon upright and sound principles, it throws away so much of the power which it possesses of promoting the welfare of the country. In cases of necessity and emergency as in times of War, this confidence is without hesitation taken advantage of, and if it is thus made use of in a case where it entails a permanent loss

upon the country, I cannot conceive what reason there can be for allowing such an invaluable portion of the power of the Government, to be thought unavailable, when it might be used to increase the wealth of the state. Supposing 1 Crore of Rupees employed in this way, and that it would only lay 1000 miles of road, the direct saving to the country or annual increase to its wealth would be 40 Lacs of Rupees, if laid out on lines where there was traffick to the extent of 100 Tons, not taking into Calculation the innumerable indirect sources of advantage which would at the least double that sum. I have supposed that lines can be found on which the traffick is 100 Tons per day. By the returns of the traffick on the Adyaur Causeway, (see appendix) it appears that in goods and travellers it was equal to nearly 400 Tons per day; on the great West and North lines leading into Madras it could hardly be less than 600 Tons, and if the cost of carriage and travelling was greatly reduced as it might be, it is more than probable that it would be 7 or 800 Tons per day. At one place in Tanjore the average of 15 days was 172 Tons in goods and travellers, bandies only, on another 75 Tons. It is often asked what is to be carried on the Railroads, as tho' there was no traffic in the Country, and I have no doubt that the extent of traffic shewn by these returns will surprise most people; but the number of travellers is still more remarkable. In the Adyaur Causeway the average of 16 days is

Foot Passengers.	3320
Palanquin Do.	7
Carriage & Bandy Do	
reckoning 3 to each.	421

Persons 3748 per day.

In one place in Tanjore the number of
men travelling on foot was 1555 per day,
At another place Do 1287

49 Supposing that 16 persons are equal to a ton and that the rate charged is, 1 Anna per ton per mile, the poorest class of travellers might be conveyed at 1 Anna for 16 miles, which would bring it within reach of almost all, and it may be confidently expected that if travelling in this country is rendered thus cheap and quick, that the number of travellers would be increased in many situations, at least, as much as in England, that is 3 or 4 fold. On a great line in the neighbourhood of Madras it would probably be not less than 5000. On several of the roads in Tanjore it would hardly be less than 3000 per day, nearly equivalent to 200 Tons.

50 I would now beg to make a few remarks on the details of the Department. If these two branches of its duties are to be vigorously attended to, I consider the following as absolutely necessary, but not sufficient to make the Department what it ought to be.

For one Division consisting of 3 Collectorates

- 1 Civil Engineer.
- 1 Head Assistant.
- 3 2nd Assistants.
- 7 Surveyors.

- 7 Maistries.
9 Draftsmen and Writers.

besides extra Officers and Surveyors to be employed on any new or extensive work.

This will of course appear at first quite unnecessary to those who compare it with the present strength of the Department, but if it is compared with the wants of the country, the present state of Irrigation, the amount of Money required to be expended, the space of country over which the works are scattered, the nature of the duties, the effects of the climate upon Europeans, and the value of the property at stake, I am not afraid of its being found by any means too great.

51. In proportioning the numbers, I suppose the principle to be acknowledged, that it is waste of money to employ any person in doing duties that can be done by others at a less cost; this principle has indeed been hitherto rejected in arranging the Department, and thus a miserably weak and inefficient Department has been still further weakened. An Assistant on 400 or 500 Rupees a month, and a Surveyor on 176 Rupees are employed in making two copies of their own Diaries, which could be done by men on 20 Rupees a month; and an experienced Surveyor capable of planning works is employed in copying plans of Tunnels and Cutcherries, which require no thought or ability at all, and for which men could be obtained at one third of their cost. It is very remarkable that such a system has never been thought of in other Departments of Government, the idea of employing a Superintendent of one of the Government Offices on 2 or 300 Rupees a month, in copying papers would at once be seen absurd, much more so an Officer on 4 or 500 Rupees. I am quite at a loss to understand how such a plan could have escaped observation, I propose that every officer should invariably have attached to him

- 1 Surveyor.
1 Writer and Draftsman.
1 Maistry.

and I cannot see how, on any principle of economy, he can be allowed to be without them. If they are not with him, he must of course do their duties, and in the mean time who should do his? If he has no Surveyor, a young European Officer not at all inured to the climate, must be employed upon a duty which of course he cannot long stand, and the consequence is, that besides being rendered often unfit for the execution of his proper duties at the time, he is after a few years (if he lives) when he is beginning to learn his business, obliged to leave either the country or the Department.

52 From this, and other causes we have never had an experienced Officer in the Department since I have been in the country, who was not quite unequal to his duties. The Civil Engineer's Office I propose shall consist of 1 Surveyor, 1 Draftsman, 2 Maistries and 3 Writers, one Writer was probably enough formerly, but certainly it is even now quite insufficient. If there is any thing like a vigorous and comprehensive system adopted, less than this cannot possibly be adequate. One or two of the Sur-

veyors if not more of the senior ones, should also have Writers.

53 The above scale allows one Officer constantly in each District, besides the Civil Engineer of the Division, for there will be one of the Officers almost invariably unfit for duty, and one employed on particular works, such as examining works of great magnitude; and allowing one Surveyor to be absent, there will be two disposable to detach on any separate works, besides those employed with Officers. There will thus be for the general duty of inspecting works, only one Officer and Surveyor for each District; they will have a range from 100 to 120 miles long by 80 or 100 broad, an expenditure to controul of not less than one Lac, and from one to three thousand works to look after, besides the communications. This must be less than a sound economy calls for. Further, unless a considerable number of Officers are employed in the Department, it cannot be expected that men of experience will be always obtainable to take charge of Divisions. The Board will excuse my alluding to my own history as an exemplification of the effect of the system hitherto followed. In 1822 after being half a year in the country, I was sent to be an assistant in the Southern Division; the Officer I was placed under had not been long enough in the Department to gain any considerable stock of experience. I remained with him one year, the principal part of my time having been spent in surveying, copying plans and Diaries. I was then placed under the Superintending Engineer at Madras for a time, and from thence was ordered to Burmah; at the conclusion of the War, I was appointed a Civil Engineer, because there was scarcely an Officer in the country of any standing who had been in the Department, and it was not to be supposed that a married man would willingly undertake the charge of a Division of the size they then were, which would oblige him to be almost always separated from his family. When I thus got charge of a Division, I was perfectly ignorant of the duties, and having a range of five collectorates and no other Officer with me, I was very soon worn out by fatigue and severe attacks of jungle fever, and after 3 years was obliged to return to England. On my return I was again appointed to the Department, but my health so soon sunk under the duties, that I have since been scarcely half my time actually employed. I am now, excepting one, the officer of longest standing in the Department, and yet have had only about 7 years actual experience; having been also, except the first year without any one to instruct me. If such a state of things was allowed in other branches of the service, what could be expected? If the irrigation is found annually to diminish under such a system, it cannot be a matter of surprize.

54 But if the Department is to be increased greatly, the question arises where are Officers for it to be found. First, there are now a good many Officers in the Corps of Engineers altogether, but it so happens that at present there is an extraordinary number of Officers absent on sick certificate, and it is very remarkable that so great a number of young Officers have so soon lost

their health as to be obliged to return to England, without having done any duty of consequence. We may however fairly expect that after a time, with our present numbers, we shall have more disposable Officers; secondly, I must presume so far as to observe, on the grievous loss of Engineer Officers employed in making roads with the Sappers; I suppose that it will be generally considered, that the plan of Officering the sappers by Engineers has not answered the end proposed. They are now employed upon precisely the same duties as line Officers were before, and which undoubtedly do not require an Addiscombe education, while duties, which cannot be done without instruction in particular branches of knowledge, are left undone for want of these very Officers. There is indeed a saving in employing Engineers in that way, as the old Pioneer allowances were withdrawn, but this saving is much more than counterbalanced by the employment of men on duties which are of less importance, than others which they are capable of performing. Thus at the very time that several Officers (educated at a great expense) were employed upon works to which numbers of officers of the line are perfectly competent, the Board were waiting for many months last year for an Officer capable of superintending the levelling of the line from Madras to Arcot, and the Tank Department wanted several Officers even to complete its present complement. And there are now two Officers of Artillery employed on the duties of Engineers, while there are Officers of Engineers employed in the duties of line Officers. I should also mention that an Officer of Engineers is employed in Travancore; it seems scarcely advisable to send Officers to foreign states if they can really be advantageously employed in the Company's country, thus rather than let the irrigation of the country be neglected, perhaps it might be deemed proper to call off every Engineer Officer from less important duties.

55. But I beg strongly to recommend the consideration of the question, whether it would not be much better not to confine the Department to Engineers. There are now abundance of officers in the line and in the artillery, who have been at Addiscombe, and doubtless many who have not, who are perfectly equal to these duties, and would gladly undertake them. If the Department is increased, and thrown open to all, I have not a doubt that the Government will soon find that they have many servants in the other branches of the army, who will be far more valuable in this Department, than where they now are, having a natural turn for such duties. Nor would I exclude those who are not in the Company's service. I would propose that the highest appointments should be open to any one who could fit himself for them. I cannot see any thing in the nature of the Department which can make it advisable to keep it exclusively for one body of men; a turn for these duties may be found in any class, and in England Civil Engineering is open to all, and the effects of it are very evident and beneficial.

56. I trust that there is now no occasion for me to say much on the importance of this subject. Tho' the

country cannot advance without good Judicial and Revenue management, yet it is indisputably certain that nothing will avail without the irrigation and communications are attended to. While the population are mainly dependent upon the local rains of so precarious a climate for their cultivation, four fifths of the population must be employed in merely raising food, every five or six years we must witness the deaths of tens of thousands by famine, and the great body of the people must be without clothing, or any thing but a bare subsistence, even in fruitful seasons. And, without communications, nine tenths of the natural treasures of the country must continue to be useless. At present, what cannot be procured on the spot where it is wanted, cannot in general be had at all. A great portion of the population are even deprived of salt, which the country so lavishly produces, because of the expense of transport. Above all, the want of communications is, and ever must be, almost a total bar to the progress of knowledge, and improvement generally.

57. Many attempts are now making to improve the state of the people in various ways, but unless there is freedom of communication throughout the country, it will be perfectly impossible that such improvements can spread rapidly. However well any new plan succeeds, if the communications are not opened, it will never extend. And again, if we want to promote the general wealth and comfort of the community, we must be sure to lay a good foundation by supplying them with plenty of food. If a man was so circumstanced that four fifths of his time was employed in getting only just enough of the plainest food to keep him in health, and the remaining fifth was not sufficient to enable him to supply himself with two yards of cotton cloth, with a prospect every four or five years of being either starved to death, or in imminent danger of it; and if we were to offer to show him how to grow sugar, he would probably say, if you will first put me in the way of insuring to myself a supply of food and a bit of cloth, and a comb, without my whole time being taken up about them, I will then employ some of what time I have to spare in raising luxuries that I want myself, or that I can exchange for others; for it can scarcely ever answer to a country to bring much food from a distance; it will always be advisable to raise most of it on the spot; but when a country is in a state to provide abundance of food for its population, manufactures &c. will flourish. Again, the price of exportable produce, of course, depends entirely upon the facility with which food is raised; and upon the price of produce entirely depends its capability of competing in foreign markets; thus if food could be raised in this country with one half of the labour that it has hitherto required, cottons, iron &c. could be produced at greatly diminished prices, and the profits upon them in foreign markets proportionally increased.

58. It is often remarked that there are so few manufactures in the country; how can it be otherwise, when almost all are required to raise food, and of the remainder such a number to carry about; and when every thing must be brought to where it is required, at such an enor-

mous price ; at a price which if it existed in the same proportion in England, would at once destroy nine-tenths of the traffic of the country.

59 If this view of the irrigation question is not upon the whole a fair representation of the case, how does it happen that Tanjore, the only district well irrigated and producing a sufficiency of food, is the only district of the twelve that is in every respect regularly advancing. If it really is not a correct view, it must at least be allowed that this is a question which should not be lost sight of, till it is fully investigated.

60 I am quite satisfied that there is nothing in the natural state of the Carnatic which should prevent its being one of the most populous and fertile countries in the world ; and I think that the results of what has been done in Tanjore and in South Arcot, even without considering the utter insufficiency of the Tank Department, are such as to give the fullest assurance of ample success, to the most extensive system of operations. Every thing is ready to commence upon it. With a healthy climate, abundance of fertile soil, unlimited mineral treasures, especially the finest iron probably in the world, ample supplies of water, if taken care of, an increasing population, a surface extraordinarily favorable for communications, internal and external peace, and almost any amount of capital at the disposal of Government, (for Crores can be obtained from England if necessary,) there is really nothing wanting but action, to produce such a change in the whole face of things as cannot now be conceived. -

61 The following is a summary of my views on this subject,

1st—That the nature and importance of the subjects of the Irrigation and communications has been hitherto altogether misapprehended ; leading to a loss of Revenue and a retardation of the progress of improvement in the state of the community, which is quite beyond calculation.

2nd—That as respects communications, no country whatever can prosper if they are not made the very first objects of attention ; and that as respects Irrigation, it is in this country owing to the peculiar character of the climate, undoubtedly the very first subject to be attended to ; in as much as we cannot rationally expect that there will not be famine and want of every kind, just in proportion as the cultivation is more or less dependent upon local rains, without the help of artificial works.

3rd—That the expenditure upon the Irrigation has certainly not exceeded one-third of what, upon the strictest principles of economy, it ought to have been ; and that from the little consideration that the subject of Communications has been thought worthy of, there has been in most cases nothing at all expended ; and in others, as in the Hyderabad and Masulipatam road, and in that from Madras to Poonamallee, the most expensive and unaccountable expenditure, totally disproportioned to the advantages to be attained, and to the real necessities of the case. The former cost at the rate of 10,000 Rupees a mile, the latter 50,000 Rupees (See Appendix.) Most of the other great lines of road in the Presidency are litem

rally at this moment impassable, at times, for want of a few bridges and trifling works that would not cost more than 200 Rupees per mile ; and some other lines on which bridges were built, are now, and have been for many years, totally impassable from want of repairs that would not exceed 20 Rupees per mile per annum. These things could not possibly have happened had the subject been viewed as it really is, one of the very first subjects to be attended to.

63 4th—That when once a country is favoured as this is with a strong and upright Government, the only things which can possibly support effectually internal arts and manufactures and foreign trade, are an abundant, certain, and cheap, supply of food, and rapid, easy, and cheap transport. Nor, without these can a nation make rapid progress in knowledge. While a people are scarcely provided with food, and not at all with clothing, they cannot be expected to think much of any other things, and while intercourse is so restricted, the state of a community approaches to that of men in a prison, each one shut up in a separate cell, so that the progress of the individuals depends wholly upon the discoveries of their own mind, instead of having also the full benefits of all the thoughts of the other inmates of the place ; whereas just in proportion as the freedom of intercourse approaches to completeness, the state of each individual approaches to the state of a person who should be possessed in himself of all the powers and capacities of the multitudes of minds of which that community is composed.

64 5th—With respect to what should be done in our present circumstances. That such a systematic arrangement should be made for the conducting of Public works, as would secure these branches of the management of the country one of the first places among the subjects which require the attention of Government ; either by the establishment of a separate Office or Board of Public works, on a liberal footing, or by such other arrangement as may appear necessary.

65 6th—That every Officer of Engineers, whose present occupation can possibly be taken up by others, be immediately made available for this Department.

66 7th—That the Department be thrown open to every person, whether in the service or not, who can fit himself for it.

67 8th—That at least double the present expenditure should at once be allowed for the Irrigation, besides very large sums for the communications.

68 9th—That capital should be obtained on loan, and on no account that any money should be paid out of the treasury for improvements. Capital paid from the treasury costs the community perhaps double its actual amount, taking into consideration the expence &c. of collecting, the cramping of private enterprise by the diminution of funds of individuals &c. &c. while capital obtained on loan costs absolutely nothing. If ten Rupees are taken from a man as a tax, it is sheer loss to him, and it must often happen that it is taken when he has an opportunity of laying it out to great advantage ; if it is taken on loan, and laid out in a way that will yield both

public advantage, and actual returns in money besides, more than sufficient to pay the lender his interest, no individual loses any thing, but the community gains. And for such works as Bridges, upon which it is not advisable to levy tolls, how much better is it that the interest of its cost should form a permanent moderate charge upon the community, than that the cost itself should be paid at once: in the latter case the present moment must be heavily taxed to obtain an advantage which will only be realized in a course of years: in the former the advantage is only paid for as it is actually possessed; in the latter case works may at once be undertaken to a prodigious extent; and the country greatly improved without delay: in the former only a small extent of work can be undertaken at first, and the community must wait many years for others equally necessary.

69—10th That various details of internal management now wholly omitted are indispensably necessary to keep the Department in any kind of order, and prevent the recurrence of such mistakes as I have endeavoured to show have hitherto been committed in it; such arrangements as these for instance; annual reports on the state of the Irrigation, both from the Civil Engineers and Collectors. A general annual report from the Board of Revenue. Rewards and Penalties to secure every person in the Department obtaining a competent knowledge of the language of the Division; Examination of Officers &c. and other details, which in almost all organized Departments are considered necessary to ensure their efficiency, but of which this has hitherto been thought quite unworthy.

70 I trust the Board will be pleased to excuse the length of time that I have taken to prepare this report. Since I resumed charge of the Division I have had to discuss and estimate for all the main works to be proposed for execution next year, and respecting which the lateness of the season would not admit of delay. I have also had to obtain and prepare various papers that affected the question; and all was to be done while moving about, and with a single office Writer, who had of course all the current writing business of the Department. It has in fact taken 3 or 4 weeks to get it copied, and I have been obliged to employ a surveyor at last in making a fair copy.

71 For the last week I have also been fully occupied with the duties entrusted to the Committee appointed by Government on the affairs of the Indian Iron Company, and which are not yet concluded.

Since writing the above, a letter has been received from the Board, which reminds me of one point of this subject which should not have been omitted.

The Regulations make no particular provision respecting the preparation of Estimates for new works of small amount. A Surveyor or young Officer in his tour finds an opening for the improvement of the Irrigation of one or two villages, the cost of which will be perhaps 1000 Rupees. He examines it, and reports upon it, and the Civil Engineer having made all the enquiry he can about it, approves of it and perhaps recommends it for Sanction. The papers are returned for his personal inspection of the spot, and report. He has now the choice of three

things, either to go at once to the place, which may take him from a week to a fortnight going and returning, in which case his pay and the pay of His Establishment will cost the Government from 350 to 700 Rupees directly; and as it will take him away from other far more important duty, the indirect loss to Government cannot be less than three or four times as much, as from 1200 to 2400 Rupees, which will double or treble the cost of the project, and probably make that an unprofitable scheme which would otherwise have been a profitable one. or 2ndly. He must wait till other more important duty leads him into that part of the Division, which may be even several years; for his time is so totally disproportionate to his duty, that he cannot see a tenth part of the Division every year, unless he very greatly neglects the great and important works in it; or 3rdly, he must give up all new works of small amount entirely. The peculiar circumstances of the Tank Department in two respects require that some specific plan should be settled, respecting the expenditure of such small sums: viz. 1st That the number of works in a Division is so greatly beyond the possible power of the Officers to attend to them, and 2ndly that they are spread over so great a space, that in a country where there are no facilities for travelling, the inspection of the most trifling work may require a fortnight of his time. Even when the Department is put on an efficient footing, it will often cost more than a small project is worth for the Civil Engineer to inspect the spot; but at present it will do so in the majority of cases. In a fixed office where all the duty is done by inspection of papers, the head of it can afford to look into very minute matters, because it costs him little time; but where the business requires the inspection of tracts of ground at a wide distance from each other, the case is entirely different; yet even in the former case it is not always considered necessary that every case should come under the personal investigation of the head of the Office; for instance in the judicial line, the enquiries of a Moon-sif are considered sufficient in cases of small sums, and he is allowed to decide them; were the Judge required to investigate every case, the only result would be that his time would be so swallowed up, that he could not possibly give the important cases that consideration which they deserved. Possibly it might be arranged that for works of a certain amount, as 500 Rupees, it might be sufficient that a Surveyor or Native Superintendent had personally inspected the spot, and that it was investigated by the Civil Engineer or his 1st Assistant; for larger works as 1000 Rupees, that it was personally inspected by an experienced Assistant, and investigated by the Civil Engineer, and for works of 3000 Rupees and upwards it should be required that the Civil Engineer should visit the spot. It certainly seems advisable that this point should be examined, and some definite plan decided upon, otherwise either nothing now involving only a small expenditure can be done in parts of the country at a distance from important works, or the Civil Engineer's time must be so taken up with them, as to prevent him effectually from duly considering the important cases which may come before him.

I am &c.

A. COTTON, Captain, *Civil Engineer*

Statement of Nunjay, Poonjay, and Extra Revenue of Twelve Collectorates, from Fusly 1210 to 1244.

NELLORE.

Fusly.	Jamanbundy of net land.	Average of each 5 years	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand Total of collections.	Average of each 5 years.
1210			16,50,000				16,50,000	
11			15,60,000		1,60,000		16,70,000	
12			17,60,000		1,10,000		18,40,000	
13			16,10,000		1,10,000		17,10,000	
14	7,40,000	7,80,000	17,70,000	16,70,000	1,20,000	1,25,000	19,00,000	17,50,000
15			18,20,000		4,90,000		23,10,000	
16			7,90,000		2,10,000		10,00,000	
17			14,60,000		4,10,000		18,70,000	
18			1,80,000		4,60,000		20,50,000	
19		7,00,000	18,40,000	17,30,000	5,40,000	4,20,000	23,80,000	
20			19,40,000		7,70,000		27,00,000	
21			19,20,000		8,00,000		27,20,000	
22			17,30,000		8,00,000		25,20,000	
23			18,70,000		7,70,000		26,40,000	
24			18,90,000	18,70,000	6,18,000	7,50,000	25,10,000	26,20,000
25			19,00,000		5,80,000		24,80,000	
26			18,40,000		5,50,000		23,90,000	
27			19,00,000		6,50,000		25,50,000	
28			18,60,000		7,50,000		26,10,000	
29			18,30,000	18,70,000	7,10,000	6,50,000	25,40,000	25,10,000
30	3,50,000		18,20,000		7,90,000		26,00,000	
31	3,80,000		17,50,000		8,00,000		25,50,000	
32	7,18,000		19,70,000		7,30,000		27,00,000	
33	5,18,000		19,20,000		6,80,000		26,00,000	
34	14,40,000	6,80,000	27,80,000	20,50,000	5,60,000	7,10,000	33,40,000	27,60,000
35	4,90,000		17,50,000		6,40,000		33,90,000	
36	7,60,000		19,60,000		5,40,000		25,00,000	
37	7,60,000		18,90,000		6,20,000		25,10,000	
38	7,70,000		18,20,000		6,70,000		24,90,000	
39	5,50,000	6,70,000	17,50,000	18,30,000	7,20,000	6,40,000	24,80,000	
40	7,80,000		18,20,000		6,50,000		24,70,000	
41	7,60,000		16,50,000		6,20,000		22,70,000	
42	7,80,000		10,80,000		5,90,000		16,80,000	
43	6,70,000		13,80,000		5,80,000		19,60,000	
44	7,30,000	7,40,000	14,70,000	15,80,000	5,30,000	5,90,000	20,00,000	21,75,000

BELLARY.

Fusly.	Jamanbundy of net land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	"		16,50,000		4,40,000		21,00,000	
11	9,20,000		19,60,000		5,50,000		25,10,000	
12	9,00,000		20,00,000		5,40,000		25,30,000	
13	9,40,000		21,50,000		5,10,000		27,50,000	
14	12,20,000	9,95,000	26,40,000	21,90,000	6,10,000	5,50,000	32,40,000	27,60,000
15	10,50,000		28,30,000		5,70,000		34,00,000	
16	8,30,000		25,20,000		5,90,000		31,20,000	
17	8,00,000		24,50,000		6,00,000		30,50,000	
18	10,30,000		27,40,000		6,60,000		34,00,000	
19	"	9,30,000	24,80,000	26,00,000	6,80,000	6,20,000	31,60,000	32,30,000
20	"		26,00,000		7,10,000		33,10,000	
21	"		26,50,000		7,70,000		34,20,000	
22	"		25,10,000		8,00,000		33,10,000	
23	"		26,30,000		8,40,000		34,70,000	
24	"		26,40,000	26,00,000	8,40,000	7,90,000	34,40,000	33,90,000
25	"		26,60,000		8,50,000		35,10,000	
26	"		25,40,000		8,30,000		33,70,000	
27	"		25,70,000		7,70,000		33,40,000	
28	"		24,60,000		8,70,000		33,30,000	
29	"		25,20,000	23,50,000	8,50,000	8,30,000	33,70,000	33,80,000
30	7,90,000		22,70,000		8,80,000		31,50,000	
31	"		23,20,000		10,50,000		33,70,000	
32	11,60,000		23,70,000		10,10,000		33,90,000	
33	10,30,000		19,70,000		9,50,000		29,20,000	
34	11,30,000	10,30,000	21,90,000	20,60,000	9,00,000	9,60,000	30,80,000	31,80,000
35	12,10,000		22,90,000		9,10,000		32,00,000	
36	11,60,000		22,40,000		9,30,000		31,70,000	
37	10,10,000		19,10,000		9,10,000		28,20,000	
38	11,50,000		22,10,000		9,80,000		31,80,000	
39	10,90,000	11,20,000	19,20,000	24,10,000	9,80,000	9,40,000	29,10,000	30,60,000
40	11,50,000		20,60,000		9,70,000		30,20,000	
41	10,70,000		20,00,000		9,70,000		29,70,000	
42	9,70,000		16,70,000		9,40,000		26,10,000	
43	11,80,000		21,00,000		8,90,000		29,90,000	
44	11,20,000	11,00,000	19,90,000	24,55,000	8,20,000	9,20,000	28,10,000	29,50,000

CUDDAPAH.

Fusly.	Jamanbundy of net Land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	"		15,30,000		1,60,000		16,90,000	
11	"		20,60,000		2,70,000		23,30,000	
12	"		21,70,000		2,50,000		24,10,000	
13	"		21,00,000		2,20,000		23,20,000	
14	"		24,40,000	21,90,000	2,00,000	2,35,000	26,40,000	24,25,000
15	"		26,60,000		1,90,000		28,60,000	
16	6,20,000		20,80,000		1,90,000		22,70,000	
17	9,70,000		25,60,000		1,90,000		27,50,000	
18	1,80,000		26,60,000		2,40,000		29,00,000	
19	1,10,000	4,95,000	24,70,000	26,00,000	3,00,000	2,20,000	27,70,000	28,20,000
20	20,000		23,70,000		3,30,000		26,90,000	
21	"		18,30,000		3,30,000		21,60,000	
22	"		21,60,000		3,70,000		25,30,000	
23	"		23,30,000		4,00,000		27,30,000	
24	"	20,000	24,10,000	23,20,000	3,90,000	3,60,000	27,60,000	26,80,000
25	"		24,40,000		4,00,000		28,30,000	
26	"		22,70,000		3,90,000		26,60,000	
27	"		23,90,000		3,70,000		27,60,000	
28	"		23,80,000		3,70,000		27,60,000	
29	"		22,90,000	23,50,000	4,00,000	3,90,000	26,90,000	27,40,000
30	"		23,40,000		4,10,000		27,50,000	
31	9,10,000		21,00,000		3,90,000		25,00,000	
32	9,60,000		21,90,000		4,10,000		26,00,000	
33	9,40,000		17,60,000		3,90,000		21,50,000	
34	9,90,000	9,50,000	19,00,000	20,60,000	3,30,000	3,90,000	22,20,000	25,40,000
35	10,10,000		19,60,000		3,30,000		22,90,000	
36	10,40,000		20,30,000		3,50,000		23,80,000	
37	10,20,000		18,00,000		3,90,000		21,90,000	
38	10,20,000		18,50,000		4,10,000		22,70,000	
39	10,40,000	10,30,000	18,40,000	19,00,000	4,60,000	3,90,000	23,00,000	22,70,000
40	10,70,000		19,50,000		4,60,000		24,10,000	
41	10,80,000		18,60,000		4,50,000		23,10,000	
42	10,20,000		13,70,000		4,20,000		17,90,000	
43	9,80,000		18,60,000		4,00,000		22,60,000	
44	9,90,000	10,30,000	18,00,000	18,90,000	3,90,000	4,20,000	22,70,000	23,10,000

CHINGLEPUT.

Fusly.	Jamanbundy of net Land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	"		13,10,000		80,000		13,90,000	
11	"		12,50,000		50,000		13,00,000	
12	"		11,20,000		40,000		11,60,000	
13	"		11,10,000		80,000		11,90,000	
14	"	"	10,60,000	11,70,000	90,000	70,000	11,50,000	12,40,000
15	"		10,70,000		2,00,000		12,70,000	
16	"		10,20,000		2,00,000		12,20,000	
17	"		10,80,000		2,40,000		13,10,000	
18	"		10,90,000		2,60,000		13,50,000	
19	"	"	11,10,000	10,70,000	3,20,000	2,40,000	14,30,000	13,20,000
20	"		11,00,000		4,20,000		15,20,000	
21	"		10,50,000		3,40,000		14,00,000	
22	"		10,30,000		4,70,000		14,90,000	
23	"		12,60,000		4,70,000		15,30,000	
24	"	"	10,50,000	10,90,000	4,20,000	4,20,000	14,70,000	14,80,000
25	"		10,40,000		4,00,000		14,40,000	
26	"		10,30,000		3,90,000		14,10,000	
27	"		10,30,000		3,90,000		14,20,000	
28	"		10,00,000		4,10,000		14,10,000	
29	"	"	9,70,000	10,10,000	4,10,000	4,00,000	13,80,000	14,10,000
30	"		9,20,000		3,40,000		12,60,000	
31	"		9,90,000		5,20,000		15,10,000	
32	"		10,90,000		4,40,000		15,30,000	
33	"		7,30,000		4,20,000		11,50,000	
34	"	"	9,10,000	9,30,000	4,50,000	4,30,000	13,60,000	13,60,000
35	"		8,90,000		5,10,000		14,00,000	
36	1,000		9,00,000		4,90,000		14,00,000	
37	2,000		8,30,000		3,70,000		12,00,000	
38	3,000		8,80,000		5,70,000		14,50,000	
39	3,000	2,200	8,20,000	8,60,000	6,20,000	5,10,000	14,50,000	13,80,000
40	3,000		8,10,000		5,80,000		14,00,000	
41	3,000		9,20,000		6,20,000		15,40,000	
42	2,000		5,30,000		6,50,000		11,80,000	
43	3,000		7,90,000		8,30,000		16,20,000	
44	4,000	3,000	7,90,000	8,30,000	7,50,000	6,90,000	15,30,000	12,20,000

NORTHERN DIVISION OF ARCOT.

Fusly.	Jamanbundy of net Land.	Average of each 5 years.	Total collection of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of Collection.	Average of each 5 years.
1210	"	"	"	"	"	"	"	"
11	"		21,60,000		3,70,000		25,30,000	
12	"		22,80,000		3,70,000		26,50,000	
13	6,70,000		23,10,000		3,30,000		26,30,000	
14	5,20,000	6,00,000	19,90,000	21,85,000	2,90,000	3,40,000	22,90,000	25,25,000
15	6,90,000		24,50,000		3,70,000		28,20,000	
16	4,00,000		15,70,000		3,48,000		19,00,000	
17	6,80,000		22,60,000		2,50,000		25,00,000	
18	"		24,10,000		3,60,000		27,60,000	
19	"	5,90,000	24,00,000	22,20,000	3,90,000	3,40,000	27,90,000	27,20,000
20	"		23,30,000		4,30,000		27,60,000	
21	"		19,50,000		4,10,000		23,60,000	
22	"		22,40,000		4,20,000		26,60,000	
23	"		22,50,000		4,40,000		27,00,000	
24	"		22,50,000	20,00,000	4,30,000	4,30,000	26,80,000	27,00,000
25	"		22,50,000		5,20,000		27,80,000	
26	"		22,50,000		4,60,000		27,10,000	
27	"		22,50,000		4,40,000		27,20,000	
28	"		22,70,000		4,90,000		27,50,000	
29	"		22,30,000	22,50,000	3,90,000	4,60,000	26,20,000	27,20,000
30	"		22,30,000		4,40,000		26,70,000	
31	14,30,000		23,50,000		4,50,000		28,00,000	
32	16,30,000		24,90,000		4,90,000		29,70,000	
33	15,10,000		1,56,000		4,40,000		20,00,000	
34	15,60,000	15,30,000	20,50,000	22,80,000	4,10,000	4,50,000	24,60,000	27,25,000
35	14,30,000		21,40,000		3,70,000		25,10,000	
36	13,90,000		22,10,000		4,20,000		26,30,000	
37	13,50,000		20,30,000		4,50,000		24,80,000	
38	13,10,000		19,90,000		5,10,000		25,00,000	
39	13,20,000	13,60,000	18,20,000	20,40,000	5,20,000	4,50,000	23,40,000	24,90,000
40	11,90,000		20,60,000		5,00,000		25,60,000	
41	13,10,000		21,80,000		4,50,000		26,30,000	
42	8,00,000		13,00,000		4,20,000		17,20,000	
43	11,70,000		19,00,000		3,10,000		22,10,000	
44	12,10,000	11,40,000	20,40,000	20,45,000	3,80,000	4,10,000	24,30,000	24,60,000

SOUTHERN DIVISION OF ARCOT.

Fusly.	Jamanbundy of net land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	"	"	"	"	"	"	"	"
11	8,10,000		17,40,000		1,60,000		19,00,000	
12	12,10,000		23,30,000		2,40,000		25,60,000	
13	11,60,000		21,50,000		2,10,000		23,60,000	
14	3,60,000	8,85,000	9,70,000	18,00,000	1,60,000	1,90,000	11,30,000	19,90,000
15	9,70,000		18,50,000		2,30,000		20,90,000	
16	5,60,000		13,70,000		2,10,000		15,80,000	
17	9,50,000		18,20,000		2,20,000		20,40,000	
18	"		19,10,000		2,30,000		21,40,000	
19	"	8,30,000	18,90,000	18,70,000	2,90,000	2,40,000	21,90,000	21,15,000
20	"		19,30,000		3,30,000		22,60,000	
21	2,40,000		14,00,000		30,000		17,00,000	
22	1,30,000		16,60,000		3,90,000		20,50,000	
23	40,000		18,40,000		3,90,000		22,20,000	
24	30,000	1,10,000	18,80,000	18,30,000	4,10,000	3,10,000	22,90,000	22,00,000
25	30,000		18,70,000		4,20,000		22,90,000	
26	30,000		18,40,000		4,50,000		22,80,000	
27	30,000		18,80,000		4,90,000		23,70,000	
28	20,000		18,70,000		5,30,000		24,00,000	
29	30,000	30,000	18,70,000	18,70,000	60,00,000	5,00,000	24,60,000	23,60,000
30	30,000		18,70,000		4,50,000		23,20,000	
31	9,70,000		18,20,000		5,80,000		23,90,000	
32	1,10,000		20,70,000		5,80,000		26,50,000	
33	6,70,000		15,10,000		6,00,000		21,10,000	
34	9,90,000	5,50,000	18,50,000	19,00,000	5,30,000	5,50,000	23,80,000	24,35,000
35	10,80,000		20,20,000		5,60,000		25,80,000	
36	11,50,000		20,80,000		5,10,000		25,90,000	
37	10,00,000		18,50,000		6,80,000		25,30,000	
38	9,60,000		17,90,000		6,00,000		23,80,000	
39	9,30,000	10,20,000	18,70,000	19,20,000	6,60,000	6,00,000	25,30,000	25,20,000
40	9,80,000		18,90,000		5,90,000		24,80,000	
41	8,70,000		16,80,000		5,80,000		22,60,000	
42	7,50,000		13,00,000		5,30,000		18,40,000	
43	8,50,000		16,10,000		5,00,000		21,10,000	
44	9,80,000	8,90,000	19,60,000	17,85,000	5,30,000	5,50,000	25,00,000	23,40,000

SALEM.

Fusly.	Jamanbundy of net Land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	12,10,000		20,40,000		1,80,000		22,20,000	
11	12,80,000		20,50,000		2,00,000		22,50,000	
12	4,10,000		19,00,000		2,00,000		20,90,000	
13	4,00,000		18,60,000		1,70,000		20,30,000	
14	1,30,000	6,90,000	18,00,000	19,30,000	1,30,000	1,80,000	19,20,000	21,00,000
15	1,00,000		18,20,000		90,000		19,10,000	
16	1,00,000		18,20,000		50,000		18,70,000	
17	1,10,000		18,40,000		40,000		18,90,000	
18	1,20,000		18,50,000		80,000		19,30,000	
19	1,20,000	1,10,000	18,20,000	18,30,000	1,30,000	80,000	19,50,000	19,10,000
20	1,00,000		17,50,000		1,20,000		18,70,000	
21	1,10,000		17,80,000		1,20,000		19,00,000	
22	1,10,000		17,90,000		1,40,000		19,30,000	
23	1,20,000		18,30,000		1,40,000		19,70,000	
24	2,50,000	1,40,000	18,20,000	17,90,000	1,60,000	1,40,000	19,80,000	19,30,000
25	2,70,000		18,10,000		1,50,000		19,60,000	
26	2,60,000		17,90,000		1,60,000		19,40,000	
27	3,00,000		17,90,000		1,60,000		19,50,000	
28	3,30,000		17,60,000		1,60,000		19,10,000	
29	3,90,000	3,10,000	17,60,000	17,80,000	1,90,000	1,60,000	19,50,000	19,40,000
30	5,90,000		17,70,000		3,50,000		21,20,000	
31	6,70,000		16,40,000		3,80,000		20,10,000	
32	7,40,000		17,00,000		3,60,000		20,60,000	
33	7,60,000		16,80,000		3,60,000		20,50,000	
34	7,80,000	7,00,000	17,40,000	17,00,000	3,20,000	3,50,000	20,60,000	20,60,000
35	8,30,000		17,90,000		3,10,000		21,10,000	
36	8,40,000		17,90,000		3,30,000		21,30,000	
37	8,20,000		17,60,000		3,40,000		21,00,000	
38	7,60,000		17,00,000		3,60,000		20,60,000	
39	7,30,000	8,00,000	16,70,000	17,40,000	3,50,000	3,40,000	20,30,000	20,90,000
40	7,80,000		17,10,000		3,70,000		20,80,000	
41	7,50,000		16,60,000		3,70,000		20,30,000	
42	6,80,000		13,80,000		3,50,000		17,30,000	
43	6,40,000		15,00,000		3,20,000		18,20,000	
44	7,60,000	7,20,000	15,40,000	16,00,000	2,80,000	3,40,000	18,20,000	19,00,000

TANJORE.

Fusly.	Jamanbundy of net. Land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	38,80,000		44,10,000		2,60,000		46,70,000	
11	27,40,000		31,30,000		1,50,000		32,80,000	
12	24,80,000		26,60,000		1,10,000		27,80,000	
13	22,60,000		23,60,000		1,00,000		24,60,000	
14	"	24,90,000	23,30,000	26,20,000	1,80,000	1,60,000	35,10,000	30,00,000
15	"		31,00,000		1,70,000		33,70,000	
16	"		28,20,000		1,60,000		29,80,000	
17	20,00,000		35,60,000		2,10,000		37,70,000	
18	60,000		36,00,000		3,80,000		39,70,000	
19	1,10,000	1,20,000	33,20,000	32,80,000	5,10,000	2,90,000	38,30,000	35,80,000
20	5,50,000		30,30,000		5,60,000		35,90,000	
21	1,30,000		30,30,000		5,10,000		35,40,000	
22	1,10,000		32,70,000		5,40,000		38,20,000	
23	1,00,000		34,70,000		6,30,000		41,00,000	
24	70,000	1,90,000	34,30,000	32,50,000	6,50,000	5,80,000	40,80,000	38,30,000
25	2,30,000		32,90,000		6,60,000		49,50,000	
26	2,10,000		33,30,000		6,50,000		39,90,000	
27	1,80,000		32,60,000		6,50,000		39,00,000	
28	1,00,000		31,00,000		7,00,000		38,00,000	
29	1,00,000	1,60,000	31,00,000	32,20,000	7,50,000	6,80,000	38,50,000	41,00,000
30	2,00,000		31,70,000		9,10,000		40,80,000	
31	6,10,000		30,60,000		8,60,000		39,30,000	
32	4,30,000		32,90,000		8,30,000		41,20,000	
33	4,70,000		43,10,000		8,90,000		52,00,000	
34	5,90,000	4,60,000	49,60,000	37,60,000	9,20,000	8,80,000	58,80,000	43,30,000
35	3,70,000		35,60,000		8,90,000		44,50,000	
36	2,20,000		30,10,000		8,80,000		38,90,000	
37	3,00,000		28,00,000		8,10,000		36,00,000	
38	4,10,000		26,90,000		10,70,000		47,60,000	
39	3,30,000	3,30,000	33,20,000	30,70,000	10,40,000	8,20,000	43,60,000	42,10,000
40	2,40,000		33,70,000		9,50,000		43,30,000	
41	3,00,000		34,90,000		9,20,000		44,00,000	
42	3,20,000		37,70,000		8,90,000		46,70,000	
43	2,90,000		38,80,000		9,60,000		48,30,000	
44	2,30,000	2,80,000	35,30,000	36,00,000	9,50,000	9,30,000	44,80,000	45,40,000

TRICHINOPOLY.

Fusly.	Jamanbundy of net Land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	"	"	"	"	"	"	"	"
11	"		14,90,000		1,60,000		16,50,000	
12	9,60,000		16,80,000		1,80,000		18,60,000	
13	10,30,000		17,40,000		1,80,000		19,30,000	
14	10,40,000	10,10,000	15,50,000	16,15,000	1,50,000	1,70,000	17,00,000	14,30,000
15	9,40,000		16,90,000		90,000		17,80,000	
16	8,90,000		15,30,000		40,000		15,60,000	
17	9,60,000		16,70,000		20,000		16,80,000	
18	9,40,000		16,20,000		90,000		17,10,000	
19	9,00,000	9,30,000	15,30,000	16,00,000	1,50,000	80,000	16,80,000	16,80,000
20	"		16,20,000		1,60,000		17,80,000	
21	"		16,70,000		1,60,000		18,30,000	
22	"		16,60,000		1,40,000		18,00,000	
23	2,10,000		16,40,000		1,50,000		17,90,000	
24	1,70,000	1,90,000	16,10,000	16,40,000	1,60,000	1,50,000	17,60,000	17,90,000
25	1,60,000		15,20,000		1,80,000		17,00,000	
26	1,60,000		15,30,000		1,90,000		17,20,000	
27	1,60,000		14,90,000		2,10,000		16,90,000	
28	1,40,000		11,30,000		2,00,000		13,30,000	
29	1,40,000	1,50,000	12,40,000	14,45,000	2,00,000	2,00,000	14,40,000	15,80,000
30	1,30,000		13,70,000		2,30,000		16,00,000	
31	7,50,000		13,80,000		2,50,000		16,30,000	
32	7,90,000		14,60,000		2,60,000		17,10,000	
33	8,00,000		13,40,000		2,60,000		16,00,000	
34	8,30,000	6,67,000	14,80,000	14,00,000	2,50,000	2,50,000	17,80,000	16,50,000
35	8,30,000		14,90,000		2,50,000		17,40,000	
36	8,10,000		14,70,000		2,50,000		17,20,000	
37	7,90,000		13,40,000		2,50,000		15,80,000	
38	7,50,000		13,70,000		2,50,000		16,30,000	
39	7,60,000	7,90,000	13,90,000	14,10,000	2,60,000	2,50,000	16,50,000	16,60,000
40	7,80,000		14,00,000		2,60,000		16,60,000	
41	7,70,000		13,20,000		2,50,000		15,70,000	
42	7,50,000		12,50,000		2,50,000		15,00,000	
43	7,70,000		13,50,000		2,10,000		15,60,000	
44	7,70,000	7,70,000	13,90,000	13,65,000	2,00,000	2,30,000	15,90,000	15,95,000

TINNEVELLY

Fusly.	Jamanbundy of net land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	"	"	20,60,000	"	"	"	20,60,000	"
11	12,90,000		23,20,000		1,80,000		25,00,000	
12	11,70,000		21,20,000		1,80,000		23,00,000	
13	12,70,000		23,20,000		1,40,000		24,70,000	
14	9,80,000	11,80,000	19,10,000	21,50,000	1,20,000	1,55,000	20,30,000	22,70,000
15	11,60,000		21,90,000		1,50,000		23,50,000	
16	12,40,000		23,30,000		90,000		24,20,000	
17	9,80,000		19,50,000		1,20,000		20,70,000	
18	"		21,70,000		1,60,000		23,40,000	
19	"	11,30,000	21,90,000	21,70,000	2,20,000		24,10,000	
20	"		21,20,000		2,30,000		23,60,000	
21	9,60,000		17,50,000		2,40,000		1,99,000	
22	"		18,40,000		2,70,000		21,20,000	
23	11,10,000		18,50,000		2,90,000		21,50,000	
24	11,50,000	10,70,000	19,30,000	19,00,000	3,50,000	2,80,000	22,70,000	22,25,000
25	11,20,000		18,50,000		3,30,000		21,80,000	
26	11,20,000		18,10,000		3,70,000		21,90,000	
27	11,50,000		18,90,000		4,00,000		22,90,000	
28	11,50,000		18,30,000		4,10,000		22,40,000	
29	11,50,000	11,40,000	18,80,000	18,50,000	4,20,000	3,90,000	22,90,000	22,40,000
30	11,90,000		19,80,000		4,40,000		24,20,000	
31	11,80,000		19,60,000		4,70,000		24,30,000	
32	11,20,000		21,10,000		4,90,000		26,00,000	
33	12,00,000		20,20,000		4,60,000		24,80,000	
34	10,40,000	11,50,000	19,80,000	20,10,000	5,10,000	4,70,000	24,90,000	24,80,000
35	10,80,000		20,00,000		5,30,000		25,30,000	
36	9,60,000		18,80,000		5,40,000		24,20,000	
37	8,50,000		17,40,000		5,10,000		22,60,000	
38	9,50,000		18,40,000		6,30,000		24,70,000	
39	9,60,000	9,60,000	17,50,000	18,40,000	6,90,000	5,80,000	24,40,000	24,20,000
40	8,80,000		17,10,000		6,80,000		23,90,000	
41	7,60,000		12,70,000		6,50,000		19,20,000	
42	8,70,000		16,90,000		6,10,000		22,90,000	
43	10,10,000		19,10,000		5,70,000		24,80,000	
44	10,20,000	9,40,000	16,90,000	17,70,000	5,90,000	6,20,000	22,90,000	23,60,000

MADURA.

Fusly.	Jamanbundy of net Land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of collections.	Average of each 5 years.
1210	"		22,50,000		1,80,000		24,20,000	
11	"		25,60,000		4,00,000		29,60,000	
12	"		29,90,000		2,20,000		32,10,000	
13	"		21,10,000		2,20,000		23,40,000	
14	"		18,60,000	23,50,000	1,90,000	2,40,000	20,50,000	26,00,000
15	"		19,60,000		1,80,000		21,40,000	
16	"		19,50,000		80,000		20,30,000	
17	"		20,10,000		1,30,000		21,40,000	
18	"		16,90,000		1,40,000		18,30,000	
19	"		17,00,000	18,60,000	1,90,000	1,40,000	18,90,000	20,00,000
20	"		15,90,000		1,70,000		17,60,000	
21	"		13,70,000		2,30,000		16,00,000	
22	"		14,10,000		2,60,000		16,70,000	
23	2,30,000		13,50,000		3,20,000		16,70,000	
24	2,90,000	2,60,000	14,70,000	14,40,000	2,90,000	2,50,000	17,60,000	16,90,000
25	3,20,000		15,00,000		3,10,000		18,10,000	
26	3,30,000		14,60,000		3,60,000		18,20,000	
27	"		14,50,000		3,80,000		18,30,000	
28	"		14,70,000		4,10,000		18,80,000	
29	"	3,25,000	14,40,000	14,60,000	5,20,000	4,00,000	19,60,000	18,60,000
30	"		14,30,000		5,00,000		19,20,000	
31	"		14,50,000		6,30,000		20,80,000	
32	4,00,000		15,80,000		6,50,000		22,20,000	
33	3,40,000		13,90,000		6,00,000		19,90,000	
34	3,90,000	3,80,000	16,00,000	14,90,000	6,10,000	6,00,000	22,20,000	20,90,000
35	4,20,000		16,30,000		6,40,000		22,70,000	
36	4,80,000		16,80,000		6,30,000		23,00,000	
37	4,50,000		15,80,000		6,80,000		22,50,000	
38	4,20,000		15,20,000		7,40,000		22,60,000	
39	4,00,000	4,30,000	15,20,000	15,90,000	7,00,000	6,80,000	22,20,000	22,60,000
40	4,40,000		15,80,000		6,70,000		22,50,000	
41	3,70,000		14,20,000		7,20,000		21,40,000	
42	4,00,000		15,30,000		6,20,000		21,60,000	
43	4,10,000		16,00,000		6,00,000		22,00,000	
44	4,30,000	4,10,000	15,50,000	15,40,000	6,30,000	6,50,000	21,80,000	21,90,000

COIMBATORE

Fusly.	Jamanbundy of net Land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of Collections.	Average of each 5 years.
1210	4,10,000		21,30,000		2,10,000		23,30,000	
11	4,70,000		20,50,000		2,70,000		23,20,000	
12	4,60,000		22,80,000		2,90,000		25,80,000	
13	4,40,000		21,70,000		3,00,000		24,70,000	
14	4,30,000	4,40,000	21,60,000	21,60,000	2,00,000	2,50,000	23,60,000	24,10,000
15	4,60,000		19,80,000		1,56,000		21,30,000	
16	4,60,000		19,00,000		90,000		19,10,000	
17	5,60,000		20,90,000		1,00,000		21,90,000	
18	"		21,30,000		50,000		21,80,000	
19	"	4,90,000	21,20,000	20,40,000	90,000	97,000	22,20,000	24,30,000
20	"		21,10,000		1,10,000		22,20,000	
21	4,40,000		18,20,000		1,40,000		19,60,000	
22	4,20,000		17,40,000		1,70,000		19,10,000	
23	"		16,90,000		1,20,000		18,10,000	
24	"	4,30,000	18,20,000	18,40,000	1,50,000	1,40,000	19,70,000	19,70,000
25	5,50,000		20,70,000		1,90,000		22,60,000	
26	5,30,000		20,00,000		2,10,000		22,10,000	
27	5,20,000		21,40,000		2,40,000		23,80,000	
28	5,20,000		21,90,000		2,90,000		24,80,000	
29	5,00,000	5,20,000	22,10,000	21,20,000	3,40,000	2,50,000	25,50,000	23,80,000
30	5,00,000		21,50,000		3,40,000		24,90,000	
31	5,30,000		21,70,000		3,40,000		25,10,000	
32	5,10,000		22,60,000		3,50,000		26,10,000	
33	4,90,000		21,90,000		3,10,000		25,00,000	
34	5,00,000	5,00,000	23,20,000	22,20,000	3,20,000	3,30,000	26,40,000	25,50,000
35	5,00,000		23,30,000		3,40,000		26,27,000	
36	5,00,000		23,30,000		3,30,000		26,27,000	
37	5,00,000		23,30,000		3,60,000		26,90,000	
38	5,00,000		22,70,000		4,60,000		27,30,000	
39	5,00,000	5,00,000	22,70,000	22,90,000	4,90,000	4,00,000	27,60,000	27,00,000
40	5,00,000		22,60,000		3,60,000		26,10,000	
41	4,90,000		21,70,000		3,90,000		25,50,000	
42	4,80,000		20,60,000		3,50,000		24,10,000	
43	4,90,000		20,10,000		3,30,000		23,40,000	
44	5,00,000	4,90,000	19,60,000	20,90,000	3,30,000	3,50,000	22,90,000	24,40,000

TOTAL OF THE ABOVE DISTRICTS.

Fusly.	Jamanbun- dy of net land	Average of each 5 years.	Total collec- tions of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of collec- tions.	Average of each 5 years.
1210								
11								
12								
13								
14	"	90,75,000	"	240,30,000	"	26,65,000	"	265,00,000
15								
16								
17								
18								
19	"	63,20,000	"	248,70,000	"	29,20,000	"	281,50,000
20								
21								
22								
23								
24	"	24,10,000	"	235,70,000	"	46,00,000	"	285,05,000
25								
26								
27								
28								
29	"	26,35,000	"	247,10,000	"	53,10,000	"	292,20,000
30								
31								
32								
33								
34	"	85,90,000	"	240,20,000	"	63,70,000	"	303,30,000
35								
36								
37								
38								
39	"	76,52,000	"	229,00,000	"	66,00,000	"	297,30,000
40								
41								
42								
43								
44	"	84,73,000	"	225,50,000	"	67,40,000	"	287,80,000

TOTAL OMITTING TANJORE.

Fusly.	Jamanbundy of net land.	Average of each 5 years.	Total collections of land Revenue.	Average of each 5 years.	Total Extra sources of Revenue.	Average of each 5 years.	Grand total of Collections.	Average of each 5 years.
1210								
11								
12								
13								
14	"	65,65,000	"	214,10,000	"	25,05,000	"	235,00,000
15								
16								
17								
18								
19	"	62,00,000	"	215,90,000	"	26,30,000	"	244,15,000
20								
21								
22								
23								
24	"	22,20,000	"	203,20,000	"	40,20,000	"	246,75,000
25								
26								
27								
28								
29	"	24,75,000	"	214,90,000	"	46,30,000	"	257,20,000
30								
31								
32								
33								
34	"	81,30,000	"	202,60,000	"	54,90,000	"	260,00,000
35								
36								
37								
38								
39	"	73,22,000	"	198,30,000	"	57,80,000	"	255,20,000
40								
41								
42								
43								
44	"	81,93,000	"	189,50,000	"	58,10,000	"	242,40,000

APPENDIX B.

Statement shewing the net Collections of Revenue and money expended on account of maramut in the Talooks of Manargoody and Chellumbrum of South Arcot from Fusly 1215. to 1243.

Fuslies.	Net collections exclusive of Jaghire.	Net collections of Jaghire.	Total Net Collections.	Maramut Expenditure.
1215.....	2,10,911	0 1		
1216.....	1,76,970	2 9		
1217.....	2,20,328	9 7		
Total.	6,08,209	12 5		
Average.	2,02,736	9 5½		
1218.....	2,13,019	1 6		
1219.....	1,68,988	5 6		

Fuslies.	Net collections exclusive of Jaghire.	Net collections of Jaghire.	Total Net Collections.	Maramut Expenditure.
1220	1,96,268	7 8		
Total..	5,78,275	14 8		
Average..	1,92,758	10 3		
1221	1,15,139	1 2		
1222	1,53,757	2 0		
1223	1,80,868	10 8		
1224	1,89,484	4 11		
1225	1,87,090	12 9		
1226	2,00,152	4 4		
1227	2,06,577	1 7		
1228	1,92,008	12 10		
1229	1,97,031	8 11		
1230	2,01,610	13 9		
Total..	18,23,720	8 11		
Average..	1,82,372	0 11		
1231	1,47,976	5 0		
1232	2,13,270	0 2		
1233	1,71,082	13 3		
1234	1,88,942	14 2		
1235	1,97,947	9 10		
1236	1,78,558	10 6		
1237	1,47,946	15 11		
1238	1,41,280	8 9		
1239	1,95,467	9 11		
1240	1,62,865	4 8		
1241	1,05,007	0 0	39,627 0 0	20,766 0 0
1242	1,43,422	0 0	40,680 0 0	23,838 0 0
1243	1,70,987	0 0	42,030 0 0	13,467 0 0
1244	2,31,893	0 0	53,619 0 0	18,333 0 0
1245	2,39,525	0 0	47,729 0 0	1,64,756 0 0
1246	2,38,053	0 0	48,695 0 0	7,945 0 0
1247			3,22,000 0 0	0 0 0
				1,96,105 0 0

GROSS PRODUCE OF THE DISTRICT OF TANJORE

Fusly.	Gross Produce of the Nunjah turf lands in Tanjore.	Total of every 5 years.	Average of every 5 years.	Increase in the average of each 5 years above the average of the preceding 5 years.	Greatest difference of produce in any two years of each period of 5 years.
	Cullums.	Cullums.	Cullums.	Cullums.	Cullums.
1211	114,23,566				
1212	65,56,491				48,67,075
1213	77,81,947				or from 100
1214	101,36,428				to 57.
1215	112,50,011	470,98,444	94,19,689		
1216	86,80,840				26,34,444
1217	111,20,623				or from 100
1218	113,15,289				to 77.
1219	112,40,690				
1220	102,31,938	525,89,382	105,17,876	10,98,187	
1221	102,44,095				17,65,843
1222	115,88,812				or from 100
1223	118,97,079				to 85.
1224	1,200,99,938				
1225	115,42,410	572,82,337	114,56,467	9,38,591	
1226	111,42,870				6,22,725
1227	115,60,725				or from 100
1228	114,12,055				to 94½.
1229	116,45,229				
1230	117,65,595	575,26,476	115,05,295	48,828	
1231	111,26,938				17,17,513
1232	122,97,039				or from 100
1233	126,10,263				to 87.
1234	128,44,451				
1235	126,96,617	615,75,311	123,15,062	8,09,767	
1236	133,43,787				11,43,119
1237	127,24,142				or from 100
1238	122,00,668				to 91.
1239	124,03,994				
1240	127,92,272	634,64,865	126,92,973	3,77,911	
1241	132,51,973				6,43,070
1242	132,56,030				or from 100
1243	128,45,822				to 95½.
1244	134,88,892				
1245	130,07,905	658,50,625	131,70,125	4,77,152	
	Average of the first 5 years	44,19,689		
1246	118,47,457	Increase	37,50,436	or 39½ per Cent.	
		Value about	18,00,000		
	Govt. share probably about	..	7,00,000		

Statement shewing the actual and Ayacut cultivation under Tanks in the North-West part of South Arcot.

No. of Tanks.	Total Nunjah cultivation of Revenue for fusly 1243.			Total Ayacut cultivation.			Total not watered at present.		
	Cawnies.	Rs.	A. P.	Cawnies.	Rs.	A. P.	Cawnies.	Rs.	A. P.
612	9,364	1,07,974	0 0	27,728	2,64,960	7 0	18,364	1,56,986	7 0

Appendix E. No 1.

Statement shewing the extent of Traffic &c. at Adiyacamemgalum on the High road between Tanjore and Negapatam from 9th May to 7th June 1837.

	Bandies.	Loaded Bullocks.	Coolies.
Total of 30 days	4,217	7,926	11,514
Average per day.	140 or tons 46	264 or tons 17	383 or tons 9
Amount of goods, allowing 3 bandy loads, or 15 bullock loads, or 40 cooly loads per ton.	Total Tons. 72		

Expense of Transport of 72 Tons per day, at 2½ As. per ton per mile Rupees 11 4 0

Total present expense of Transport per mile per annum for goods only „ 4106 4 0

Appendix E. No. 2.

Statement shewing the extent of Traffic &c. at Chavoody Teroovasel on the High road between Negapatam and Tanjore from 16th to 30th August 1837.

	Palankeens.	Loaded Bandies.	Bullocks.	Coolies.	Foot Passengers.
Total for 15 days	31	5,880	7,256	7,348	19,308
Average per day.	2	392, or tons 130	483 or tons 32	489 or tons 12	1,287
Amount of goods, allowing 3 bandy loads, or 15 bullock loads, or 40 cooly loads for a ton.	Total Tons. 174				
Total number of Travellers.	1289 persons				

Expenses of Transport of 174 Tons per day, at 2½ As. per ton per mileRs. 27 3 0

Total present expense of Transport per mile per annum for goods 9923 7 0

2 Palanqueen Travellers at 1½ anna per mileRs. 0 3 0

1287 Foot Travellers, reckoning their time worth on an average 2 annas per day, and the distance travelled on foot 24 miles, or 1 pice per man per mile6 11 3

Total Rupees 6 14 3

or per annum Rupees 2,515 1 3

add for goods „ 9,923 7 0

Total expense of present Traffic per mile per annum Rupees 12,438 8 3

Statement shewing the extent of Traffic &c. at the Adyaur Causeway on the sea coast road leading into Madras.

	Foot Passengers.	Palanqueen.	Carriages and Buggies.	Carts.	Cattles.
May 1st	3110	6	108	256	102
do 2nd	2402	7	124	315	156
do 3rd	3740	13	195	492	398
do 4th	3854	5	128	422	285
do 5th	3405	17	135	394	331
do 6th	3820	7	134	382	218
do 7th	2930	6	155	316	31
do 8th	2854	12	108	282	144
do 9th	2997	7	107	415	57
do 10th	3064	8	164	423	146
do 11th	3435	3	157	452	157
do 12th	3155	10	152	404	164
do 13th	3305	8	192	490	369
do 14th	3255	4	136	394	282
do 15th	3255	2	116	315	215
do 16th	3205	2	135	234	302
Total for 16 days....	53,036	117	2246	5994	3355
Average per day	3315	7	140	375	210
Amount of goods Total 139 Tons.					
Total number of Travellers	3842	Allowing 3 for each Bandy.			

Expense of Transport of 139 Tons per day at 2½ As. per Ton per mileRs 21 11 6

Total present expense of transport per mile per annum for goods „ 7917 5 6

7 Palankeen Travellers at 1½ Annas per mileRs 0 10 6

3315 Foot Passengers, reckoning their time worth on an average 2 Annas per day, and the distance travelled 24 miles, or 1 pice per man per mile „ 17 4 3

140 Bullocks and other bandies at 2 Annas per mile „ 17 8 0

Total Rupees.... 35 6 6

or per Annum Rupees 12,928 15 9
add for goods do. 7,917 5 6

Total expense of present Traffic per Mile Rupees20,846 5 3

Statement shewing the amount expended annually on account of Earth and Masonry works performed in the Province of Tanjore from Fusly 1217 to 1246.

Fushies.	A.D. year.	Annual expense on account of irrigation works.			Annual Expense on account of roads.			Total.											
		Expense on account of irrigation works.	Expense on account of servants.	Total.	Expense on account of Roads.	Expense on account of Sib-bendy.	Total.	Total of Columns 3 and 6.	Total of Columns 4 and 7.	Total of Columns 5 and 8.									
1	2	3	4	5	6	7	8												
1217	1807	75,235	2	632	0	75,867	2	0	0	0	0	75,235	2	632	0	75,867	2		
1218	1808	38,379	4	630	0	39,009	4	0	0	0	0	38,379	4	630	0	39,009	4		
1219	1809	32,336	0	394	4	32,730	4	0	0	0	0	32,336	0	394	4	32,730	4		
1220	1810	88,357	8	1631	12	89,989	4	0	0	0	0	88,357	8	1631	12	89,989	4		
1221	1811	55,279	0	219	4	55,498	4	0	0	0	0	55,279	0	219	4	55,498	4		
1222	1812	90,013	0	2194	0	92,207	0	0	0	0	0	90,013	0	2194	0	92,207	0		
1223	1813	1,02,509	12	1866	12	1,04,376	8	0	0	0	0	1,02,509	12	1866	12	1,04,376	8		
1224	1814	73,997	0	3222	0	77,219	0	0	0	0	0	73,997	0	3222	0	77,219	0		
1225	1815	93,692	0	3319	0	97,011	0	9,667	12	193	4	9861	0	1,03,359	12	3512	4	1,06,872	0
1226	1816	77,160	0	3357	8	80,517	8	30,587	8	934	12	31,522	4	1,07,747	8	4292	4	1,12,039	12
1227	1817	45,539	0	3598	9	49,137	9	15,941	5	872	8	16,813	13	61,480	5	4471	1	65,951	6
1228	1818	77,673	13	3610	13	81,284	10	16,234	7	840	12	17,075	3	93,908	4	4451	9	98,359	13
1229	1819	1,30,896	14	4160	11	1,35,057	9	24,962	10	551	12	25,514	6	1,55,859	8	4712	7	1,60,571	15
1230	1820	50,809	3	3266	11	54,075	14	10,351	4	421	6	10,772	10	61,160	7	3688	1	64,848	8
1231	1821	52,512	2	3831	4	56,343	6	10,511	5	312	10	10,823	15	63,023	7	4143	14	67,167	5
1232	1822	54,206	1	4167	4	58,373	5	8,771	15	311	2	9,083	1	62,978	0	4478	6	67,456	6
1233	1823	66,375	14	4402	6	70,778	4	4,924	10	208	2	5,132	12	71,300	8	4610	8	75,911	0
1234	1824	57,904	2	4150	10	62,054	12	3,154	7	226	0	3,380	7	61,058	9	4376	10	65,435	3
1235	1825	59,600	9	4301	2	63,901	11	4,503	8	323	0	4,826	8	64,104	1	4,624	2	68,728	3
1236	1826	32,983	12	3056	8	36,040	4	17,751	5	1,597	13	19,349	2	50,735	1	4,654	5	55,389	6
1237	1827	25,267	15	3071	3	28,339	2	7,526	4	912	10	8,432	14	32,794	3	3,983	13	36,778	0
1238	1828	28,548	5	4451	12	33,000	1	3,675	4	576	14	4,252	2	32,223	9	5,028	10	37,252	3
1239	1829	32,910	10	5455	13	38,366	7	4,217	1	707	12	4,924	13	37,127	11	6,063	9	43,291	4
1240	1830	83,245	14	5544	13	88,790	11	8,379	8	555	3	8,934	11	91,625	6	6,100	0	97,725	6
1241	1831	1,00,662	2	5384	14	1,06,047	0	7,945	0	427	6	8,372	6	1,08,607	2	5,812	4	1,14,419	6
1242	1832	1,05,054	14	5811	6	1,10,866	4	1,201	10	66	0	1,267	10	1,06,256	8	5,877	6	1,12,133	14
1243	1833	99,943	2	5798	13	1,05,741	15	6,117	12	336	8	6,454	4	1,06,060	14	6,135	5	1,12,196	3
1244	1834	1,13,736	12	6599	2	1,20,335	14	341	13	20	4	362	1	1,14,078	9	6,619	6	1,20,697	15
1245	1835	59,048	3	5588	2	64,636	5	3,801	5	357	14	4,159	3	62,849	8	5,946	0	68,795	8
1246	1836	1,53,716	7	5847	14	1,59,564	5	3,438	12	130	0	3,568	12	1,57,155	3	5,977	14	1,63,133	1
Total		21,57,594	4	1,09,566	2	22,67,160	6	2,04,006	5	18,883	8	2,14,889	13	23,61,600	9	2,20,449	10	2,48,250	3
Average of 30 years.		71,19	12	3652	3	75,571	15	9,273	0	494	12	9,767	12	81,192	12	4,146	15	85,339	11
Average of 22 years.																			

4th January 1838.

REPORT ON THE METHOD OF REBUILDING THE SALIENT ANGLE OF THE DEMI-BASTION AT THE S. E. ANGLE OF FORT ST. GEORGE, WITH A FEW REMARKS ON THE COMPARATIVE VALUE OF DIFFERENT METHODS OF RAISING WATER BY LIEUTENANT C. C. JOINSTON.

Fort St. George consists of four regular fronts, to the N, N W. S W. and S. while to the East, or sea face, a long irregular rampart connects the salient angles of the Demi-Bastions terminating the N. and S. fronts towards the East. It is not the intention here to enter into any detailed account of the fortifications in general, but merely to offer a few remarks on that portion of them immediately adjacent to the Demi-Bastion. A vide Plate vi. near the salient angle of which, from supposed causes subsequently detailed, a large crack opened vertically in the escarp supporting the sea face line of rampart, and the revetment on being thrust forward a few inches, carried with it the salient angle of the work, thereby causing a crack in the face of the Demi-Bastion, as also one in the retaining wall of the berme;* these cracks in the course of time were found to increase to such an extent, that it was deemed expedient to remove to the foundations the portions of revetments contained between them; that is from the crack *d* on the sea face to the crack *c* on the face of the Demi-Bastion.

It will be observed in the same Plate and Section *b e* that from the point *d* a range of cisterns with a casemate battery above, extends along the East Ramparts to the north, the cross walls of which necessarily relieve the escarp of a very considerable portion of the pressure of the mass of earth in rear, whereas from the same point towards the salient angle of the Demi-Bastion, the only additional support given to the escarp was that of one counter-fort.

Arrangements having been made for the supply of all the materials for rebuilding the work, operations were commenced in December 1843, and on my taking charge of them at the end of March 1844, the escarp walls had been cleared away to within a few feet of the original basement line, and the work people were employed in removing the cubes which formed a portion of the old foundations; at this time the water between dams which had been constructed across the ditch at either end of the work, was baled out to within one foot of the base of the cubes, and a few yards of the foundations of the face of the Demi-Bastion under repair being then enclosed by an embankment, the water was thrown out with basket scoops, and the existence of wells ascertained, a point until then involved in obscurity, there being no plans or records of the original construction of the Fort in any of the public offices at Madras.

* The passage left between the exterior base of the rampart and the ditch, to serve as a means of communication with a bridge, or over the ditch to the counter-guard (vide plate) a work of two faces raised in advance of the Demi-Bastion. The Berme also serves to receive the ruins of the rampart if breached, and prevent them filling up the ditch.

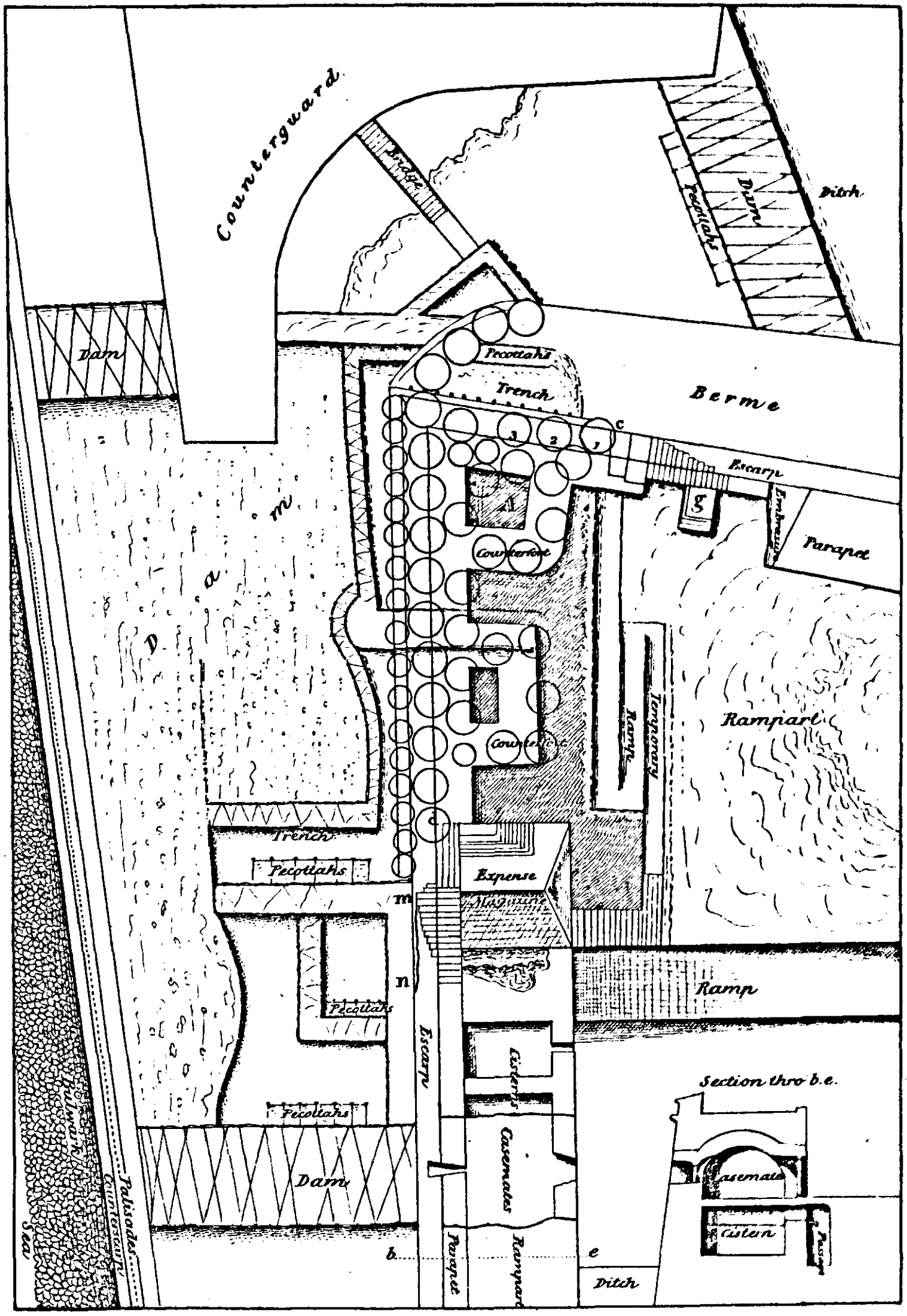
The labour of baling out the water was very great, owing to the immense number of strong springs forced in between the dams in every direction by the pressure of the surrounding water, not only in the ditch itself, that being comparatively trifling, but from the sea; to check, which it was found necessary to fill nearly the entire breadth of the ditch, to a little above the high water level, with a strong dam of blue clay and sand, supported by piles and planking.

The existence of wells being ascertained, in order that a thorough examination of them might be made, a trench was sunk about 2 feet below their upper surface, between the face of the Demi-Bastion and the retaining wall of the Berme (that being distant enough from the counter-guard not to endanger its being undermined) but owing to the confined space in which the work was carried on, there was not room in this trench to allow of a sufficient number of pecottahs being fixed to keep down the water; to get over this difficulty it was found necessary to *divide* the work, and accordingly another strong dam was thrown across the ditch at a distance from the salient angle of the work, to include one counterfort on the sea face.

This dam being completed, five pecottahs were worked in the trench, and soon reduced the water to such a level as to allow of new wells being sunk, and an examination made of the old ones, the portions of the wells, dams, and trenches, will be seen by reference to plate vi.

On the face of the Demi-Bastion, only one well was crushed, which consequently was removed and a new one was sunk in its place. A circumstance worthy of remark, considering that the remainder of the wells were perfect, is the uneven line in which they have been placed, as it scarcely appears possible that they could have been thus shifted entire after being sunk. It will be seen in the Plate that the three wells 1, 2, 3, very much out of place, recede pretty regularly, from which I am inclined to think some mistake must have been made in marking out the original line, at this particular point, and that it was not considered worth while to destroy the wells when once sunk, in order to replace them in their proper positions.

Along the sea face the whole line of wells were in perfect order, but placed two feet within the outer edge of the revetment, which I should imagine was one great cause of the injury sustained in this part of the work, for the soil, at this level a deposit of soft blue mud, being partially washed away here and there, or even being much softened in front of the wells, the projecting portion of the revetment would be deprived of all sup-



port, and the great pressure of the rampart behind would evidently tend to force the whole escarp forward, as has been the case to the extent of 6 inches.

But the chief cause of the injury, in the opinion of the Chief Engineer, was want of stability in the revetment, it having been thrust forward by the pressure of the earth when saturated with water, which it was unluckily allowed to become by sufficient attention not having been given to preserve the slope of the surface of the rampart, the earth of which had sunk in the middle, and formed a sort of basin to retain the rain water.

The position of the crack *d* was in favour of these suppositions, as it opened exactly at the point, where the escarp was deprived of the support of the cisterns and casemates extending along the sea face, as before mentioned, and though the foundation for a considerable distance under the portion of the escarp left standing, was evidently shaken, when the salient angle of the work was thrust forward, a crack of some 4 or 5 inches wide having opened at its base, as shown by the dotted line *m n* Plate vi, still it retained its original position.

Were it not for the support received from the cistern and casemates in rear, I have no doubt that the whole of this portion of the sea face line of fortification would have been thrown forward; as it is, no further injury need be apprehended, for as the crack has been well filled in, and additional wells, crowned with a slope of solid masonry, sunk in front of it, the wall is in all probability more strongly supported than originally.

The soil in the ditch to a depth of about three feet is a deposit of soft blue mud; and below it, as far as can be ascertained, a pure white sand; in this latter the wells have been firmly bedded between three and four feet, and a quantity of brick rubble having been well rammed into the blue mud, there is no danger of their being broken or displaced.

The method of extending and connecting the counter-forts will give very great additional strength to this angle of the fort, and in case of a siege it would be difficult to establish a breach in it, unless the enemy's fire happened by chance to be directed exactly between the counter-forts, spaces of only 9½ ft. in length; the old escarp, and walls of the expense magazine were very carefully stepped off to ensure their binding with the new masonry, from which owing to its increased breadth, it will be seen that they will derive great additional support.

The faces of the revetments to a little above the high water mark in the ditch, were plastered with an hydraulic cement procured from England by Colonel Underwood, and which was found to set so rapidly, that had it been absolutely necessary, the water might have been immediately admitted upon it. A supply of this valuable material ought to be always kept in store, as it is well adapted for protecting the masonry throughout the fortifications exposed to the action of salt water, and would give it a neat and finished appearance, instead of the rough exterior it now presents when the water is low.

The retaining wall of the Berme immediately in front of the face of the Demi-Bastion was much cracked and shaken when the sea face was thrown forward, but as the weight of earth which it has to support is very trifling, it was merely considered necessary to remove the broken portion of the masonry, and having driven a line of strong 7½ ft. teak wood piles in front of the old wells, to rebuild the wall very carefully, filling in the space between it and the face of the work with brick rubble mud and clay well mixed and rammed; the trench before mentioned as having been here excavated to 1½ feet below the upper surface of the wells was filled in, in the same manner.

Teak and Autcha wood piles were also driven in front of the step of masonry raised on the wells at the junction of the new and old walls on the sea face, as it was at this point that the crack *m n* had opened—instead of throwing in merely sand behind the revetments, the whole extent of them as far back as the rear of the counter-forts, a distance of 12 feet, was filled in with clay, sand, and brick rubble to above the high water mark, where 11 small drains were built, each 11 inches high by 4½ inches wide, to carry off the rain water that may penetrate thus deep into the rampart, and which would otherwise find its way down to the foundations, and tend to weaken them—at 10 feet above these, again, another row of smaller drains, 9 by 4 inches were built to relieve the upper portion of the revetment.

As the labor and expense of baling incurred in the rebuilding of this work were both very great, it may be interesting to annex a statement showing the average quantity of water removed daily, with the total quantity and expense of the same during the whole time.

The method of baling the water was by means of the pecottahs Plate vii Fig. 2 commonly in use throughout India, each being easily worked by two men, as the difference of level to which the water had to be raised never exceeded 14 feet, and averaged probably not more than 10 feet. The iron buckets used were all the same size, and held if properly filled 1 cubic foot of water, but allowing ½ cubic foot for the quantity returned each time the bucket was lowered, say not more than 5-6th cubic ft. was actually delivered. The number of strokes per minute, at the usual rate of working was 10, so that $5\text{-}6\text{th} \times 10 \times 60 = 500$ cubic feet of water raised 10 feet high, or 5000 cubic feet raised 1 foot high per hour, by one pecottah.

The average number of pecottahs daily at work was 13, giving the quantity of water discharged in the 24 hours (the work being continued day and night) $500 \times 24 \times 13 = 156000$ Cubic feet, raised 10 feet high by 52 men; whose pay allowing 5 Annas per man, amounted to Rupees 16-4-0. The pecottahs were kept at work for 73 days, so that $156,000 \times 73 = 113,88,000$ cubic feet, the total quantity of water discharged during the whole operation; and 52 men, or Rupees $16\frac{1}{4} \times 73 =$ Rupees 1186-4-0, the total cost of the same, exclusive of machinery.

Another mode of raising water common in this country, is by means of basket scoops, Plate VII. Fig. 3, worked with hand ropes, of which, having the result of some experiments by me, as well as of the performance of bullocks, they may be here inserted with advantage.

In working with the baskets, if the difference of level be at all considerable, there must be a number of them, and in the experiments to which I now refer, where the water was raised 10 feet, 6 men were employed, two at the lower step of 3 feet, and four at the upper one of 7 feet, the scoops held about $\frac{1}{2}$ cubic feet, (the largest commonly used), and 19 strokes of the latter were made to 25 of the former, or $20\frac{1}{2}$ were the average number of strokes made in a minute, then $20\frac{1}{2} \times \frac{1}{2} \times 60 = 416$ cubic feet, the quantity of water raised 10 feet high, or 4160 cubic feet, raised 1 foot per hour by 6 men.

The greater the height to which the water has to be raised, the greater will be the advantage derived by the labour of bullocks, as it has been observed that in raising water 11 or 12 feet, and 40 to 45 feet, the difference of delivery in favor of the shorter draught is only about 2-7ths.

In the 1st experiment where the water was raised 11 feet, one bullock delivered per hour 44 loads, each being 1.75 cubic feet, which gives $44 \times 1.75 = 77$ cubic feet the quantity of water raised 11 feet high, or 847 cubic feet raised 1 foot per hour by 1 Bullock.

In the 2nd experiment, where the water was raised 45 feet, one bullock delivered per hour 32 loads, each being 1.75 Cubic feet giving $32 \times 1.75 = 56$ cubic feet, of water raised 45 feet high, or 2520 cubic feet raised 1 foot per hour by one Bullock.

In these experiments the machinery was very simple, merely consisting of a wheel placed above the mouth of the well, as represented in Plate VII. Fig. 1.

From some observations made by Captain Best, it appears that two good Bullocks raised 90 buckets, each containing 4.135 cubic feet to the height of 20 feet in each hour, that is $\frac{20 \times 4.135}{1} = 186.075$ cubic feet of water raised 20 feet high, or 3721.5 cubic feet raised one foot per hour by one bullock.

The Retta cuppilay represented in Plate VIII is an improvement on the common cuppilay, the machinery being so arranged that the bullocks, both in raising and lowering the buckets, work in a ring on level ground, the diameter of which is equal to the depth of the well, whereas in the common cuppilay shown in Plate VII. Figure 1, the bullocks draw down an inclined plane, and have then to be walked up it, backwards, to lower the buckets.

By the Retta cuppilay, four bullocks raised 180 buckets, each containing 5.28 cubic feet to the height of 15 feet in one hour, that is $\frac{15 \times 5.28 \times 4}{1} = 237.6$ cubic feet of water raised 15 feet high, or 3564 cubic feet raised 1 foot per hour by one bullock.

With the assistance of a good common pump, a man can raise a hogshead of water, or nearly 8 cubic feet, 10 feet high in a minute, giving $8 \times 60 = 480$ cubic feet of water raised 10 feet high, or 4800 cubic feet raised 1 foot high per hour.

From the foregoing data, the following table is calculated, showing the performance of the different methods of raising water.

Method of Baling.	Height raised in feet.	No. of men or Bullocks employed.		Lifts per hour.	Cubic feet.		No. of hours labour.	Total performance, in the time.		Effect of labor. Raised 1 foot high.			
		Men	Bul.		Per lift.	Per hour.		Cubic feet.	No. of pounds.	Per minute.		Per day.	
										Cubic feet.	No. of Pounds.	Cubic feet.	No. of Pounds.
1 Pecottah.....	10	2	0	600	500	6	3000	187500	83.33	5208.36	30000	1875000	
2 Do.....	20	2	0	300	432	6	2592	162000	145.8	9112.5	52488	3280500	
3 Do.....	20	2	0	240	384	6	2304	144000	129.6	8100	46566	2916000	
4 Basket Scoops.....	10	6	0	1320	440	6	2640	165000	73.33	4550	26400	165000	
5 Common Bullock Cuppilay.	11	0	1	44	77	12	924	57738.18	14.116	882.25	10163.52	635220	
6 Do.....	20	0	1	90	180	6	1080	675.00	60	3750	21600	1350000	
7 Do.....	45	0	1	32	56	12	672	42000	42	2625	30240	1800000	
8 Retta Cuppilay in Horti- cultural Garden.....	15	0	1	180	237.6	8	1900.8	118.800	59.4	3712.5	28512	1782000	
9 Common Pump.....	10	1	0	60	480	8	3840	240000	80	5000	38400	2400000	

Fig. 1. Drawing water with common Bullock Cappelay.

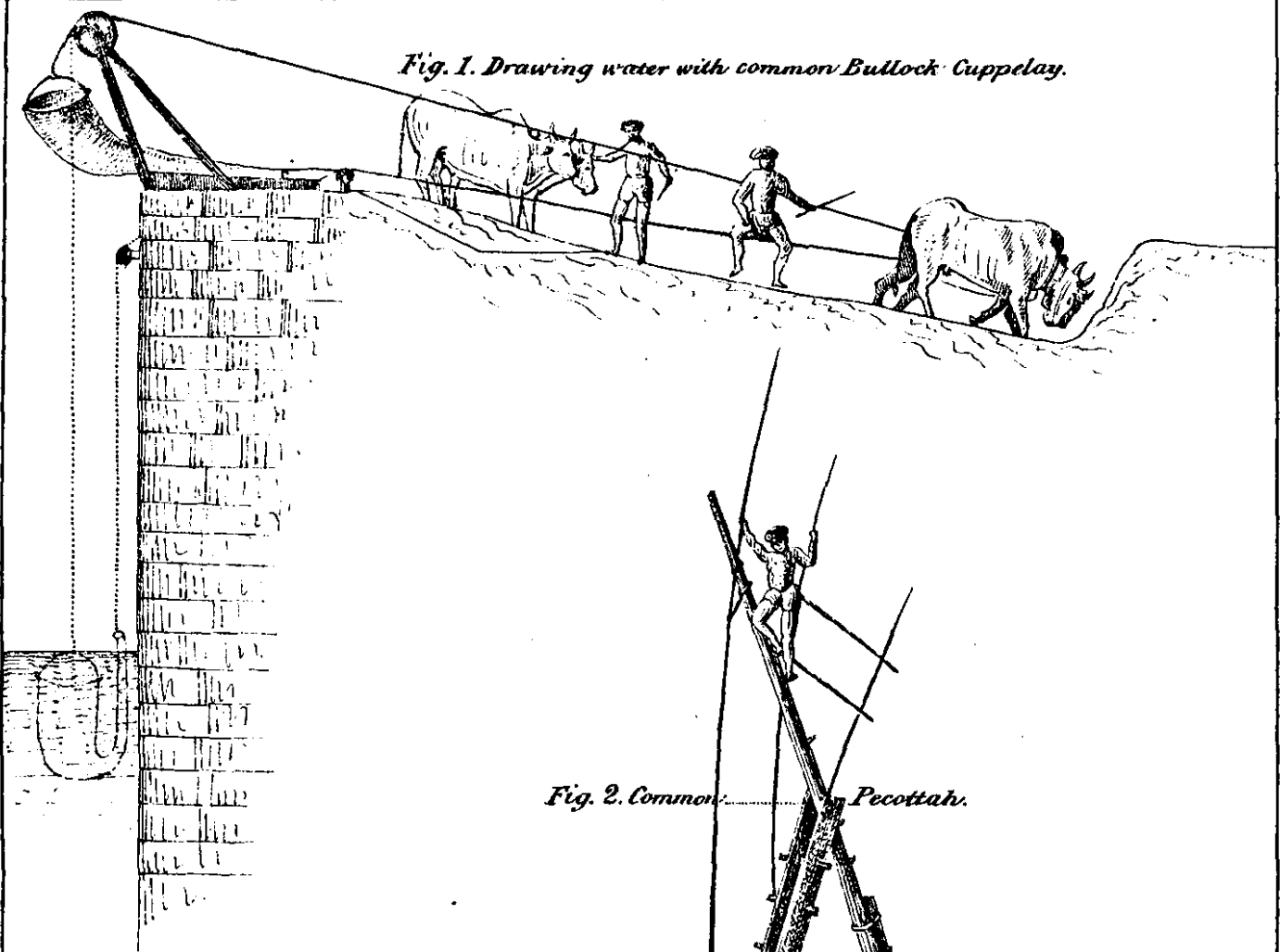


Fig. 2. Common Pecottah.

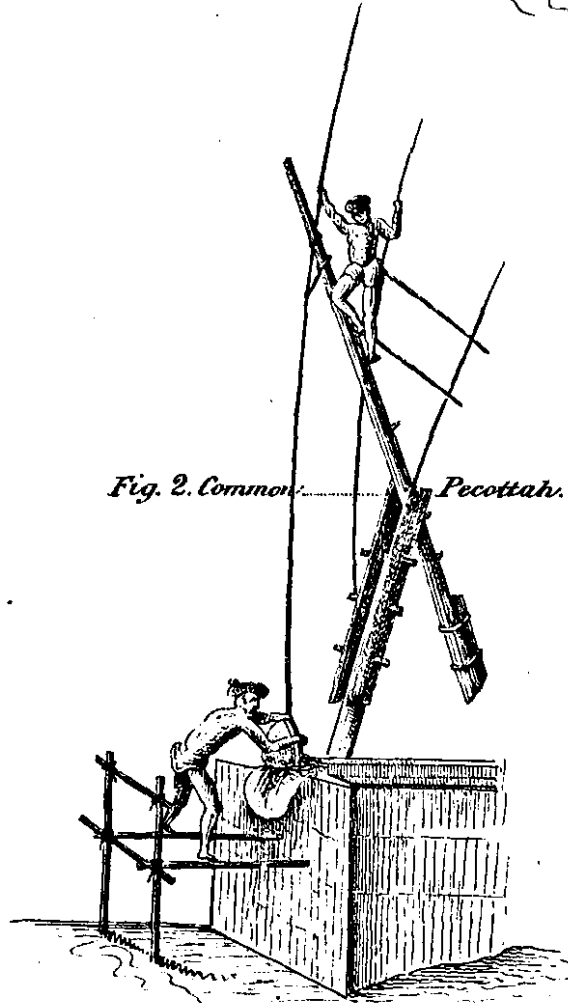


Fig. 3. Baling with Basket Scoops.



In order to form some idea of the relative expense of raising water at Madras by the above methods of employing men and Bullocks, extract from the table the results of the different experiments, and calculate in each the number of cubic feet and pounds delivered per Rupee:

Method of Baling.	Height raised in feet.	Delivery per Rupee raised 1 foot high.	
		Cubic feet.	Number of lbs.
1 Pecottah.....	10	96000	6000000
2—Do.....	20½	1586304	9914400
3—Do.....	45	115704	7231500
4 Basket scoops.....	10	28160	176,0000
5 Common Bullock Cuppilay.....	11	54208	3368000
6—Do—Do.....	20	115200	7200000
7—Do—Do.....	45	161230	10080000
8 Retta Cuppilay.....	15	152004	32313600
9 Common Pump.....	10	122880	7680000

Where it is necessary to hire bullocks, the pecottahs would be by far the cheapest method, as a bullock with driver per day would be 8 Annas, or a pair of bullocks with driver 12 Annas, but estimating merely for their work, the keep of one bullock is Rupees 3—8—0 and allowing a driver for one pair at Rupees 3—12—0 per month, the expense of each bullock will be Rupees 5—6—0, or about 3 Annas per diem.

From the above table it will be seen, that for heights not exceeding, say 21 feet, the greatest advantage is derived from the pecottahs, but for any thing beyond

that, as two pecottahs would then become necessary, from the bullocks.

For the basket scoops, the greater the height the less will be the advantage: the greatest advantage will always be derived from the pump.

For heights of about 10 feet, the ratio will be thus, expense of pecottahs to that of Bullocks : : 1 : 2—nearly—
 “—Bullocks to baskets..... : : 1 : 1½—,”—
 “—Pecottahs to—do..... : : 1 : 3½—,”—
 “—Pump to pecottah..... : : 1 : 1½—,”—

The cost of the different machines here spoken of, would in Madras, be nearly as follows, tho' with the exception of the pump, they might be made much cheaper at most other places.

Cost of Pecottah Complete.....Rs. 26—0—0
 Set of Baskets for raising water 10 feet „ 0—4—0
 Common Bullock Cuppilay..... „ 35—0—0
 Retta Cuppilay in Horticultural Garden
 from..... 205 to 300—0—0
 Common Pump.....250 to 300

From the above data, taking into consideration the prime cost of machinery, the Basket scoops will probably be the cheapest, where the quantity of water is limited, and no repetition required; but for nearly all general purposes in this country, I am of opinion that the pecottah will be found the most efficient.

Madras Breakwater.—This work was commenced, and partially carried on with success; but the funds failed before its completion, so that its indefatigable projector was obliged to abandon the undertaking. So far, however, as the experience gained by what was done went, there was no reason whatever to anticipate any disappointment of the expectations held out by the scheme, and nothing but the failure of the pecuniary means of completing it, a disaster which was hastened by the destruction of part of the craft and implements employed on the work, by the violent hurricane of 1837, was the cause of its being put a stop to. As it was, however, many thousand tons of stone were deposited on the scite of the breakwater, and it was in parts raised to a considerable height. It is important also to state, that subsequent surveys which have been made of it have shown, that although two or three severe storms have since occurred, there has been no material derangement, or change of its form. It is probable, that even should the original scheme never be carried out to its full consummation, the benefit of what has been done will not be lost; for a Company has now been formed for the purpose of erecting a Pier, for the landing of goods and passengers at the same spot; a work which will be incomplete without some shelter for the protection of boats at its extremity; and this probably cannot be secured in a better manner than by filling up the remaining section of the breakwater, to whatever extent, as regards its length, may be found necessary.—ED.

NOTES AND OBSERVATIONS OF EXPERIMENTS WITH AVERY'S ENGINE AND THE SCREW PROPELLER, BY CAPTAIN A. COTTON.

I have been long detained at Singapore, without strength for any personal exertions, so I amused myself by contriving experiments with the rotatory engine and water screw. I lost many very important opportunities for ascertaining particular points, from the complete state of debility both of body and mind I suffered, and from being, without a single companion who could take sufficient interest in the matter to help me in making observations, but still I gained a great deal of information which was highly satisfactory to me, and especially I cleared up one point, which had hitherto completely puzzled me, and the solution of which, has greatly confirmed my confidence in both engine and screw. I purpose now giving you an account of these trials, and telling you the inferences that I draw from them. If I could have had your help for a few months in this enquiry it would have made all the difference to me, but I have never had any body who could help me in the matter, except for so short a time, that it was only of small use to me. My present trials were made as all my others have been, without exception, under the daily expectation of their being stopped effectually by my removal, under the greatest hindrances from want of money, and at the dearest rate from having every thing to make on the spot with most inadequate means. I was particularly anxious to try the engine with the screw, on many accounts, but especially because the application of steam to transport by sea, appears to me beyond all comparison the most important of all, in the present state of the world. Just in proportion as this is improved and extended, must the influence of England be felt throughout the whole earth. I began by putting the new boiler and engine I had at the College into a sampan, one of the common boats that ply at Singapore, and fitting it with the water screw. I used the same screw as I had formerly tried at Porto Novo, and on the first trial, it went about half a mile an hour, which as you may suppose surprised me not a little, though it tallied with my former trial of the screw, when I could not obtain from it nearly so great a speed as I expected, and was unable to determine how much of the failure to attribute to the engine, and how much to the screw. The day after the first trial, it occurred to me to read again what Tredgold said of the screw, and I found that the form of screw I used, viz. with a diam. of 21 inches and a length of 12, would cause a loss of power of 8-9ths; I immediately tested his theory by cutting away so much of the screw as left it only 13 inches diam. to 12 inches length, and the boat then went about 1½ miles an hour; this at once satisfied me that the fault had been in my former trial as well as in this, in the proportions of the screw. By Tredgold's theory, the screw, to give a maximum effect, ought to be about 5 feet long to 1 ft. diam. I could not try it at so great a length as this, but so far as I did try it, it seemed to me certain that so great a length is not required, though undoubtedly the effect of the screw depends upon the

proportion, and that by making the screw either too short or too long, any amount of effect may be lost. I will now give you an analysis of my concluding trial, after a great many alterations of various kinds. I could have gone on increasing the speed of the boat by many things, but my experiments were cut short by my finding an opportunity of proceeding on my journey. And as I had obtained, I think, all the data that I required for establishing a trial upon a larger scale, probably it would not have been advisable to spend any more time upon this small boat. I give you this trial as contained in my notes; I had in the course of my trials met with many smaller things that puzzled me, which more particular experiments had cleared up, so that by this time there was no point in the detail of the operation of the engine that I could not account for.

Expet. 4th August.

Orifices open $\frac{1}{8} + \frac{1}{8} = \frac{1}{4}$ sq. in.

Pressure 41 lbs. $\frac{1}{8} \times 41$ lbs. = 38½ oz.

Vel: 60 (strokes of pump) $\times 35 \times 8$ ft. = 16,800 ft. per minute:

Speed of boat 22 ft. in 3½ sec. = 352 ft. per min. = 4 miles.

Friction. 8 oz.

Resistance. 4

Inertia. 3

15

38½ oz.

ft.

Net power. $.23\frac{1}{2} \times 16,800 = 24,500$ lbs. thro' 1 ft.

24,500

= 70 lbs. power upon screw.
352 (speed of boat.)

N. B. The boat went a head $\frac{2}{3}$ of the length of the screw, by many trials; allowing for this source of waste of power.

$70 \times \frac{2}{3} = 52\frac{2}{3}$ lbs. = net power in screw. Resistance of boat (by other trials) = 40 lbs.

Net power on screw $52\frac{2}{3}$ lbs. do. on boat 40 lbs. 4 : 3

Total power of engine.

Effective as above stated. 24,500.

Add $\frac{1}{3}$ Friction, (as belonging properly to the screw)

16,800 $\times \frac{1}{3}$ lbs. . 4200.

28,700 lb. thro. 1 ft.

= $\frac{1}{3}$ horse power.

Net effect on boat $352 \times 40 = 14,800$ lbs. or $\frac{1}{3}$ of gross power of engine.

Water consumed (by Theory) $\frac{38\frac{1}{2}}{14\frac{1}{2}} = 2\frac{2}{3}$ C. ft. per hour.

Vel: of Screw $5 \times 3\frac{1}{2} \times 19$ In. = 29½ ft. to 22 ft. advance of boat.

29½ : 22 :: 4 : 3

or Vel: of boat $\frac{2}{3}$ of that of screw.

These are the notes of the experiment taken at the time. I must add some remarks.

1st. The area of the orifices was determined by very careful measurement.

2nd. Great care was also taken to ascertain the pressure, but I cannot be certain of it; though it is not likely to be more than 1 lb. wrong, from the checks that I used.

3rd. The actual pressure at the end of the arms had also been most carefully checked before, by hanging weights on them, with different numbers of orifices open, and with different weights on the valve.

4th. The strokes of the pump were repeatedly counted, as was also the number of seconds the boat took in passing over 22 ft., and as the number of the strokes of the pump was on many different occasions, and at different speeds, compared directly with the space passed over by the boat, these two observations were a check to each other. A length of 22 ft. was marked on the boat; a person in the boat threw a chip a head, and as it passed the first mark called out, a person in the stern also calling out when it passed the second mark, which gave the time, exceedingly accurately, and it was always repeated several times.

5th. The friction was ascertained by hanging weights on the arms; when the screw was in gear a little additional friction would be caused by the pressure of the end of the axle of the screw against the boat; but it must have been exceedingly small, for the pressure was only 40 lbs., and the leverage upon it was about 500 to 1; and on the other hand, the friction of the engine would be rather less after working a little while, than when it was stopped for a few minutes to try the weights.

6th. The resistance of the steam to the arms has been ascertained by a great number of trials at various times, with this and other engines, so that it could not be much out, and altogether it is not a very large item in the expenditure of power.—When trying this at the College, I made it just double this, which puzzled me greatly, as it differed materially from so many former trials, but I have since ascertained that I had made a mistake in the pressure of steam, upon correcting which those trials agree well with other trials. It gives about 2½ oz. for every square inch of longitudinal section of the arms (of this form 2½ inch × ½), at 33,000 ft. per minute.

7th. The inertia is calculated entirely from Theory; but 1st, had it been materially different from that, it seems impossible that it should not have been detected in the various trials made with different engines, and 2d In Barker's mill, water being 400 times heavier than steam of 45 lbs., the Inertia must be 400 times greater, and hence any error in the theory in this respect, would be most clearly shown; but in the experiments made with Barker's mill the results agreed to the greatest nicety with those calculated, which seems to leave no possible room for doubt on this point.

8th. Having by making these deductions, ascertained the actual power in operation, I divide it by the velocity of the boat, which gives the total power in operation at that speed, and it remains to account for this power.

9th. A portion of this must be lost by what is called the, "slip of the screw," that is, the difference between its length, and the distance the boat is driven by one revolution; this is easily ascertained by observation; the length of the screw was 19 inches and the boat passed through 22 feet during 18½ revolutions, so that it went a head ¾ of the length of the screw in each revolution. Upon consideration, it seems clear to me that this is a direct loss of ¼ of the power, for the pressure acts thro' 4 feet, while the boat goes only 3 feet; this is precisely similar to the loss in the paddle wheels, by the difference between the velocity of their circumference and that of the boat; in walking in sand we are very sensible of a direct loss of effect by the foot pressing against a yielding medium.

10th. Deducting, therefore, on the above account, there remains a pressure, which it seems can differ from the actual resistance of the boat, only by the quantity lost by the oblique action of the screw upon the water, on which account it appears obvious that some waste of power must take place. It appears then that just one half of the actual power of the engine acts upon the boat. But if that power in operation is considered, viz. the actual pressure at the end of arms multiplied by the velocity (thus including the resistance of the steam to the arms, the inertia and the friction of the engine itself) the power is

$$38\frac{1}{2} \text{ oz.} \times 16,800 = 40,320 \text{ lbs. thro' 1 ft.} \\ = 1\frac{1}{2} \text{ horse power.}$$

The proportion of net effect to this
is 14,800 : 40,320 :: .37 : 1

To compare this with the common engine working
paddle wheels:

Gross power of Engine.....	1
Loss by friction of Engine.	
Working Pumps &c. by	
Good authorities.....	.368
	.632
Loss by slip in general ¼....	.158
	.474
* Loss by friction of Paddles Axles, and lift of water by floats; perhaps ¼.....	.079
Proportion of gross power of Engine acting in boat. }	.395
Do. in above experiments...	.37

It must be observed with reference to this comparison that as regards the engine used in the experiment, it was a four Horse engine, worked only to 1 Horse power, and consequently, the loss by friction and resistance of steam was greater than it need to have

* This appears never to have been accurately ascertained

been; and as regards the screw, its area was rather too small for the boat, causing a needless loss by slip, by Mr. Smith's experiments it was about $\frac{1}{4}$, and when Mr. Erricson used two screws of larger area, the loss was only $\frac{1}{10}$. I do not think it need exceed $\frac{1}{4}$; and secondly the loss of effect from the oblique action of the screw was in this case $\frac{1}{4}$, the diameter being $\frac{2}{3}$ of the length; by Mr. Tredgold's theory, to obtain a maximum effect of the screw, its length ought to be more than five times its diameter; I am inclined to think that this will be found in practice too long, for the net effect of the screw used in the experiments seemed clearly to be greater than his theory would give for that proportion, but I think that a proportion of 2 ft. length for 1 ft. breadth would give a somewhat increased effect, and probably the loss on this account would not exceed $\frac{1}{4}$. The power and net effect of this engine and screw would then be thus calculated.

Friction. 6 oz.
Resistance. ... 4
Inertia. $4\frac{1}{2}$

14 $\frac{1}{2}$
38 $\frac{1}{2}$

$24 \times 23,520^* = 35,000 \text{ lbs. } 1 \text{ ft.}$

Gross Power $23,520 \times 38\frac{1}{2} \text{ oz.} = 56,400 \text{ lbs. thro' } 1 \text{ ft.}$

Then
Gross Power..... 1
Loss by Friction, Resistance &c. $\frac{14\frac{1}{2}}{38\frac{1}{2}}$38
Do. by slip of Screw $\frac{1}{4}$08
Do. by oblique action $\frac{1}{4}$7
Proportion of gross power acting upon } .47
vessel..... }

Upon the whole it seems to me pretty certain that the effect of the screw will exceed that of paddles by perhaps $\frac{1}{4}$, which seems also to be proved by the experiments of Smith and Erricson.

11th. The quantity of water consumed is stated to be calculated by theory; there was no time to measure this accurately, but that the actual quantity did not differ much from this is certainly proved, by the time it took to lower the water in the boiler from one tap to the other. By the theory, 1 C. ft. of water per hour, will keep an orifice of $\frac{1}{16}$ Sq. In. fully supplied at 50 lbs. pressure, or it will keep up a constant pressure of 1 lb.; and this effect varies as the square root of the pressure, so that at 40 lbs. the effect would be $\sqrt{\frac{40}{50}}$ lb. = $14\frac{1}{2}$ oz. Up to 60 lbs. the experiments that have been made shew that this theory cannot be greatly

* This velocity supposes that the resistance to the arms is $\frac{1}{4}$ of what it is in the experiments, at any given velocity; which is what it would be if the engine was of a size proportioned to the supply of steam.

wrong, but the actual consumption of water has not been minutely ascertained.

The dimensions of the boat and engine were,

Length of boat 30 ft.

Breadth. $4\frac{1}{2}$

Model, very nearly that of modern steam boats, excepting that it was not nearly so flat in the floor.

Bottom not coppered, and in a very rough state; the friction probably double that of an ordinary rowing boat having the same extent of surface.

Weight of boat, by estimation. .1000 lbs.
Boiler. 700
Water. 400
Engine. 200
Sundries. 200
5 People. 700

3200 lbs.

By different trials, I satisfied myself that it makes no difference whatever as to effect, whether the screw is formed of one continuous thread, or of any number of portions of a complete thread placed at the same angle.

Draught of Water. $1\frac{1}{2}$ ft.
Diameter of Screw. $12\frac{1}{4}$ inch.
Distance between Threads. 19 inch.
Actual length of screw. $9\frac{1}{2}$
having 2 half threads.

Length of arms of engine 30 In. Diamr.

Area of Longitudinal section of do. = 6 sq. in.

No. of Revolutions in above experiment 2100 per min.
Do. Do. of screw 300 per min.

It is remarkable that the resistance of the steam to the arms obtained by particular experiment, agrees very nearly indeed with the resistance of water to boats of the same proportion, viz. breadth $\frac{1}{2}$ of the length, as obtained by Mr. Russell's experiments, allowing for the difference of the density of the medium viz. 1720 to 1.
Resistance of steam per sq. in. at 33,000 ft. per min. 7.5 oz.

Resistance of water at 1 knot per hour per sq. ft. = .87 lbs.
Do. per sq. in. = .006 lbs.

= .1 oz.

Do. at. 33,000 ft. per min. = 10900 oz.

Do. of steam being $\frac{1}{16}$ 6.8 oz.

Do. by experiments with steam. 7.5 =

Difference.

The power was transferred from the engine to the screw by band-wheels, and in consequence of the confined space it was effected by two bands, together reducing the speed about 7 times. For the screw, I think, that perhaps the speed might best be reduced by means of an endless screw cut in the axle of the arms, but this must be made the subject of trial on a large scale, as it is entirely a practical question.

These experiments suggest the following remarks; first respecting the engine.

1st. The results entirely confirm both the conclusions drawn from former experiments, and also the theory, and at the same they have accounted for several

peculiarities in different former trials, which I could not account for; especially, the trial at Porto Novo of the water screw; in that case, the cause of the failure was evidently in the proportions of the screw, for at first, the same screw was tried with the same results in these experiments.

2d. The actual effect obtained was 28,700 lbs. thro' 1 foot or $\frac{1}{2}$ Horse Power for $2\frac{2}{3}$ cubic feet, being in the proportion of 1 Horse Power to 3 cubic feet at 41 lbs. pressure. To compare this with the water consumed in Cylinder Engines, as stated in Mr. Parke's late excellent papers published by the C. E. Association.

	C. Ft. per H. P.	H. Power of Engine.
Single Atmospheric Engine ..	2.22	40 $\frac{1}{2}$
Non-Condensing do. ..	2	13
Double-Condensing do. ..	1.14	26
Cornish-Condensing Expan- sive do.....	46	104 $\frac{1}{2}$
Avery's Engine, present Ex- perts.	3	$\frac{1}{2}$ at 41 lbs.
Do. Experts. at Hobart.	2	1 $\frac{1}{2}$ at 60 lbs.

It appears from this, that while the high pressure Cylinder Engine consumes 2 Cubic Feet per Horse Power, the Rotatory in the present experiments working at 41 lbs. required at the rate of 3 Cubic Feet per Horse Power, and a single Condensing Engine required $2\frac{1}{2}$ Cubic Feet of water. There cannot be a doubt that the Rotatory Engine would therefore work with a much less proportion of water than either of these Engines; considering the following circumstances of the comparison.

1st. Avery's Engine was of 4 Horse Power, but only worked up to $\frac{1}{2}$ Horse Power, not having a larger supply of steam; had the Engine been in proportion, the consumption of water would obviously have been much less.

2d. It was only $\frac{1}{2}$ Horse Power, while the other Engines were, one of 40 and the other 13, in which of course there was much less waste by Friction, &c. Mr. Brunton judged that it would take 3 Cubic Feet of water to work a 1 Horse High Pressure Engine.

3d. It was worked at 41 lbs.; these Engines are ordinarily worked at from 80 to 100 lbs.; at 80 lbs. it would take by calculation, $1\frac{1}{2}$ Cubic Feet of water to produce the Power at the end of the Arms, obtained in the experiments viz. 38 $\frac{1}{2}$ oz., and consequently about 2 Cubic Feet for 1 Horse Power. In the experiment at Hobart, the Engine produced a blast sufficient to melt near 5 cwts. of Iron per hour, which is more than what is usually reckoned for the effect of $1\frac{1}{2}$ Horse Power; this was working at 60 lbs. Pressure, with 3 Cubic Feet of water, giving 2 Cubic Feet per Horse Power.

4th. The Engine was working at a comparatively low speed viz. 16,800 feet per min.; a large Engine would work at 40 or 50,000 feet, to give a maximum effect, and on this account also the work of a large Engine would be greater in proportion than that of a small one.

5th. At this low velocity the effect of centrifugal force is trifling; at higher pressures and velocities it would probably be considerable *by Theory*; agreeing however perfectly with the experiments made with Barker's Mill, in which the centrifugal force is a very large item indeed—it is 1 lb., per Sq. In. for every atmosphere of pressure, at 30,000 feet per min., and varies directly as the pressure and the square of the velocity; hence if the pressure at the end of the arms including the effect of centrifugal force were 100 lbs. effective, or 7 atmospheres, the effect of that force would be at 45,000 feet per min., $1 \times 7\frac{1}{2} \times \frac{45000^2}{30000^2} = 17$ lbs. per Sq. In., and the pressure in the boiler would be 83 lbs.

6th. This is the actual work of a new kind of Engine, made by a man who had never seen one before, and it is compared with an Engine that has been improved upon for 60 years.

Considering these things, can it be doubted that, that even as respects consumption of fuel, it will far surpass the present high pressure, and fully equal the common low pressure Engines, when it has been improved upon for a series of years? The following is the calculation of the effect of 20 Cubic Feet of water, at 83 lbs. Pressure and 45,000 feet per min.

Effect of 20 C. F. at 1.4 lbs. per C. F. at 100 lbs. Pressure 28 lbs.

Friction....	2 lbs.
Resistance..	6
Inertia.....	4
	—
	12
	28

16 lbs. at 45,000 = 22 Horse
= Power or $\frac{10}{11}$ C. F. per H. P.

It must further be observed that no experiments have been made in working the arms in a vacuum, which would of course be done in the case of a Steam Vessel on a long voyage; this would obviously add to the effect, 1st by giving an additional pressure of 12 lbs.

2d. By either saving $\frac{1}{2}$ of the resistance of the steam, which in the above case would increase the effect by about $\frac{1}{2}$; or, which would be of greater importance, by permitting the Engine to be worked at a higher velocity.

If worked at the same velocity, the above calculation would be thus modified:

Effect of 20 C. F. at 1.5 lbs. per C. F. at 112 lbs—30 lbs.

Friction....	2
Resistance..	1
Inertia.....	4
	—
	7
Airpump ..	2

9
30

21 lbs. at 45,000 = 28 $\frac{1}{2}$ Horse
= Power 7 C. F. per H. P.

These effects of working the arms in a vacuum are obvious; from a careful consideration of the theory it appears however, that a considerable increase of pressure will also be obtained from a cubic foot of steam, but it requires to be confirmed by experiment.

With regard to the screw it should be observed; 1st.—That I was satisfied from these trials that the net effect obtained from it, will considerably exceed that of paddle wheels. The loss in each evidently consists of two different sums;

1st.—The loss by slip, or the difference between the speed of the axis of the screw, or the circumference of the wheels, and that of the boat.

2d.—The loss by indirect action, viz. by the oblique action of the screw, and by the striking and lifting of the water by the floats of the wheels.

The first is certainly less in the use of the screw than the paddle-wheel; and in the second, it seems probable that the screw will also have the advantage, tho' this has not yet been proved.

2d.—As respects the operation of the screw, it appears in every way preferable; all the objections to paddle-wheels are removed by this means; there is no commotion in the water, no resistance offered to the air, no tremulous motion from the striking of the floats on the surface of the water, and it is not exposed to injury from the blow of a sea, or from shot.

3d.—But by far the most important effect is, that the resistance it encounters from the water is uniform under all circumstances. This most remarkable fact seemed to be fully proved by three different experiments made on this occasion. First; the boat was secured to a post by a rope made fast to a spring dynamometer, and the resistance shown, when the engine was worked at a certain speed, was found to be in exact proportion to the effect of the engine when worked at other speeds when the boat was under weigh, calculating the resistance to increase as the square of the velocity of the screw; secondly, it was tried directly thus; the boat was made fast to a post, and the full power of the steam applied, the engine made a certain number of revolutions; the rope was then cast off, and the boat allowed to go thro' the water, and no perceptible change was seen in the speed of the engine; lastly the boat, when the engine was making 1,550 revolutions, and going thro' the water at $3\frac{1}{4}$ miles, was made fast to a cargo boat measuring 15 tons, and having 30 people in her; by which the speed of the boat was reduced to $2\frac{1}{4}$ miles, but the engine worked at the same speed; on casting off the cargo boat the steam boat increased her speed to $3\frac{1}{4}$ miles as before, but the velocity of the engine continued the same; the speed was ascertained by counting the strokes of the pump, which continued at 44 per min. the whole time. This will probably appear surprising at first, but I think if you consider the operation of the screw, you will see that this must be the case. You must observe that this effect does not require any nicety of observation to ascertain it; if there was any difference of velocity caused by the motion of

the boat, as it was equal to $\frac{1}{2}$ of that of the screw, it seems evident that it must have been very considerable, so that it could not escape observation. Further, when the boat was made fast to a post and the engine worked at a certain speed, the resistance of the screw as measured by the dynamometer, corresponded with the effect of the engine when working at the same speed, calculated from the pressure at the end of the arms and the velocity while the vessel was under way. The vast importance of this effect of the screw is evident; it would be impossible under any circumstances to throw an excessive strain upon the engine; in the heaviest head seas, the strain will be always uniform. This must make a most material change in steam navigation.

The rotatory engine and screw combined, certainly appear from these trials to make the most convenient apparatus for impelling a boat; in first cost, in facility of management, in liability to get out of order, in weight, it must have very greatly the advantage of the present engine and machinery. The weight certainly need not exceed 5 cwt. to the horse power, including the whole apparatus, whereas with the present engines it is about a ton. The engine itself, the only moving part, is so insignificant an apparatus, that a ship might carry half a dozen spare ones at an insignificant cost. With respect to the objection that has been made, and will of course be made, that, tho' it may answer on a small scale it could not be used of 2 or 300 horse power; it is really so childish as to be hardly worth noticing; judging a priori, it is a thousand to one that what can be done in a small scale can be done in a large one, and no doubt 50 years ago, it would as confidently have been said, that the idea of an Engine with cylinders 8 feet diam. was perfectly ridiculous; yet it is far less reasonable to think that so light and simple an engine as the rotatory, could be constructed of 300 horse power, than one that required such enormous weights of both cast and malleable iron in its construction. There will of course be practical difficulties, but what reason can there be for supposing that they will be found insuperable, after what has been accomplished in the case of a far more complicated machine. Certainly, the presumption is that in any engine the practical difficulties will be in proportion to the weight and complication of the apparatus, and those to be met in the rotatory engine will bear no comparison to those already overcome in the Piston Engine.

With respect to the speed attained in the present trials, it is to be observed, that 1st, the boat was nearly swamped by the apparatus, which was much too heavy for it, and a larger boat with the same load would have produced less resistance; 2d that the bottom was in a very rough state, so much so as very materially to affect its speed; 3d the boiler had become leaky and could not be worked to the pressure it formerly bore; 4th from the smallness of the boat, the space for the band wheels was too confined, causing a needless amount of friction; 5th the screw was of insufficient area, and too short; 6th the shaft of the screw was very rough, the bearings merely filed not turned.— If the work could have been continued two or three

weeks, all these defects might have been removed, and a speed of full eight miles an hour might have been attained.

Before concluding, I may as well mention one or two things that this set of trials have led to my observing, tho' not immediately connected with either the engine or the screw.—One is, that the resistance to vessels arising from friction is so important an item, as to observe as much attention as that arising from the displacement of water. By a careful analysis of many sets of experiments of which I have statements, I find that in very long vessels, the proportion of resistance from friction is actually double that from displacement; or two thirds of the whole; this is in vessels well finished; I have no direct experiment of the friction of copper, but I think from examining all the accounts I have of the resistance of vessels, that in large steamers, the resistance of friction is not less than that of displacement. Hence much might perhaps be accomplished to facilitate steam navigation by attention to this point; we see also from this, the reason why fish are supplied with a lubricating fluid exuding from the skin; it is probable that this reduces the total resistance they meet with by two-thirds.—Another observation is, that the resistance of displacement is by no means in proportion to the section of a vessel; the resistance in the case of the best experiment I have with small boats, is .32 lbs. per sq. ft. at 1 knot per hour, the section being 2.3 sq. ft. (this is deducting friction) while the resistance to a Steamer of 900 tons, and section of 400 sq. ft. calculated from the actual power of engine is about .21 lbs. in-

cluding friction, and probably not more than .1 lb. per sq. ft. without the latter. I have not seen this touched upon in any of the experiments I have met with in resistance; it appears to me very unaccountable that resistance should not be in proportion to the area. Further, vessels are proved undoubtedly to rise above their bearings at high velocities; in Mr. Russell's experiments this is very perceptible, at $8\frac{1}{2}$ knots, and at $10\frac{1}{2}$ it is considerable; a boat weighing 800 lbs. and loaded with 430, rose at that speed $\frac{1}{4}$ of its total draft of water, and its resistance, was $\frac{1}{4}$ less than it should have been, calculating the resistance to increase as the square of the velocity. In a boat weighing $2\frac{1}{2}$ tons, loaded with 2 tons, moving at 13 knots, the resistance was more than $\frac{1}{2}$ less than it should have been by the same rule. It is very satisfactory to see so many openings by which a way may be found to the attainment of a much higher velocity of transit by sea than has been yet attained, and I fully expect that within a few years, the ocean will be every where traversed at 20 knots an hour in fine weather. I shall be very much obliged if you will have the kindness to send this to _____ for his perusal, for I have not time to copy it. My health is I think now improving more decidedly.

August 1841.

ARTHUR COTTON.

I purpose trying among my friends in V. D. L. to form a Company, to establish a Steamer of 150 tons, worked by this engine, and if I cannot get a large vessel, to get a river boat of 20 or 30 tons established for passengers.

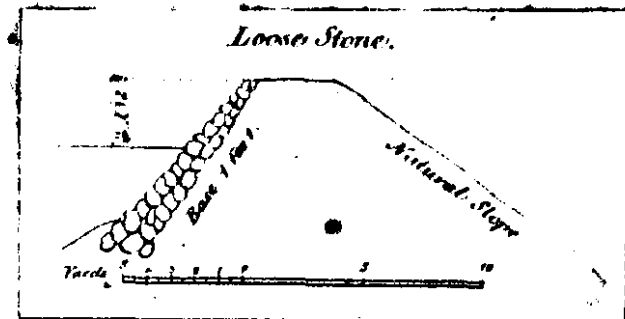
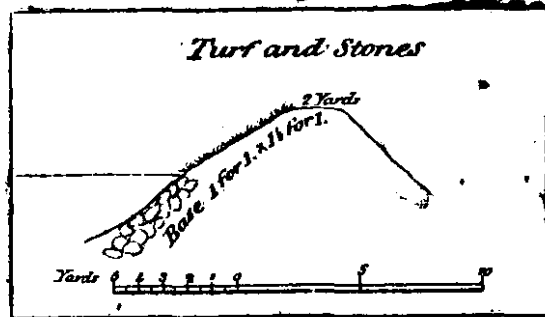
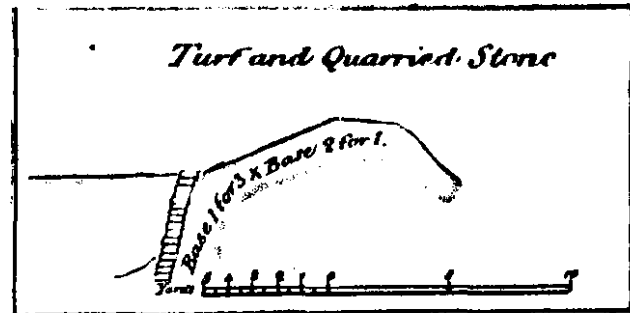
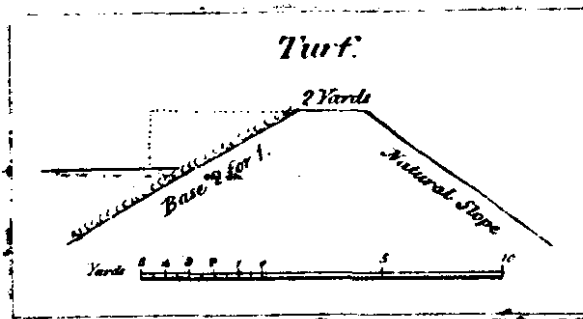
Since the above experiments were made, an Engine on this plan has been tried for working a Corn Mill, grinding from $2\frac{1}{2}$ to 3 Bushels per hour. Upon a comparison of this with several common high pressure Piston Engines, applied to the same purpose, it was found that the former consumed less fuel per Bushel of flour, than any of the latter, tho' they were all Engines of greater Power. The power was transferred from the Engine to the Mill by the following apparatus; a pulley on the axle of the Engine, was connected by a Belt with a drum on a long Iron Shaft, near the other end of which was an endless screw, 3 inches long and 3 in diameter; this worked in a brass cogged wheel 15 inches diameter and 3 inches thick, fixed on the spindle of the upper stone. This formed a very neat apparatus, and the stone worked with the greatest regularity of motion, without any fly wheel. A. C. April 1845.

**MEMORANDUM ON THE SYSTEM OF IRRIGATION IN THE
MADRAS PRESIDENCY, BY CAPTAIN S. BEST.**

1. The simplest and most usual description of work is the **TANK**. This is formed by raising across the upper part of a valley an embankment, by means of which water, supplied by the periodical rains, by jungle streams, or by river channels, is collected and retained for irrigating the lands and bringing the crops to maturity during the hot months. The fields occupying the lower part of the valley are then watered from the tank through sluices of irrigation erected in its bank.

2. The banks of the generality of tanks seldom ex-

ceed 5 yards in height. Many of them are formed of earth only, in a few instances carefully turfed; while some of the larger works and, in countries where stone is abundant, many of the smaller banks also, are protected by loose blocks of rough stone laid on the inner sloping surface, or disposed in the form of a nearly upright revetment, without mortar or cement. The object of these rough stone facings is not so much to support the earth work, as to protect it from the action of the waves during stormy weather, and from damage by the monsoon rains.



Many tanks are often formed in the same valley, the bed of one beginning where the cultivation under that above it ceases. In consequence of this, the breaching of one tank often leads, by the sudden influx of its waters to the bursting in succession of those below it. This is more particularly the case, when heavy and sudden rains succeed seasons of drought, during which the earth of which the tank banks are composed loses its tenacity and is soon saturated by water. Another and the general cause of the breaching of tanks is the neglected state of their banks, which are not in all parts sufficiently raised above the surface of the water in them. High winds exciting waves in the tank, throw the spray over the lowest parts of the banks, which are thus gradually worn away, until at last the water over tops them, and a breach ensues.

3. In order to provide for the outflow of such water as may enter the tank after it has received as much as the state of its banks enable it safely to hold, portions of the bank (generally at one or both extremities, and frequently across the bed of the jungle stream by which

the water arrives) are formed of masonry, the height of which is so regulated as to allow the surplus water to pass over; and their lengths, which vary from 5 to 200 and 300 yards, by the size of the Tanks and the quantity of water which they receive during floods and the monsoon rains.

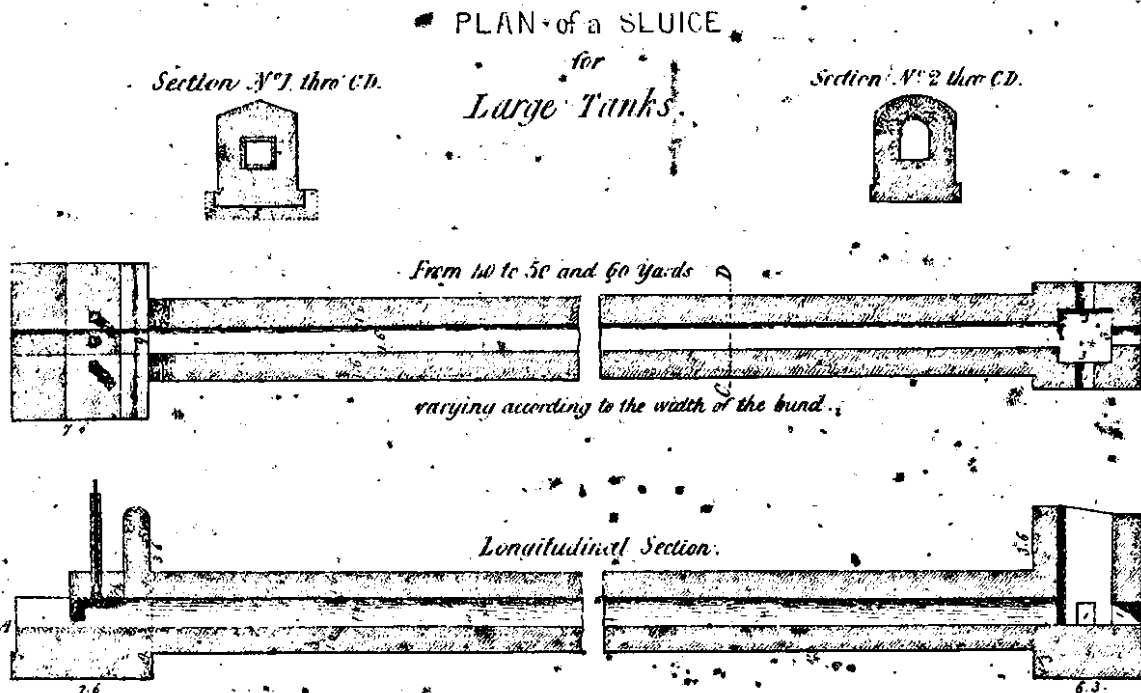
Works of this nature are generally known in this Presidency by the name **CALINGULAH**, a Tamil word of originally much wider import. Along the upper surface of these, a row of upright stones two to four feet apart, and from two to eight feet high are generally inserted. The intervals between these stones are filled up with earth, straw, and rubbish, to increase the capacity of the Tank when the rains are moderate; but when the supply of water is too great, and the Tank is in danger of being breached, the interstices are cleared, to allow a larger quantity of water to escape, the rapidity of the outflow being increased by the additional vent thus afforded. The damstones are made of such height that the top of the temporary bank raised between them is nearly on the highest level to which water can rise in

the tank without endangering its bank. In some Tanks, the excess of water flows out from vents pierced at a low level in masonry walls similarly placed. These vents are closed by vertical planks, inserted side by side, or by shutters. Works of this description termed SURPLUS SLUICES, allowing the water to flow out with greater rapidity, are of smaller dimensions, and less expensive than Calingulahs. They have also the very great advantage of permitting the escape of mud and sand from the bed of the Tank; by the accumulation of which all such works are otherwise liable, in the course of time, to be filled up and rendered useless. Vents to be closed by planks or shutters have frequently been constructed in the lower part of the body of Calingulahs. But the common Calingulah is the usual way of allowing the surplus water of Tanks to escape.

4. SLUICES OF IRRIGATION consist of long tunnels of cemented brick or stone, arched or covered with flat stones, passing through the banks of Tanks, and on a level with the bed of the Tank; furnished at the extremity,

inside the Tank, with a contrivance for regulating the quantity of water that flows to the fields, and at the other end with a cistern or basin, the walls of which are pierced with holes at different levels, through which water running to the branch channels is carried to fields at various elevations. The sluices in large Tanks have sometimes cisterns at the inner end also, the object of which is to prevent the accumulation of mud at the head of the sluice.

The ordinary contrivance at the head of the sluice, known by the name of PAVAL, consists in a vertical door (often merely a block of stone) which is removed to allow water to flow, only when the tank is nearly empty, and in a portion of the covering (which is of stone) being pierced with a conical hole, in which a conical block of wood attached to a long bamboo, is moved upwards or downwards from a frame of two large upright stones and two or three placed transversely for the sluice man to stand on. These latter have holes in them through which the bamboo is lifted or lowered. The orifice



through which the water issues is blocked by this description of stopple, or opened to any desirable extent, according to the demand for water.

5. Irrigation by tanks is often combined with that by rivers, the water from the rivers being brought into tanks that are favourably situated, by means of channels cut through the river bank and intervening ground.

6. Irrigation from RIVERS requires far more scientific knowledge and enquiry than irrigation by means of tanks only, such as is above described. It is easy to judge of the possibility of retaining water by stopping the course of the natural drainage or of jungle streams of moderate dimensions; but to decide on the possibility of partially diverting the waters of rivers into entirely new courses, and on the positions that these new courses should occupy, so as with the least expense of excavation to obtain the greatest and most constant supply of water, requires not only a just appreciation of the difficulties of digging in soils of varying hardness, and to varying depths, but the taking of accurate sections on different lines by which to ascertain the relative levels, and the fall that can be allowed to the beds of the proposed CHANNELS: in short, a knowledge of the form of the ground both accurate and comprehensive.

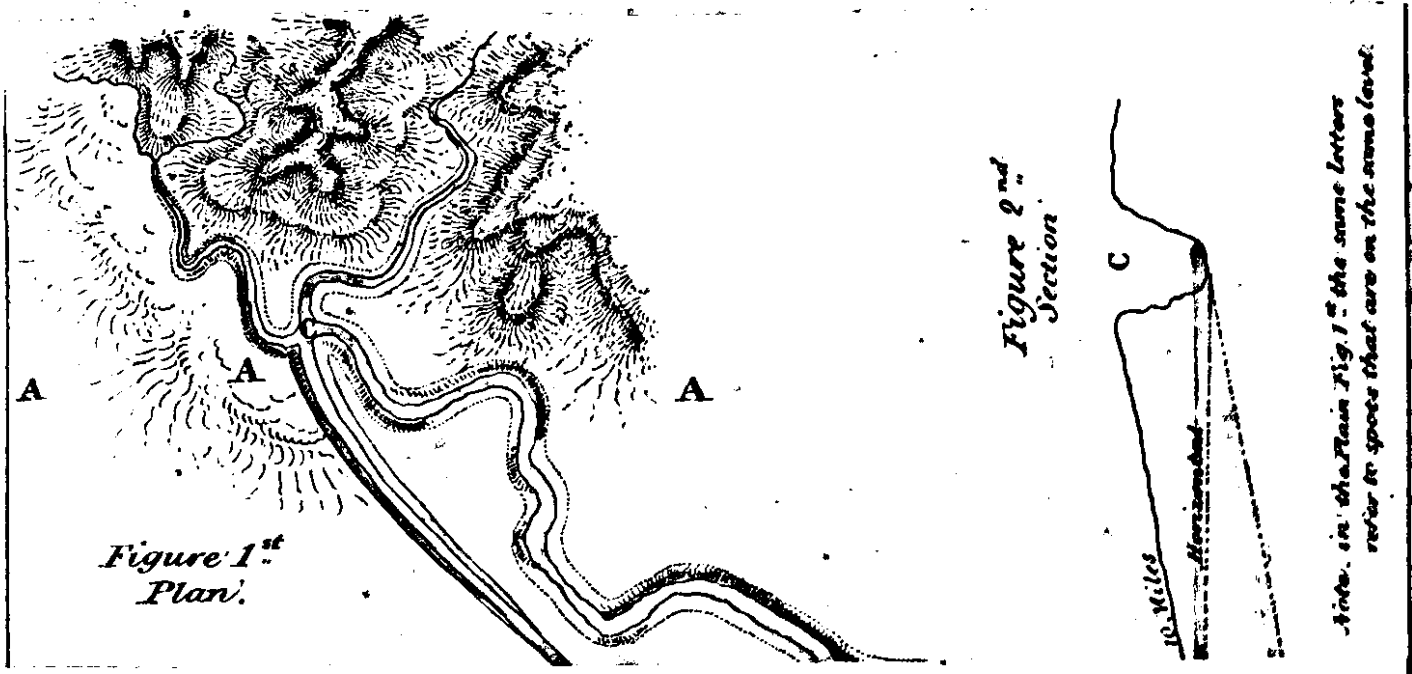
7. A plain which it is desirable to irrigate can hardly be so situated, but that the bed of a neighbouring river is at some part or other of its course relatively higher in level. Supposing a surface A B to slope from A to B at the rate of 2 feet in a mile, and to be traversed by a river C D, the bed of which falls at the same rate, but is throughout 20 feet below its banks, it is evident that the part of the slope which is 10 miles from A towards B will be on the same level as C, and that were a channel C E excavated, with a horizontal bed, water from the river above C would flow along it until it reached E, whence it might be conducted to irrigate the lower portions of the slope E B.

8. In like manner, if the bed of the channel were made to fall one foot per mile, it would at 10 miles be only 10 feet below the country; and at 20 miles, having gained a foot per mile, it would emerge on its surface.

9. The case is more unfavourable, but still similar, though the country should also slope, as it most frequently does, towards the river, as well as towards the sea. In this case the water to the lands farthest from the river must be brought from a part of the bed nearer to its sources, and the excavations must be deeper: or, as it will often happen, the expense bearing too high a ratio to the attainable advantage, the irrigation must be restricted to those lands which lie nearest to the course of the river, and at the lowest levels.

10. Channels of irrigation have been taken off rivers such as the Palaur in Arcot, the fall of the bed of which is at the rate of nearly 10 feet in a mile, and its ill defined banks 6 to 8 feet high; as well as from such as the Kistna, which runs with a fall of less than 1 foot per mile, and between steep banks of 35 feet.

11. It is the relative fall of the river and of the country on its banks, which determines the least length which the channel can have in order that its bed should emerge above the surface, and its water be brought to use; but when the freshes are of short duration, and channels are led to tanks, it is evidently desirable, in order that they should deliver water rapidly, that they should be wide, and the velocity of water in them considerable, although to afford slope to their beds, their length should be extended, and the expense of excavation increased. Six or eight yards may be considered the greatest depth to which irrigating channels have yet been excavated in this Presidency, but the general average is not more than 2 or 3 yards. Great portions of some channels have been formed by throwing up one bank only on the lower side of a slope; thus, (vide figures 1 and 2,) and



Note. in the Plan Fig. 1st the same letters refer to spots that are on the same level.

the heads of some river channels, by separating part of the bed of the main stream by means of an artificial bank, protected by river grasses, &c.

12. In some cases, these artificial banks are carried for very considerable distances up the rivers, or obliquely across their sandy beds.

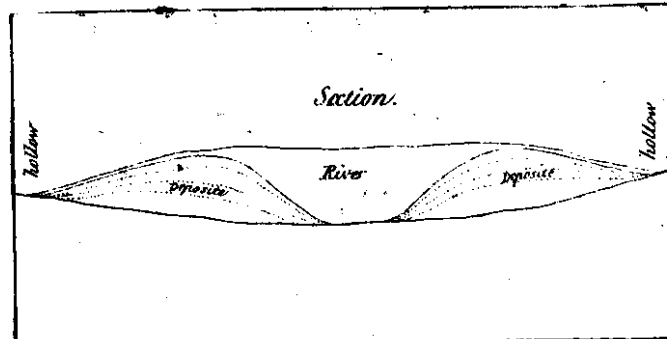
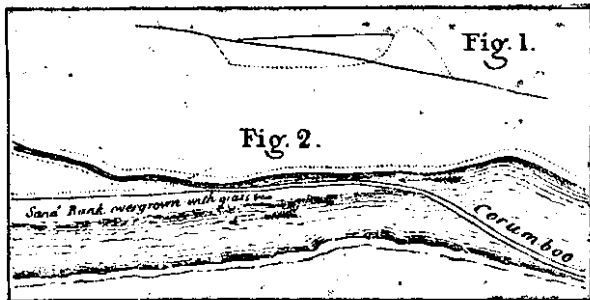
13. Such banks, termed **CORUMBOO**, are generally over-topped and carried away by all freshes of more than $1\frac{1}{2}$ yard depth of water. They are temporary expedients or substitutes for permanent dams or annicuts, to turn the early and low freshes of rivers into irrigating or tank channels, and being liable to be partially, and sometimes entirely destroyed by every full fresh, require to be repeatedly repaired, and occasionally reconstructed during every season. They are usually constructed and kept in repair by the proprietors of the lands which they irrigate, without any cost to Government.

14. In the Kistna and Godavery banks, the channels not having been excavated to more than 15 feet depth, no water enters them until those rivers are partly filled, and the lands do not receive water from them excepting during the season of freshes, or for about 4 months of the year.

15. In such cases, when the bed of the channel at the head is not made as deep as that of the river, it may as well be horizontal, for to obtain some water during a longer period by having the head of a channel deep is more desirable than to sacrifice this advantage for the purpose of obtaining increased velocity by giving slope to the bed. In fact, the velocity depends not upon the slope of the bed, but upon that of the surface, and these are rarely the same in channels such as those of irrigation, which are seldom or never uniform in depth

or dimensions, in direction, or in any other respects. The interior of the Masulipatam District, South East of a line drawn from Bezvara through Ellore and Rajamundry, is in great part lower in level than the beds of the rivers at the points crossed by the same line, and might be irrigated from the rivers, even when their waters are lowest, if channels were cut of sufficient depth through the ground which slopes from their borders with a fall of 4 feet a mile gradually reduced in approaching the Colair Lake, a shallow basin which occupies the centre of plains, almost flat, and from 6 to 12 feet only above low water in the neighbouring sea.

16. The extreme depth of such channels would be for the Kistna 35 feet, and for the Godavery 25 feet, but it must be noticed that the channels now in existence, and the depth of which below the country at their heads nowhere exceeds 15 feet, are liable to be partly blocked by deposits of sand which require to be annually removed. The velocity of these rivers being at the freshes about 5 miles per hour, even their upper water is then mixed with large quantities of earth and sand, which being brought into the channels with the water, is deposited chiefly in their beds as the velocity gradually decreases. It seems probable that the country traversed by the Mahanuddy would also if examined prove to fall from the banks of that river and to be susceptible of irrigation in the same way as the Kistna and Godavery Delta. This confirmation may indeed be predicted of all country inundated by the overflow of rivers, the sediment of which is deposited in greatest quantity near their banks: raising the neighbouring ground and gradually forming a slope in reverse of that which first determined the course of the stream. On both banks of the Kistna, and on the West bank of the Godavery, the meeting of these two slopes is occupied by the



drainage of the great inundations, and has been made use of, to serve as channels for irrigation also, but as it is necessarily low in level relatively to the ground to be irrigated, this arrangement, adopted by the natives probably to save immediate expense and to secure the flow of water, is not recommended for imitation.

17. Most of the works in the Madras Presidency are old native works, such as have been kept in repair and in use, or such as have been restored or modified by the Officers of the British Government. The positions

adapted to the formation of tanks have for the most part been already occupied, and very few of the rivers or even mountain streams have been allowed to reach the sea without having been forced to contribute some of their water to channels and reservoirs. There are very few complete systems of works which owe their existence to our Government, although there are, on the other hand, but few works which have not undergone alteration, repairs, and improvement, since the countries came into British possession, and the attention of scientific officers was directed to them.

18. In consequence, among a vast variety and number of works, there are few or none that could be held up as models for close imitation—while the irregularities in the slopes and widths of channels, the crookedness of their courses, said in some instances to have been determined by astrological considerations, generally turned to avoid difficulties by no means insuperable to our more efficient means, and always subjected to the caprice and the interests of petty proprietors, unbalanced while under the old unsettled governments, have prevented the obtaining of such useful data as might have been derived from observations made on works constructed more according to principles of art.

19. The word 'annicut' is Tamil, and means generally dam or weir. It is a pity that in English writing, English words, the signification of which is more exactly limited, should not have been used in preference. Our Engineers have with one exception (the grand annicut at the end of Seringham Island, which is a waste weir or reservoir) restricted the use of the term to a dam across a stream, and that of the word 'Calingulah' to a work of similar form in the bank, either of a supplying stream or of a tank. No such distinction is made by those natives who have not been taught to make it by Europeans.

20. The chief object of annicuts is to raise the water of the streams they are built across, in order that a portion of it should be diverted into channels leading, as the case may be, directly to the fields or to tanks, in which the water is stored up to be used as required. Some annicuts are, like Calingulahs, furnished with damstones to sustain temporary banks of mud &c. and to raise the water in the river beds during the dry season and the early and low freshes; such temporary embankments being washed away by the freshes. Others are provided with sluices, or have low parts or gaps left in them, seldom exceeding five feet each; within which limit, it is not difficult to provide means of closing, such as shutters &c. By these, the sand is more or less prevented from accumulating to the height of the crown of the dam and parts of the beds of the rivers, generally inconsiderable however, are thus formed into pools extending towards their sources.

21. These are in no instance looked upon in the light of tanks. They may, for a trifling period at the very end of the dry season, answer the same purpose, but the irrigation depends in all cases either upon the continual flow of a small quantity of water during the early part of the hot season, or upon tanks generally far away from the river, and which are supplied by channels during the freshes.

22. Almost all the rivers in the Carnatic, are little more than beds of dry sand during the hot season, and very little water can then be procured from them for the purposes of irrigation. During the Monsoons they are more or less full, and it is then only, or at least chiefly, that a portion of their waters is directed by means of annicuts and channels into the adjoining country, to moisten and fertilize the rice and garden

lands. During the periodical rains there is generally too much water, and in the hot months none, and the object of all the expedients and works of irrigation is to rectify these evils, by collecting and retaining in tanks or reservoirs, portion of the surplus water of the monsoon, for the irrigation of the country during the dry season.

23. When the slope of the country is gradual, it is evident that a dam across a river may, by raising the water in its bed, very much diminish the length of an irrigating channel to be led off it, and it might appear that annicuts would on this account be found general in the lower parts of the courses of rivers, where the fall is gradual. But this is not the case, because the lower parts of rivers are generally wider, their beds sandy and unfavourable to such buildings, and their banks low. The obstruction of the bed in such localities, would raise the surface of the water in freshes, and render necessary the formation of banks, to prevent the inundation of the country through which the river passes: for, however advantageous such inundations are in the Deltas of the Ganges and Godavery, they are most carefully guarded against on the banks of the Cauvery and Tambrapoorny, where the crops are raised, not by inundation, but by a very artificial, and (as far as the science of agriculture is concerned) a very perfect system of irrigation.

24. Annicuts are most generally useful nearer to the sources of streams where they traverse rocky country. In such situations, rocky foundations can generally be obtained, and the work built securely, while, although the fall of country is great, and channels do not need to be very long, yet without annicuts, the difficulty arising from the nature of soil, in such parts generally stony, and which it would be necessary to excavate to a great depth, would be very often absolutely insuperable.

25. A rocky bed tho' a great advantage, and always to be preferred in selecting a site for an annicut, as contributing to reduce the cost and increase the stability of the work, is not however an indispensable requisite. Several annicuts have recently been built with perfect success and at a moderate expense across rivers, the beds of which consist entirely of pure sand to a depth far beyond the foundations of these works.

On such occasions, the chief point to be studied, is the formation of a strong and substantial apron beneath the annicut, to break the over fall of the water, and prevent the foundations being undermined. The manner of doing this will be understood from an examination of the plans and sections of the Coleroon Annicuts.

26. Generally, in the wide and flat beds of rivers near their mouths, the scanty supply of water during the dry season is collected and turned into channels by means of the temporary embankments of grass, baskets, sticks and sand, which have already been mentioned by the name *corumboo*, but there are two modern annicuts in such situations, mention of which must not be neglected even in a notice so cursory as this is.

27. These are the new upper and lower annicuts across the Coleroon, built at the suggestion, and under the superintendence of Captain Arthur Cotton of the Madras Engineers. Both these works have superseded and rendered unnecessary the construction of extensive corumboos; while, unlike corumboos, they resist the action of freshes, and assist the irrigation in all states of the river. The upper annicut is built where the Agunda (or whole) Cauvery divides into two branches: the Coleroon, which seeks the sea by a straight course, falling at the rate of about 2 feet per mile; the smaller but more useful branch, (which retains the name of Cauvery) flowing on a more elevated bed; and, after having in the short distance of 40 miles, gained no less than 15 feet on the level of the bed of the main branch, dividing and subdividing until its ramifications spread over the greater part of the Tanjore District, in irrigating which almost all its water is gradually exhausted. For many years previous to 1836, the Tanjore cultivation had pressed so closely upon the supply of water afforded by the Cauvery, that in seasons falling at all below the average, extensive tracts of valuable land either remained uncultivated, or were subject to the still greater evil of being cultivated in vain. The defect was chiefly attributed to the accumulation of sand in the upper part of the stream near its separation from the Coleroon, and to remove which various expedients were devised and adopted, with partial but only temporary success, and inadequate to the necessities of the case.

At this conjuncture, viz. in 1834, Captain Cotton, then Civil Engineer of the Division, devised the annicut which is built across the Coleroon about 100 yards below the separation of the two rivers, and by raising the bed of the Coleroon about 6 feet, has, without diminishing, except in a trifling degree, the capacity of its section for the passage of high freshes, rendered available for the supply of the Cauvery and of Tanjore all the water which even in the driest season, and when most wanted for irrigation, used to pass waste to the sea. The lower annicut was built in the same year, about 70 Miles down the same river, and serves to turn the water that accumulates in the intervening part of the river bed, from the drainage of cultivation, and the springs that ooze from the sand, into the country on both sides, and irrigates extensive and fertile tracts of land in the

Tanjore and South Arcot districts, between the annicut and the sea.

28. These two works are very similar in form, consisting of walls of brick in chunam, the surface only being covered with cut stone, the foundations of which rest on rows of brick wells sunk in the sand, and filled with rubbish; and are protected by an apron of stone work, on the paved surface of which the water falls, and its tendency to undermine is in great measure destroyed. Several sluices or vents of 3 to 6 feet, by 3 to 6 feet, have been left in the body of the work, for the purpose of allowing the water to flow through in high freshes and carry sand with it; but the capacity of those is not sufficient to exercise a decided influence on the bed of the river, and it has notwithstanding these contrivances been generally much raised by deposits of earth and sand in front of the dams. Many of the details of these projects, and the principles on which they are built, will be found in the two reports printed at pages 62 and 131 in the 1st number of the professional papers of the Madras Engineers.

29. The most perfect specimen of river and channel irrigation under this Presidency, is that of the Delta formed by the Coleroon and Cauvery rivers in the province of Tanjore. A large portion of the waters of the two rivers is consumed in irrigation, and the numerous channels with their ramifications spreading over the country, and throwing off smaller branches as they proceed to irrigate and fertilize the fields, bear a strong resemblance to the veins and arteries of the human body.

30. The system existed in considerable perfection when the Province came under the British rule, and afforded proof of the attention bestowed on irrigation by the native Princes, and of the possession by the inhabitants of much experience and practical knowledge of the principles and laws for managing and conducting running water. All that has since been done has been to improve and extend the same system by the application of European science, and to render more abundant and certain the sources of supply.

31. A sketch of the rivers and channels is now under preparation, which with a memoir on the subject by Major Cotton will be forwarded for the purpose of being transmitted to the Bengal authorities as soon as completed.

(Signed) S. BEST,

*Secy. to the Board of Revenue,
Department of Public Works.*

MEMORANDUM REGARDING THE DEMOLITION OF THE BOGUE FORTS IN THE
CANTON RIVER BY LIEUTENANT J. G. JOHNSTON.

The two Southern Bogue Forts called Chuenpee, and Tycocktow, were captured by the British on the 7th January 1841, but, in consequence of a treaty which was made on that occasion with the Chinese, hostilities were suspended, and it was not until their renewal on the 26th of March of the same year, that the more formidable Batteries situated on Anunghoy, North Wontong, and Tiger Island, fell into our possession. Two days after the latter event, Lieutenant Rundall and myself were directed to place ourselves under the orders of Sir Le Fleming Senhouse R. N. for the purpose, with the assistance of working parties of seamen, of destroying these works.

Lieutenant Rundall was subsequently directed to join a portion of the Force that had proceeded higher up the Canton river, and the Superintendance of the demolition of the three formidable batteries, one termed the North, and two the South Anunghoy, devolved on me.

As an opportunity of blowing up large structures of such great strength, formed with masses of well cut granite, very rarely offers, a brief outline of the mode in which it was effected, illustrated by drawings of works so curious in themselves, may prove interesting.

The revetments of these Forts, with their parapets, were formed with large blocks of granite varying in size from 40 to 80 cubic feet; the intervening spaces or centre of the rampart being filled up with stones, brick and clay; the upper surface of the Rampart was likewise covered with large slabs of granite.

North Anunghoy Fort was 462 feet in length, with a Rampart 24 feet in width, and mounted 40 guns placed in embrasures at intervals, as represented in Figure 11. To destroy this 20 shafts were sunk at distances of 23 feet immediately behind the parapet, to a depth of 9 feet, which gave 8 feet as the line of least resistance outward, or towards the river.

In the Magazines found in each Fort, there was a considerable quantity of Chinese powder, some of it loose in tubs, but the greater portion packed in linen bags, each of which contained about 4 lbs. These were found very convenient, and when the shafts were sunk to the required depth, a few bags filled with sand were laid at the bottom; and then the charge of 56 lbs. or 14 of these Chinese bags having been deposited, a piece of hose $\frac{3}{4}$ of an inch in diameter, about 10 feet long, and protected with a casing of bamboo, was filled with powder, and one end inserted in one of the bags composing the charge, while to the other a bit of portfire one or two inches in length was attached.

The mines were then all very carefully tamped, and 5 or 6 portfires lighted, one after the other, as quickly as possible, when the explosions were frequently simultaneous. The result was that in each case the exterior revetment was completely thrown out, and the rear of the rampart considerably shaken, while here and there

the stones were dislodged from the interior revetment. Of the portion of rampart between each mine 16 or 17 feet was quite destroyed, and the remainder, on which the disturbed masses of stone &c. were accumulated was much injured. In the destruction of this Fort the Seamen employed belonged to Her Majesty's Ship "Melville."

By the means just described the North Anunghoy Fort was so much ruined, that to erect a battery elsewhere, would be far more feasible than to attempt to rebuild it. But as there was a very ample stock of Chinese powder remaining in the Magazines, the charges of the mines for the demolition of the South Anunghoy Forts were somewhat increased.

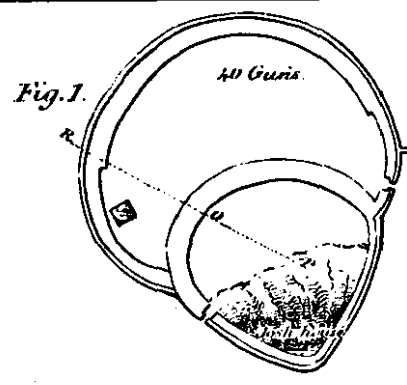
South Anunghoy
Long Fort. The total length of the rampart of this Fort was 771 feet, and its width 29-3. It mounted 64 guns, and the embrasures instead of being shaped as those in North Anunghoy, were formed as represented in Figure 10. In the Rampart of this Fort, shafts 9 feet deep were sunk at intervals of 24 feet, or behind every second Merlon; while the line of least resistance which was towards the river was only 7 feet. The mines were loaded, tamped and fired precisely in the same way as before described, but the charges used were all 80 lbs. The demolition was most complete, scarcely a single block of granite was found in the position it previously occupied.

South Anunghoy
Circular Fort. The total length of the rampart of this Fort was 742 feet, its width 28 feet 10 inches, and it mounted 40 guns. In order to destroy it 30 Shafts were sunk in the rampart, at an average distance of 24 feet, their depth being 9 $\frac{1}{2}$ feet, and the line of least resistance towards the river 7 $\frac{1}{2}$ feet. The quantity of powder used for each charge was 80 lbs. the explosion occasioned the exterior revetment to be thrown out in several places, and the mass of rampart generally was reduced to ruins. Within this Fort, as shewn in Figures 1 and 6, there was a second line of rampart formed of brick 12 feet high and 22 feet wide. No guns however were placed on it, and it was evidently a very old work. It was destroyed, as were also the walls which surrounded the rear of each Fort, by pursuing the same plan that was adopted in the demolition of the batteries.

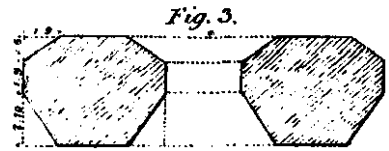
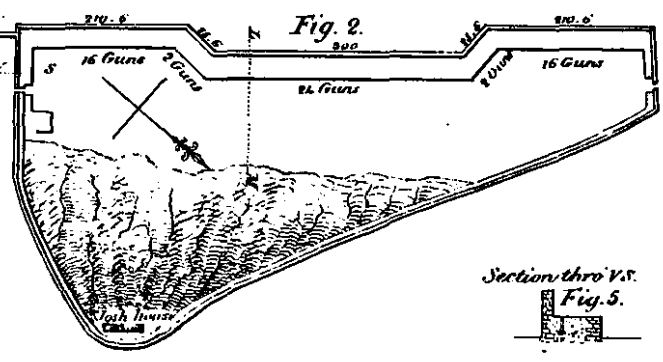
The Seamen engaged in dismantling the South Anunghoy Forts were from H. M.'s Ship "Blenheim."

The majority of the guns found in the Fort, a list of which is subjoined, were spiked, had their trunnions knocked off, and balls wrapped in wet canvas rammed tightly into them. Six of the largest were burst by loading them with a charge of 32 lbs. of powder, and then tamping them well up to the muzzle with small bags of sand. A less charge than 32 lbs. was found to be of no avail, as in spite of great care in the tamping, the sand was invariably blown out.

The Chinese powder used was very coarse grained, and it was at first thought to be much weaker than similar sized English, but in the one or two instances



South Anunghoy Forts
Scale 240 feet to an Inch.



Ground Plan of the Merlons of One Gun. Portion.

Section thro' L.M. showing the position of the charge.
Scale 72 feet to an Inch.
Fig. 4.



Section thro' V.S.
Fig. 5.

Section thro' R.O.P. Scale 72 feet to an Inch.
Fig. 6.

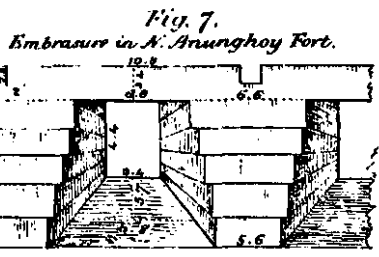
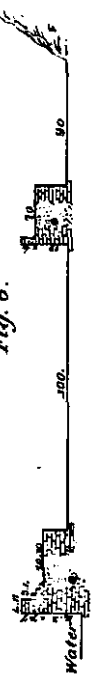
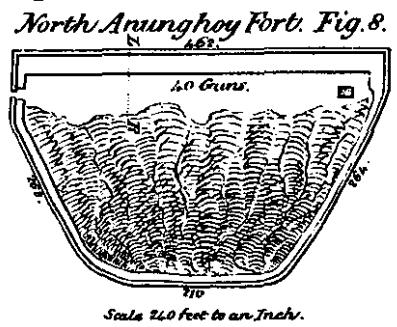
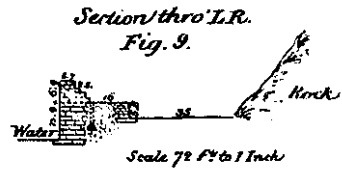


Fig. 7.
Embraiser in N. Anunghoy Fort.



North Anunghoy Fort. Fig. 8.

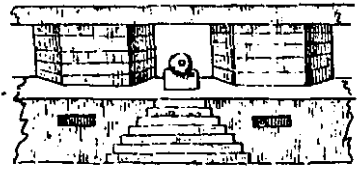
Scale 240 feet to an Inch.



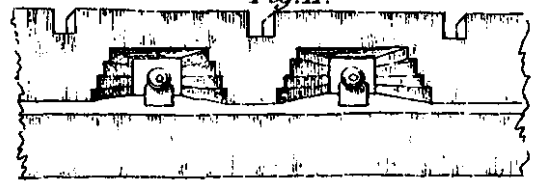
Section thro' L.R.
Fig. 9.

Scale 72 feet to 1 Inch

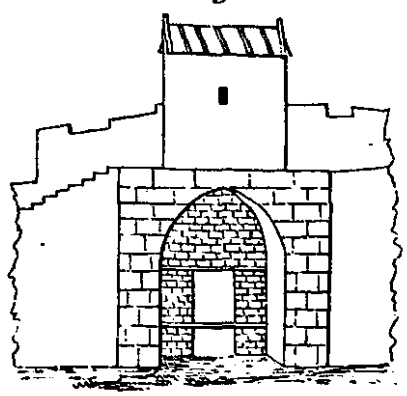
Parapet & Rampart of the long Fort from the interior.
Fig. 10.



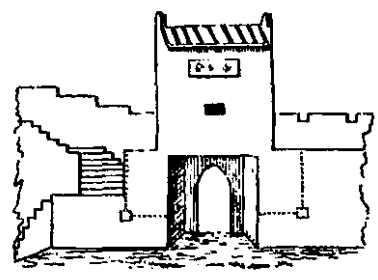
Parapet & Rampart of Circular Fort from the interior.
Fig. 11.



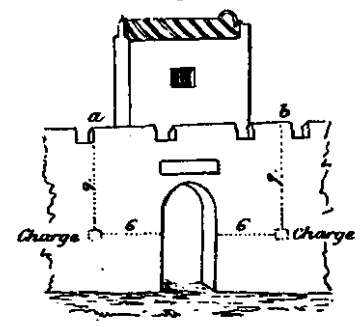
S. Gate of Circular Fort, from the interior.
Fig. 12.

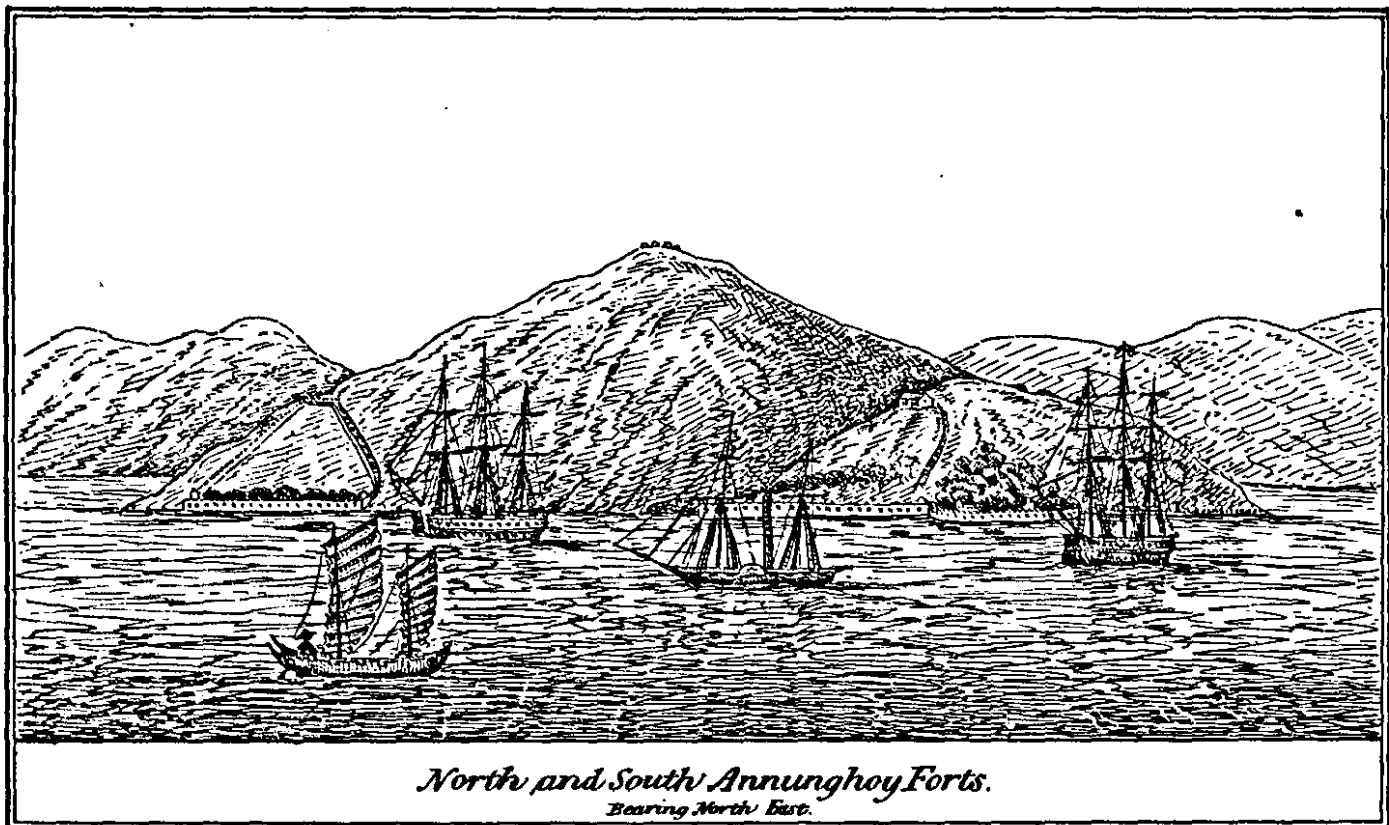
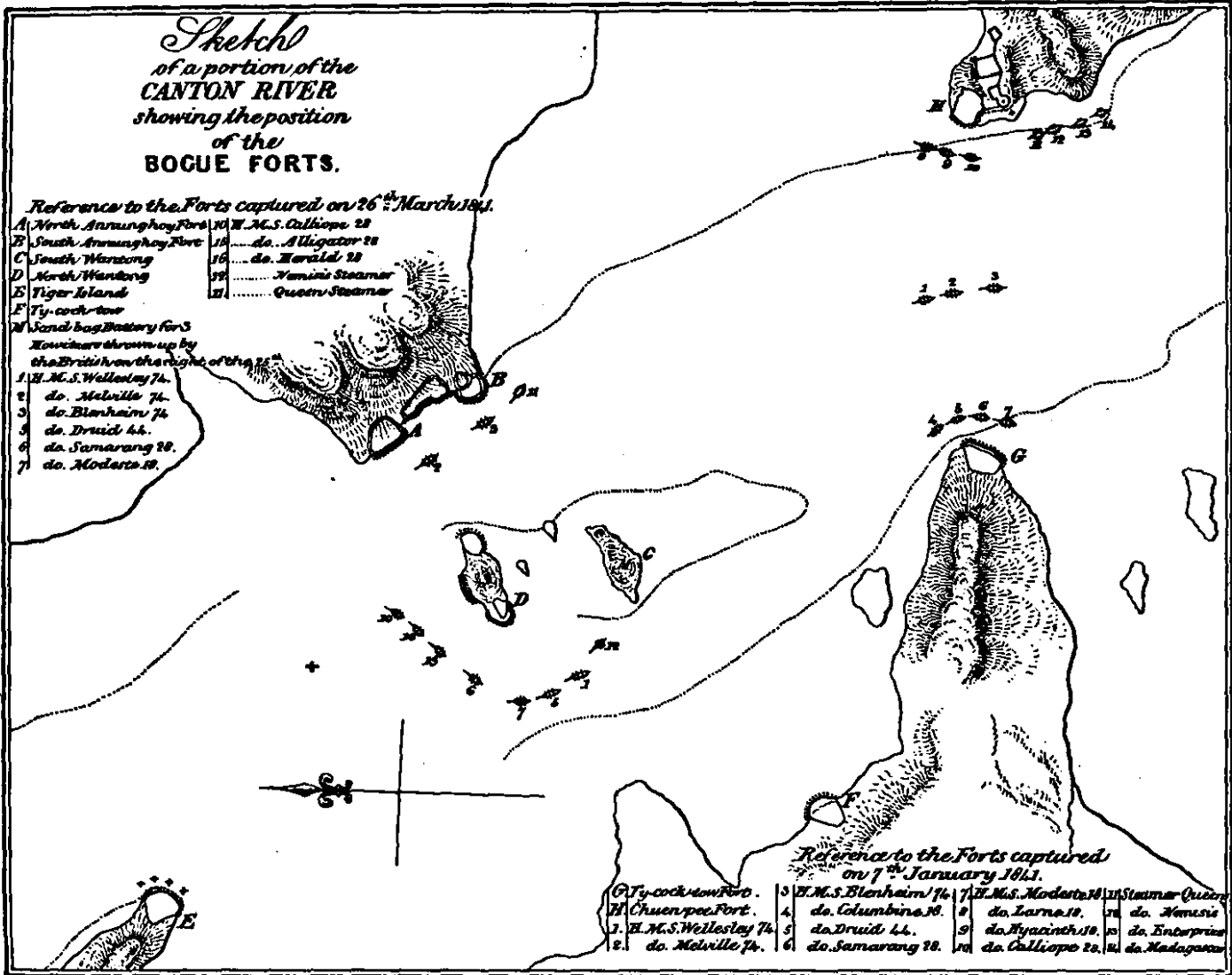


Interior view of S. Gate of long Fort.
Fig. 13.



N. Gate of long Fort from outside.
Fig. 14.





where, for the sake of experiment, English coarse powder was used, its effect did not appear to be much greater. The component parts of the Chinese powder on a rough analysis were ascertained to be 75-7 salt-petre, 14-4 sulphur and 9-9 charcoal, which is about $\frac{1}{4}$ more of sulphur, and $\frac{1}{4}$ less of Charcoal, than is used in the manufacture of English powder.

Total quantity of powder used in the destruction of the Forts, North Anunghoy.

	mines	charges in lbs.	
Rampart.....	23	56 =	1288
Gateway.....	2	80 =	160
			1448

Return of Ordnance found in the Anunghoy Forts.

Nos.	Guns	Iron.
3	65	pounders.
15	42	"
24	32	"
12	24	"
9	18	"
59	12	"
23	9	"
16	6	"
5	4	"
2	3	"

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South Anunghoy Long Fort.

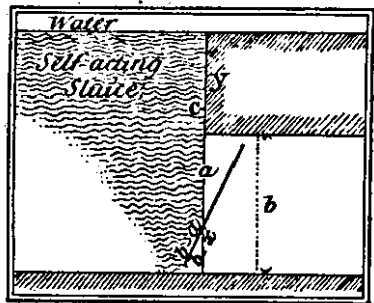
	mines	charges in lbs.	
Rampart.....	32	80 =	2560
2 Gateways...	4	80 =	320
Wall in rear..	35	50 =	1750
			4630

South Anunghoy Circular Fort.

	mines	charges in lbs.	
Rampart.....	30	80 =	2400
Old wall in rear	7	80 =	560
2 Gateways...	2	80 =	160
			3120

Total quantity of powder used 9198 lbs.

Self acting Sluice.—In a self acting sluice, given the height at which the water is wished to rise before the sluice opens, and the whole depth of the sluice; required the proportion of the upper and lower leaves, or in other words, the place of the horizontal axis.



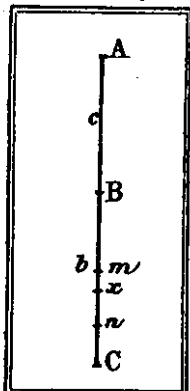
In the accompanying figure let b denote the total height of the sluice— c the height to which it is wished the water should rise above the top of the sluice, and let x denote the depth of the upper leaf, or the distance of axis below the upper edge. Then—

$$x = \frac{2b^2 + 3bc}{3b + 6c}$$

If, the sluice being already constructed, and its dimensions of course known, it is required to ascertain how high the water must rise to open it. Then putting a for the depth of upper leaf and $b - a$ for the lower, and y for c or the head of water.

$$\text{Then } y = \frac{2b^2 - 3ab}{6a - 3b}$$

The first equation is come at as follows. The total pressure of water upon the sluice may be considered as made up of two parts, 1st that of the water above the top of the sluice, and 2nd that of the water opposite the sluice. If $B C$ represent the sluice, A the top of the water; then the 1st is the pressure of $A B$, and the 2d the pressure of $B C$ —Call $A B = c$ and $B C = b$ (as before) then the pressure of the water in $A B$ acts uniformly on $B C$, and its centre of pressure would be at $m = \frac{1}{2} B C = \frac{1}{2} b$.—The pressure of the water opposite $B C$ is not uniform, and its centre of pressure is at n , distant from B by $\frac{2}{3} c$. m, n is therefore $= \frac{2}{3} c - \frac{1}{2} b = \frac{1}{6} b$. Now the two pressures being both concentrated in m and n , a mean point between them where the two would balance one another, would divide $m n$ in the inverse ratio of the pressures at m and n , that is—



$$m x : x n :: \text{pressure at } n : \text{pressure at } m.$$

But the pressure at m is represented by c .

and that at n $\frac{1}{2} b$.

$$\text{Therefore } m x : x n :: \frac{1}{2} b : c$$

$$\text{or } m x + x n : m x :: \frac{1}{2} b + c : \frac{1}{2} b$$

$$\text{or } m n : m x :: \frac{1}{2} b + c : \frac{1}{2} b$$

$$\text{Whence } m x = \frac{\frac{1}{2} b \cdot m n}{\frac{1}{2} b + c} = \frac{\frac{1}{2} b \cdot \frac{1}{6} b}{\frac{1}{2} b + c} = \frac{\frac{1}{6} b^2}{\frac{1}{2} b + c}$$

$$\text{Therefore } B x \text{ (or } x \text{ in the upper figure)} = \frac{1}{2} b + \frac{\frac{1}{6} b^2}{\frac{1}{2} b + c} \text{ that is } = \frac{2b^2 + 3bc}{3b + 6c} \text{ QED.}$$

The other equation of the value of y is found from this, substituting y for c , and a for x .

N. B.—The effect of an additional foot of water over and above the head necessary to produce equilibrium is as $x^2 : (b-x)^2$ because the action of this additional head being uniform the leverages are in both cases in the middle of the respective leaves, and are therefore as x and $(b-x)$ and the areas are also in the same ratio.

J. T. S.

REPORT ON THE DESTRUCTION OF THE GATES OF CHIN-KEANG-FOO BY MAJOR T. T. PEARS, C. B.

In the attack against Chin-keang-foo, on the 21st of July 1842, by the British Force under the command of His Excellency Lieutenant General Sir Hugh Gough, G. C. B., it devolved upon the Engineer Department to arrange for the blowing open of one of the gates of the city; His Excellency the Commander in Chief, on ascertaining the existence of a formidable wet ditch in front of the West and South faces, on which side the attack was to be made by the 3d Brigade, having instructed the Commanding Engineer to reconnoitre the West gate with a view to forcing an entrance therein.

A brief account of the circumstances under which this was undertaken, and the mode of its accomplishment, is likely to prove interesting and instructive; instances of the forcing of gates by powder bags on actual service being hitherto rare.

Although the Tartar Troops defended the city walls with great courage and obstinacy, the execution of the proposed project of blowing open the gate was greatly facilitated by the circumstance of the whole suburbs having been permitted, as has been observed in all Chinese cities, to grow close up to the very gate itself. Not only did the houses run close up to the Canal or ditch, but two narrow rows of buildings actually stood upon the stone bridge which crosses immediately in front of the gateway. Thus, while the suburbs themselves greatly facilitated the previous reconnoissance, and enabled every preparation to be made within a few yards of the gateway, the buildings on the bridge (after crossing which no fire could bear upon the assailant,) acted as traverses, which protected him while crossing from all fire, except that proceeding from a few embrasures immediately above the bridge, and the upper room of a large and substantial guard house standing immediately over the gateway; the fire from which was for a long time well maintained, enfilading the bridge itself, as well as the high street of the suburbs for some considerable distance. A cross street running parallel to the Canal, with but one narrow row of houses between, served as a secure place close to the bridge in which to make the necessary preparation, while the houses themselves were made use of as shelter for a covering party to keep down the fire from the embrasures immediately above the bridge.

The gateway here about to be blown open was, (though unknown to us) the gateway of an outwork in front of the true city gate, which was itself single. The outwork or bastion was closed at the rear by a thick and lofty rampart, having a substantial arched gateway in the centre, not however furnished with doors. The whole work was connected by two high, but narrow walls, with the body of the place. The ramparts about the gateway are 28 feet 6 inches in height, built of brick and mortar, and apparently of very modern construction, with the exception of the basement which

is old, and of stone. The parapets are pierced with regular embrasures at intervals of 15 feet, with a small square loop-hole, nearly on a level with the terreplein between each pair of embrasures.

The outer gateway is a long arched passage built of brick and mortar, 70 feet in length, 12 feet in width, and 12 feet 6 inches in height, to the crown of the arch, which is semicircular. The great length of the arched passage is owing to the greatly increased thickness of the rampart at this particular place, rendered necessary for the support of the guard house above.

The gate consisted of two massive folding doors fixed 6 feet within the archway, which thus afforded the most perfect shelter to a person fixing the powder bags.

These doors, the dimensions of which were 10 feet 7 by 6 feet each, and 5 inches in thickness, were well constructed and fitted, their outer surface being neatly and closely covered with iron plates.

The mode of swinging them common in China is as follows. Constructed of very thick planks, the inner one (or that nearer the wall) on each door has $\frac{1}{4}$ of its breadth prolonged at each end about 15 inches, and this portion rounded serves as a point upon which the door swings.—Of these pivots the lower ones move in a stone groove let into the ground, the upper in a circular mortise cut in a massive beam fixed for the purpose across the archway. It must be observed, that the archedway without the door was contracted considerably in its height, being a few inches less than the door itself, the top and pivot side of which was, therefore, not visible from without, but the edge of which when closed, rested against the interior of the archedway thus contracted.

The means at hand for forcing the gate consisted of three powder bags each containing 58 lbs. of powder. Having frequently, on landing with this expedition, to carry the bags some distance, the mode that has been hitherto adopted at the suggestion of Captain F. C. Cotton of the Engineers, has been to make the bags with a strong loop at top, and appoint two men to carry each by means of a stick 6 feet long by two inches by three thick. This stick (upon which the bag containing each bag when travelling is slung;) is notched at one end, and having a short spike at the other, is found to be most convenient in fixing the bag against doors, or walls &c.; and in that respect fully answers every purpose by merely letting the loop pass into the notch at one end, placing the bag against the door, and propping it up as closely as the thickness of the bag will allow it to stand.

Each powder bag has a common 20 seconds fuze carefully attached to one corner at bottom, having about one inch only of its length let into the bag, the canvass of which is closely and carefully bound round it. The bags are of common canvass tarred over.

The party intended to cover the advance of the bags having been thrown into and about the adjacent houses, opened a smart fire on the ramparts and the guard house above. The bags being arranged in the by-street out of fire—slow matches prepared &c. &c.; on the first appearance of cessation of fire from the embrasures, the party advanced across the bridge with the powder bags—one sepoy being sufficient on such an occasion to carry each bag with its prop, the former on his head, the latter in his hand. On reaching and examining the gate, it was clearly ascertained that the doors were barricaded, within, to the height of about 3 feet 6 inches by bags of earth or stones, and I entertained some doubts at the moment whether under such circumstances the gate could be blown open, unless by using such a charge as might endanger the whole gateway.

The arch above appearing, however, sound and good, as well as the general appearance of the adjacent walls, I resolved on applying the 3 bags, and placed them thus:—Two placed side by side were fixed by props which were gently raised so as to admit a portion of the third. The latter was laid lengthways resting partially upon and between the head of the others and the doors.

Thus placed, the centre of the charge was a few inches above the line to which the door appeared barricaded within.

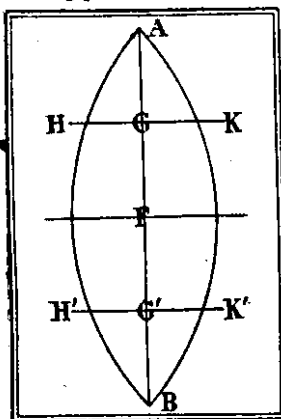
The match was applied to the fuze hanging from the corner of one of the lower bags. In a few seconds the explosion took place. A dense cloud of dust and smoke burst out filling every avenue to the gateway to such an extent that it was almost impossible for a moment to pass through it. The 18th Royal Irish, however, and the remainder of the 3d Brigade, pushed through the passage which proved to have been most completely and effectually prepared for them. The arch remained perfect and did not appear even shaken, whereas the two massive doors were blown completely out of their places, and without being broken, lay one flat on the middle of the passage, the other against the side wall, at a distance of 19 feet from their original position. Some beams which seem to have been placed as props or bars, were shattered and burnt, and cast a considerable distance beyond. The bags of earth which had been placed behind the doors, appear to have been, some thrust away entirely, and the rest pressed down so as to offer no impediment to the advance of men across, them even in the dark.

In conclusion I am bound to express my acknowledgments for the great assistance rendered me on the occasion by Lieutenant and Adjutant Rundall of the Engineers, and Conductor Almond of the Sappers and Miners.

Periscopic Reflectors—Comparison with the common English reflectors by the late James Dalmahey, Esq.—I amused myself by making some calculations respecting the relative dimensions of these two kinds of mirrors, of which the old kind is generated by the revolution of a parabola about its principal axis, and the new one by the revolution of the same curve about its parameter, or double ordinate through the focus. The result is, that twelve of the new mirrors produce an illumination equal to, and much better distributed than that from the old mirrors, having a reflecting surface less than two-thirds of that of the latter. The various dimensions of the mirrors, are compared in the following Table, in which the symbol m represents the distance of the focus from the vertex of the generating parabola.

	Old Mirror	New Mirror	Ratio of New to Old.
Height of mirror	$4m$	$4m$	1
Breadth	$4m$	$2m$	$\frac{1}{2}$
Area of aperture	$*12.56m^2$	$5.33m^2$	$\frac{1}{2.35}$
Area of reflecting surface	$14.48m^2$	$9.14m^2$	$\frac{1}{1.68}$
Area of reflecting surface estimated in a direction continually at right angles to the generating parabola	$*12.56m^2$	$8.37m^2$	$\frac{1}{1.5}$

A peculiarity in Captain Smith's mirror is that its height may be considerably reduced with but a small reduction of its illuminating power. To illustrate this, let the accompanying diagram represent the aperture of the mirror.



At equal distances $FG, F'G'$ from the focus F , let two planes passing through the lines HK and $H'K'$ cut the mirror at right angles to the axis of revolution AB . Let m bear the same value as before; $y = FG = F'G'$; $\pi =$ the ratio of the circumference of a circle to the diameter.

Then if 2π (equal to the surface of a hemisphere to radius 1) represent the illuminating power of the whole mirror $ABCD$, the illuminating power of that part of it included between the sections through HK and $H'K'$, will be equal to $\frac{4my}{y^2+4m^2} \times 2\pi$. If m be substituted for y , that is if the illuminating power of the middle half of the height of the mirror be calculated, it is found to be $\frac{1}{2} \times 2\pi$ or $\frac{1}{2}$ ths of the whole. The area of the same portion is $5.97m^2$ or about $\frac{1}{3}$ of the whole. If therefore the height of the mirror be reduced by one half, its reflecting surface will be reduced by $\frac{1}{3}$ and its illuminating power by $\frac{1}{2}$. One of the few disadvantages of Captain Smith's mirror is that the opaque support of the light near the focus intercepts a zone of the densest light, instead of merely a spot, as in the old mirror.

DESCRIPTION OF A CRANE USED IN THE CONSTRUCTION OF THE MADRAS LIGHT HOUSE BY CAPTAIN J. T. SMITH, ENGINEERS. F. R. S.

In the construction of the new Madras Lighthouse, the work was very speedily brought to a stand for want of the means of hoisting the granite blocks with which the edifice was to be faced; they were of the weight of about half a ton each, and although the hoisting of such masses as these, to any required height, would be considered a trifling undertaking in Europe, with the plentiful means of mechanical aid there available, yet I dare say many of my readers will be aware that in this country such a job, attempted in the rude way in which the natives usually set about such things, was not a little formidable.

The general design of the building is that of a Doric Column standing on a square pedestal or die, flanked by four corner buttresses; the construction of the latter was however postponed until after the completion of the Column, in order to save time; so as to admit of the light being exhibited at as early a period as possible. It had been resolved also, for the sake of economy, that the column should be erected without any scaffolding, but as its interior was to be in great part filled up by a geometrical stair, intended for future ascent into the lantern, it was found to be impossible to raise the materials by the inside; and it was the difficulty of effecting this object externally, which led to the contrivance now to be described.

If the sides of the proposed building had been strictly vertical from bottom to top, so that the materials could have been raised at once, in a directly perpendicular line, from the ground to the edge of the work, there would have been much less trouble in effecting the object; but in consequence of the diameter of the Column being much less than that of the square pedestal on which it stood, any line drawn from its edge while the lower part of it was in progress of erection, to the nearest point at the foot of the pedestal to which the stones could be brought, was unavoidably a very oblique one; so that in providing means of hoisting the stones one of two difficulties had to be encountered.

In attempting to raise them in an oblique direction, it was necessary to keep them from swinging into their natural position and striking against the building, by means of a guy, which being managed by a few Coolies easily produced that effect; but then it was found that, for want of a counteracting force, the crane was liable to be dragged laterally off the top of the work, unless it could be secured against such an accident by being made incapable of any movement in a horizontal direction, which it was found very inconvenient to do in practice, in such a situation.

In attempting to hoist the stones vertically, the difficulty presented itself of contriving an apparatus which should be able to lift them from a point at so great a horizontal distance from the edge of the support upon which the machine itself was to stand; a difficulty which may be aptly illustrated by a comparison of the labour attending the raising a heavy weight immediately from one's feet, or at arms length. Taking into consideration

the difference of the diameters of the Column of the Lighthouse and the pedestal on which it stood, and adding to the latter also the further projection given to the basement beneath the pedestal, and allowing also for the distance within the edge of the column at which it was necessary to rest the foot of the crane, to guard against injury to the masonry, the nearest point to which the tackling for hoisting one of the larger stones could be brought was found to be fully 6 feet horizontally in front of the edge of the work; and as the column rose and its diameter became gradually reduced, it was expected that this distance would be increased. It was therefore necessary that the crane to be used for hoisting the stones should have its jib of 8 or 10 feet in length, and it would therefore require to be very firmly secured in the building if it were one of the ordinary description, to obviate the risk of its being broken down, especially by the larger weights which towards the conclusion it was necessary to raise for the construction of the capital of the Column, and plinth of the lantern. Many contrivances for effecting the object were thought of, and one or two were made more or less the subject of experiment, the last of which answered the purpose so satisfactorily, and seems to be so well adapted, from its simplicity, cheapness, and power, to be of general service in the construction of similar buildings, that I am induced to give it a separate notice.

The whole area of the upper surface of the Column as it was under construction, was so very small, that it was found exceedingly desirable to get rid of every superfluous encumbrance, and in fact every thing not actually necessary for use; and on this account it was very important that the apparatus for hoisting the stones should be easily removable at pleasure.

In the Mechanics Magazine there is an account of a Machine for raising the blocks used in the construction of a monument, the plan and arrangements connected with which were under the direction of General Pasley, in which the circumstances were in some respects similar to the Madras Lighthouse, and advantage might have been taken of the very ingenious contrivance used on that occasion, had it not been essential to it, that the upright pillar which supported the cross head by means of which the stones were raised and brought on to the column, essentially required to be secured in its vertical position by being passed through circular holes bored in two of the thorough stones which occurred at intervals of every few feet of height in the monument whereon it was used. Such an arrangement was almost impracticable in the column of the Madras Light House; for the geometrical stair which filled the interior, instead of winding round a solid newel or pillar, enclosed a well of 2 feet diameter, which opening was necessary for the descent of the weight by which the machinery was to be worked. There was therefore no solid part in the centre of the building in which the upright post belonging to that contrivance could be secured, and

Pl. XI.

Drawing of a CRANE
used at the
MADRAS LIGHT HOUSE.

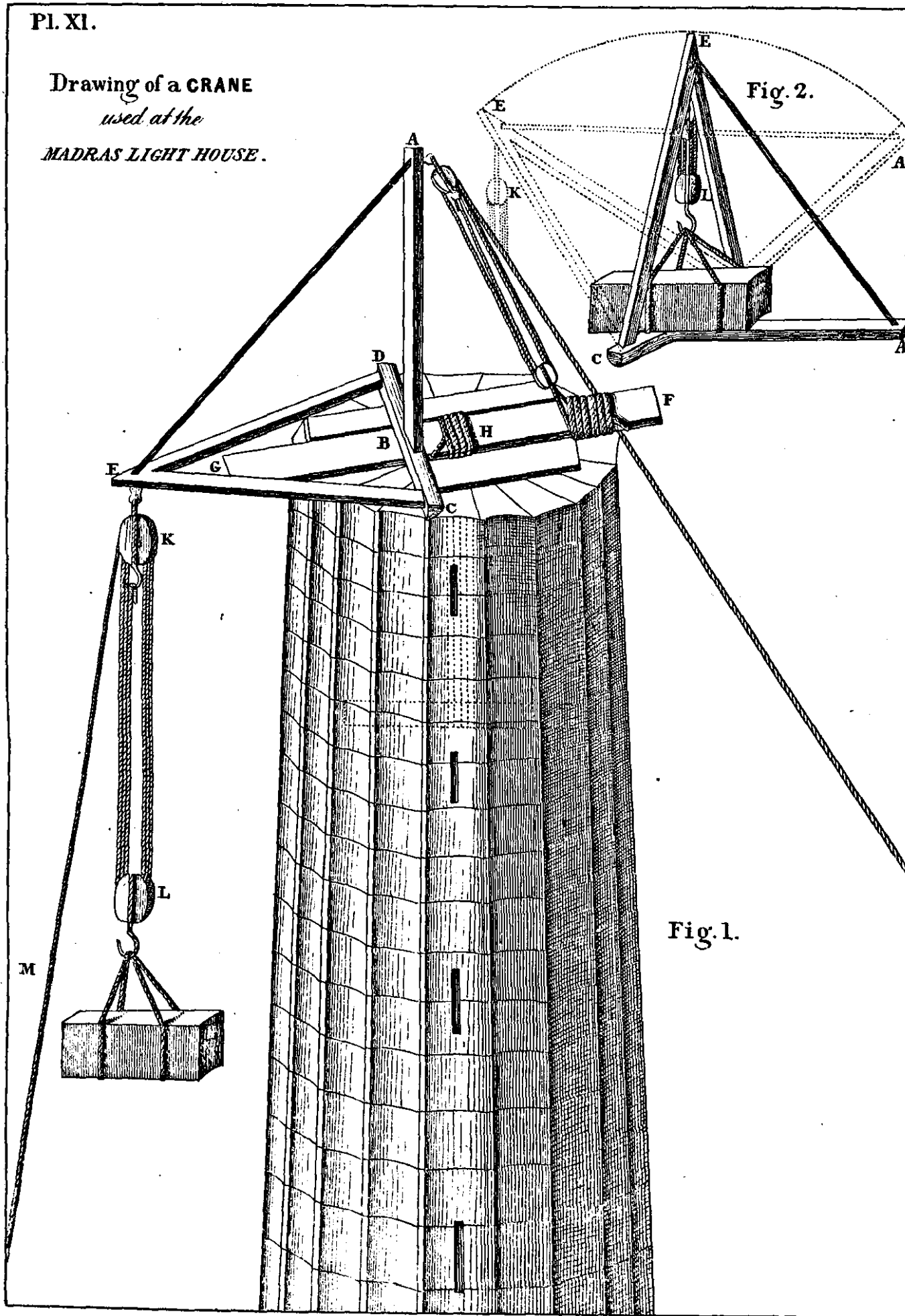


Fig. 1.

Fig. 2.

although perhaps this difficulty might have been overcome, by constructing a frame work to answer the same purpose, and afford the support which the thorough stones in the monument did, yet a very slight consideration of the unwieldiness of such a machine, satisfied me that it could not have been adopted without causing very considerable inconvenience and delay, and other forms and apparatus were carefully investigated; at last the contrivance represented in Pl. XI was hit upon, and was found upon trial to be admirably adapted to the purpose.

The best explanation of the nature of this apparatus, and of the mode of using it, will be obtained by a reference to the drawing, wherein a representation of it is given, whilst in actual operation in hoisting one of the blocks of granite to be used in the work. The crane itself was an exceedingly simple machine, formed by framing together three spars of wood, so that they formed an isosceles triangle, the two sides being about 10 feet long each, while the base which was of much larger circumference was about 9 feet in length. After these had been mortised and well secured together, a fourth spar was attached perpendicularly to the centre of the same base, but in the direction of a plane at right angles with the plane of the isosceles triangle; and the upper end of this vertical post was connected by a strong wrought iron tie bar with the apex forming the junction of the two sides of the triangle. After these parts had been all firmly secured together, and hooks attached to each end of the iron tie bar, the apparatus was complete, all that was further required to bring it into use being a couple of pairs of double or treble blocks, and the necessary quantity of stout English rope for working them.

On an inspection of the figure, the principle by which the apparatus was brought into action will be at once apparent. When the crane is placed upon the building, the triangle E D C lying flat, and the upright post A B being perpendicular to it, it is very evident that any weight whatever suspended from the point E, may be supported by a force applied at A, the base D C acting as a pivot round which the whole apparatus is capable of motion, and the crane itself being in its mode of action very similar to a bell crank. By this means the power necessary to support the weight suspended at E, a distance of 8 or 10 feet from the edge of the building, is transferred to the point A, and from thence by means of a tackle to the horizontal plank F G, which last is firmly lashed by ropes going down the centre of the hollow space or well, mentioned above as having been left in the middle of the geometrical stair, to a transom, or cross beam, the ends of which were let into apertures left for the purpose in the lower part of the building.

When the crane was to be used, the end of the tackle

* The stability of the arrangement was casually shown by an occurrence which might have been attended by some serious accident. During the hoisting of a very heavy block, the rope broke, and the stone immediately commenced to descend with great rapidity, but after falling through nearly half the height of the column, and when it must have acquired a most formidable momentum, it was brought up and stopped short by the entanglement of the rope, and no accident ensued.

After being accustomed to its use, the natives had such confidence in it that it was a common thing to see a stone cutter seated at the end of it,

A I was made fast, and the point E thus became immovable, and capable of sustaining any weight which the strength of the timber and the ropes enabled them to bear;* and the stone was accordingly lifted by means of the tackle K L, which was worked by coolies, the end of the rope K M being, for the sake of convenience, passed through a fixed pulley, attached to a large stone buried under ground; an arrangement suggested by Lieutenant Ludlow who was in charge of the work, which greatly facilitated the operations, and added to the effective power of the men employed upon it. The stone having been raised to such a height as was judged most convenient, or about 5 or 6 feet below the block K, the haulyard M was made fast, and the tackle A I was resorted to. By hauling upon this the point A was brought down into contact with the plank F G, and the stone swinging round in the manner represented in figure 2, was delivered upon the body of the work. It was originally expected that the tackle A I would be most conveniently used by the workmen on the stage D C F, but as the dimensions of the Column became more and more contracted, it was found necessary to change this arrangement, and to carry the haulyard down to the ground, where it was dealt with in the same manner as the other K M. In fact the great necessity for keeping the upper surface of the column as clear as possible, led to the practice, in the latter period of its construction, of taking the crane itself to pieces and sending it below; for the labour of hoisting the whole of the stones required for one course of masonry occupied only a single day, whilst that of securing them in their places and fitting them together was the work of many more.

The largest stones raised were those which belonged to the capital of the Column, and the plinth of the lantern, as above stated, all of which weighed upwards of a ton each, but although some little doubt was entertained at first, no difficulty was experienced, and the apparatus having been carefully examined and judiciously strengthened by Lieutenant Ludlow, no accident whatever occurred.

Indeed it may be considered an important fact in connection with the use of this machine, that the edifice was completed from first to last, without the occurrence of a single misfortune†, although during the course of it, between 6 and 700 stones were raised to the height of from 20 to 110 feet, the largest weights being raised to the full height, and the machinery, lantern, and the chief parts of the lighting apparatus taken up by the same means.

It is unnecessary to add more, than that the whole cost of the crane was very small, and amounted to something less than 75 Rupees; including the blocks, which were of course afterwards available for other purposes.

J. T. S.

10 feet from the edge of the column, and 100 feet above the level of the ground, quietly adjusting a rope, or attending to the tackle during the hoisting of a heavy block.

† We very nearly had one fatal accident, which however was Providentially escaped from—One of the workmen fell down the well of the stair, the depth of about 60 feet, the planking which covered the top having been accidentally removed. Instead of being killed on the spot, as might have been expected, the man was only slightly bruised, and a good deal frightened, and after a few days rest and care was again fit for work.

**COLLEROON ANNICUTS,—REPORT ON THE 5TH DIVISION BY MAJOR H. C. COTTON
ACTING CIVIL ENGINEER.**

It is impossible to become acquainted with the province of Tanjore, without viewing with admiration and wonder, the degree of perfection to which the irrigation was brought before even the British possession of the country, and indeed before the date of any existing record. The main branches of the Cauvery, with the branch that retains the parent name, the minor channels separating from those, and the innumerable ramifications threading the whole surface of the Delta are so disposed, that one can scarcely believe that it was a gradual work, each portion the accidental result of what had been before done, but the work of consummate skill and science, planning the whole system at once, and establishing it.

Changes have taken place during the last 40, or 50 years, disordering in some measure the irrigation of certain tracts, and remedies have been of late years applied, but these have been almost entirely confined to restoring those tracts to the condition they had been in at some former period. But viewing the system generally, we find the levels of the main branches perfectly well adapted to supply the smaller, and these to distribute again the water to the lands, apparently with the least possible waste of labour in the excavation of channels; the least multiplication of sluices and aqueducts, to give the supply to the different levels required, and the most convenient distribution to the various villages and farms; while the drainage of all is at the same time most admirably provided for.

The difficulty of obtaining a full supply of water in the Cauvery, or Southern main branch, for the irrigation of all Tanjore, has been the grievance of ages; Colonel Caldwell imputed it to the beds being so raised by the accumulations of sand from the Colleroon Head to the sea, as to turn the water into the course of the latter river; and declared his opinion, that though temporary measures might improve the supply, nothing but opening the mouth of the Cauvery, and forcing a great body of water by that course to the sea, could carry off the continual influx and accumulations of sand, and therefore nothing else could keep the beds on a sufficiently low-level to ensure a supply of water; and he anticipated that in not many years the rivers would be dry, and the country ruined. This was I believe in 1803: he raised the grand annicut where the bed was high, and where in consequence great part of the water escaped to the Colleroon. This was the first improvement, but it was temporary; the supply fell off, and an opening about two miles from the present head of the Colleroon, through which a great body of water passed back to the Colleroon was closed, thus throwing the separation of the rivers further West, and taking advantage for the moment of the deep channel then forming the head of the Cauvery. This was soon found to be a mere temporary improvement; the deep channel filled with sand, and the river was as badly supplied as ever. This was the second attempt, partially suc-

cessful for a time, but not at all rising above the fears and anticipations of Colonel Caldwell. His prophecy was growing more fearful, and its realization apparently more near at hand. It was then proposed to make sluices on the bank between the Cauvery and Colleroon, for the purpose of discharging surplus water, with a view to clear the Cauvery in a measure of its accumulating sands. This was the third experiment, or rather the third improvement, for they were all such in a greater or less degree—and this was decidedly a radical and permanent one, leading to no harm, because an agent under command, to be employed when, and in whatever degree desired; and to a certain extent as I shall show, beneficial to the river at the time and still more so eventually.

The river bed at the grand Annicut and below that was much lowered, but near the head where the other set of sluices are, no change was effected, because the two rivers being so nearly on a level at that spot, there was no strength of current through those sluices, and no sand discharged. The supply of the river fell off again, and with yearly increasing rapidity, and in 1835 there was so great a difficulty towards the close of the season, to draw by means of a Corumboo any water into the Cauvery, that in all probability the next season would have been as nearly as possible what Colonel Caldwell had prophesied. But here I must remark, that the evil, though the same, was not by any means from the same cause as that on which he grounded his prophecy—Had the bed of the Cauvery been ever so wide and deep, towards its mouth, this evil would not have been averted, the supply could not in the slightest degree be affected by it; for suppose the bed of a river to be raised 15 feet at a distance of 60 miles from its source, and suppose the fall in those 60 miles to be 135 feet, and to be thus reduced to 120 feet, the diminution of supply would be $\frac{1}{10}$ only, and such a change is beyond what has, I believe, any where taken place in the course of ages; the beds of many of the rivers no doubt rise gradually, when not well supplied with water in high freshes, or when altogether without vent, but that is comparatively a very trifling and remote evil as affecting its supply, and in like manner the deepening of the extremities would be but a trifling and remote improvement; as long as the parent channel continues deeper, or has a greater fall than the branch at the point of separation; the Branch suffers from the formation of sand banks at its head, this is always the case in all the channels small and great, and this has been the great cause of failure in the Cauvery itself, and has rapidly followed every improvement of the River, which left the Colleroon still the deepest channel at the point of separation, as well as with a greater fall—The raising of the bed of the River originally established an elevation above the bed of the Colleroon, and this no doubt must be considered the primary, though not the immediate cause

of the evil, and none of the former improvements tended to counteract it; but the same cause remaining, the same effect ensued, whether that cause increased or diminished—So likewise the deepening of the lower parts is a primary step to the restoration of the original level and fall of the river, but this can never amount to the fall of the Coleroon which takes a shorter course to the sea, and therefore never can remove the evil entirely. Here therefore is the reason that the under sluices alone could not prevent the closing of the head of the river, though they deepened the bed for many miles of its course—all of them being too far from the head to affect it at all, except the first set, which, till the Annicut was built, had not sufficient fall.

The river, as I stated above, was deepened at a distance of 20 miles from its head, by the use of the several sets of sluices, and there was ample capacity at the grand Annicut for a full supply of water if it could have been brought there, but the head itself was choked with accumulations of sand, and the supply diminished in proportion.

It is very remarkable, that the beds of the rivers generally, do not appear to have risen since the period of Colonel Caldwell's report. No accurate observations have been taken to prove this, but I can discover no grounds whatever for supposing that they have risen. One proof of this fact is that the rocky bed of the Vennaur 8 miles from its head is bare rock still, and as far as is known, this part of the river which would so plainly show a change is in the same state as it was 50 years ago—Another proof is that of all the channels which fall into the rivers, for the drainage of the land, none that I can discover have ever become choked by the rising of the bed of the rivers—I feel convinced that the outlets for the sand (through which during high freshes and during the heavy local rains much water escapes to the sea) have been nearly, if not quite sufficient to prevent any such rising of the beds as Colonel Caldwell anticipated, and on which his prophecy of the ruin of Tanjore was grounded.—The grand Annicut certainly required to be raised to accord with the then state of the river bed, and it was there no doubt that much of the supply of water was lost, but I feel convinced that even at that time the head of the river was the main seat of the evil. Much money was expended from time to time in deepening the head, and raising temporary Corumboos, as well as on the great work of closing what was called the Govinda Calagum above referred to, and by these means the battle was fought inch by inch, but it was after all a retreat before an overpowering enemy, delaying the conquest, but without a prospect of victory, until the weaker party was joined by a strong ally, and an entirely new arm was brought into the field—This new and most opportune work was the upper Coleroon Annicut projected by Captain A. T. Cotton after much study and experience, the effect of which has been found perfect; giving the Cauvery its full supply of water as long as there is so much in the entire river above, and giving such power to the upper (or 20 vent) sluices in the Cauvery bank, as to keep the head

of the river permanently deeper than that of the Coleroon, and therefore the first of the two Rivers to be supplied in times of scarcity.

The Annicut alone would have unfailingly supplied the Cauvery with its water, and the head would never I think have been liable to close up as before, but in combination with the sluices it gives a perfect command over the bed of the river, which is an advantage scarcely within the view of those who most deeply studied the project. Had Colonel Caldwell's project of deepening the river towards the sea been effected, and as he anticipated from it, the whole river deepened throughout its course, what would have been the consequence—The whole system of the irrigation of the district would have been disordered—The lowering of the beds which now command the lands would have caused the branch channels to require dams every where, to raise the water to them, or new branches from a distance above those which now supply the fields would have been required; while the head of the river, totally uninfluenced, would have continued as it has done to close with sand, and the supply of the river to fall off.

The upper Coleroon Annicut was built in 1836, and there were at that time 4 sets of sluices in the Cauvery bank for the discharge of sand viz. the 20 vent sluices 2 miles, and the Permal coil 50 miles from the head of the Coleroon—These were kept in use when water could be spared during the 5 first seasons, and from all that could be discovered (by no very accurate observations) the river beds had rather deepened than otherwise, but certainly no very important change had taken place. In consequence of some alarms being expressed as to the effect of the Annicut in throwing into the river more sand than could be discharged—I thought it desirable to make as good a trial as possible of the season of 1841 by not opening the sluices of the Grand Annicut and those to the eastward, and the long continuance of the high freshes has made the season one especially well calculated to give the river an unusually great influx of sand, while the monsoon being very light, the lower parts of the river did not receive the cleansing which a heavy monsoon ensures, the local rains having the effect of discharging vast accumulations of sand into the sea, while they introduce none.—Still the sections taken show no increase of sand, but rather a decrease. Accompanying my report of 9th March 1842 is a set of sections showing the changes in the bed of the river during the season, and with one or two exceptions, out of 40 sections, the bed is lower at the close of the season than before.

A considerable change has in the course of the 6 seasons taken place at the separation of the Cauvery and Coleroon. The deep channel of the main river was along the north side leading down into the Coleroon, the south side being raised with sand banks and the head of the Cauvery itself choked up with them. The effect of the Annicut was to throw a strong stream directly across the head of Seringham, sweeping out a very deep channel of no inconsiderable mass of sand

and opening the head of the Cauvery during the season. The Cauvery was then secure of a full supply of water as long as the main river could furnish it, and though there was an unheard of scarcity of water in the main river that year, the crops throughout Tanjore were tolerably abundant. There can be no doubt had the Annicut not been built that very year, the loss would have been incalculable, and in the 2d. 3rd. and 4th years the south west monsoon was also exceedingly light, and the rivers very scantily supplied, so that the benefit of the Annicut was in fact felt to a degree which no foresight could possibly have anticipated, but which making no very palpable appearance in the Revenue accounts, unsupported by the consideration of the deficient supply of water in the main river, has not earned for the work that credit, which its immense effect gained where the circumstances were all known. The Revenue of Tanjore being so materially affected by the varying price of grain, makes it difficult to show distinctly the benefit the district has derived from the Annicut; but the price of land gives a very remarkable proof of its effect, and to show the feelings of the people most interested and best able to judge of the actual advantage derived from the Annicut, I need only to repeat what has been often said to me, that at the expense of 1 Rupee per Vaily of land the work could be built at the expense of the people, *annually* (if necessary) with immense profit to them, quite independently of the increase of revenue obtained by Government; and these remarks have been backed by an offer of 1 Rupee per Vaily from the land holders under the Vennaur, if the Government would build an annicut across the Cauvery at its head; for a sum of about 30,000 Rupees.

Since the construction of the Colleroon annicuts they have been annually improved and strengthened, and are now brought to the condition of good permanent works, not only well fitted for the purpose for which they were constructed, but requiring very trifling annual repairs. The centre branch of the upper annicut was lowered last year; its present height, 4½ feet, being sufficient to throw into the Cauvery a full supply of water for all Tanjore. The lower Annicut is now to be raised 4 inches, and covered with cut stone, which seems to be at present all that work requires. The raising is chiefly intended to add to the supply of the Vuddavaur and Veeranum, for the benefit of the lands on the north side of the Vettaur River, across which an annicut is proposed to be constructed. The lands irrigated by the lower Annicut are, the Talooks of Mannargoody and Chellumbrum in south Arcot, and a considerable tract of country along the south bank of the Colleroon extending to the sea.

The 20 vent sluices have been greatly improved by the enlarging of the vents; they now discharge a great body of water in high freshes, and of course also a great volume of sand, and are I think in plan as well as in effect an excellent work: this is the first outlet from the Cauvery to the Coleroon. They have been strengthened by rough stone defences, and seem to be very secure.

The 150 yard Calingulah is the next outlet for flood water, and by this a considerable quantity of sand also escapes. The work has no solid apron, but one of loose stones, which has been annually improved by the addition of rough stone, and the whole work is now in good order. A foot bridge was constructed on the crown of it in 1838.

The Grand Annicut is the third outlet. It has 360 yards gorge, and ten vents through its base, and the fall between the two rivers being here considerable, the discharge both of sand and water is very great.

On the shapeless body of this ancient work is a bridge of 30 arches, of 30 feet each, constructed in 1838, and an extremely useful communication.

The Coiladdy Calingulah, of 100 yards gorge, and still greater fall than that at the grand Annicut, is the fourth outlet, and has an immense effect on the floods of the river, discharging in the highest freshes about half the water that reaches that point, with much sand also. A low apron was added to this work last year, and it is now in good order, but it would be the better for a covering of cut stone. The bridge over the Calingulah makes it a very complete work.

The Vuddavagoody sluice is the fifth outlet, it has 12 vents and is a low work discharging water over it in the floods (having been lowered 4 feet since its construction). The body is of great thickness, and contains a considerable mass of cut stone work and brick masonry that might have been dispensed with, without diminishing its strength; a low apron was found necessary to secure the foundations, and was added last year.

The Permaul coil sluice is the sixth and last point of discharge for the flood water of the Cauvery; it has 6 vents. The water passing out by this sluice falls into the Munnyaur, and is discharged from that channel by another sluice into the Colleroon. This arrangement limits the use of this sluice, and I think it would be very desirable to carry the water from it under the Munnyaur direct to the Coleroon. It might then be used freely for the discharge of water in times of flood, as well as for sand, for which alone it was intended. It would be necessary to carry the Munnyaur by an aqueduct over the channel leading from the sluice to the Colleroon, on account of the navigation, and on this account also a new channel would be required from the Permaul Coil lock to the Munnyaur.

Previous to the construction of the Coleroon annicut, much pains were taken so to regulate the distribution of water as to give a fair proportion to each main branch, and several important works were constructed for the purpose; and although the abundance of the total supply for the district has rendered this a less important consideration, it still requires attention. The Vennaur river which is the first main branch has always been ill supplied in comparison with the other branches: some improvement has been made in the last two years to its head, and this improvement is still going on, and I think with the promise of considerable effect—It has

a second head affording it some help in low freshes, and I think it very desirable that a third should be opened from the Cauvery, either opposite Coiladdy, to fall into the river immediately below the Cutchamungalum Annicut, or about 3 miles from the head immediately below the grand Annicut.

One or other of these projects, both of which have been fully investigated, should I think be taken into consideration, if it is found that the improved form of the head of the river does not fully answer the purpose of giving it a due share of the whole supply of water.

The Codamoorty which is the second great branch, was formerly ill supplied also, compared with the Parent river, but a favorable change has taken place in its bed, and it is now deeper than the Cauvery—An Annicut across the Cauvery for its benefit was recommended 4 years ago, and obtained the sanction of Government, but it has not been found necessary to construct it.

The Arasalaur is the third great branch from the Cauvery—It has also a head in the Trimulroyen, which is a branch of the Codamoorty—This channel has been greatly improved of late, by a new open head from the Cauvery, which indeed it had originally, but owing it seems to its drawing too much from the Cauvery, it was closed many years ago—The river in 1836 was entirely dependent on the Trimulroyen, and a head with a limited sluice was formed for it in the Cauvery; this being still found insufficient, the new head without a sluice was opened 2 years ago—This head is now becoming too great, and another change will shortly be necessary, either merely closing the present opening and cutting one lower down, or reverting to the use of the head sluice.

The state of the Tritrapoondy Talook in Tanjore now calls for much of the attention of the Civil Engineer, I have made a general report on its condition and sent to the Board two projects for its improvement, but there is a vast deal more to be done, and there is no part of the 5th Division now where a considerable outlay would make so great a return.

In the Trichinopoly district some improvements have of late years taken place, and others have been projected, but have not received the support of the Board. There is a wide field for extending cultivation in the talooks north of the Colleroon—The waters of the Vellaur, and several copious jungle streams might be made to yield revenue by irrigating these tracts.

The improvement of the Wyacondan channel branching from the south bank of the Cauvery has been long in contemplation, but with many other equally important subjects is deferred, until the Civil Engineers time is available for it, or till he has the assistance of other Officers.

In the talooks of Manargoody and Chellumbrum in South Arcot very extensive improvement has been made, Channels have been laid out over a great tract of waste land, and the Vuddayaur, which is the main

channel, has been widened; and the whole being supplied by means of the lower Colleroon Annicut, they never fail; a great deal also has been done for the distribution of the water to the old cultivation, and with these improvements in the irrigation, a system has been planned, and to some extent carried out, of the drainage of the talooks, so that the whole state of the cultivation is in a condition to advance rapidly; but it is unhappily checked by the low prices of grain, the consequent poverty of the people, and the want of some considerable change in the laws affecting the tenure of the land, and encouragement to those who are willing to cultivate.

A line of navigation has been established from the Cauvery across the Colleroon, and through Manargoody and Chellumbrum, to Porto Novo—This most valuable project obtained the sanction of the supreme Government almost two years ago, and it is now nearly completed—The traffic from Coimbatore and Salem formerly went down the Colleroon direct to the sea, but since the construction of the Colleroon Annicuts that river is seldom navigable for more than two or three days at a time, and usually only at one period in the month of July; when the freshes are at the greatest height. To remedy this serious loss to the mercantile community, this new line has been established. Its course is down the Cauvery, and uniting with the Trichinopoly trade, it follows the course of that river to Permaul Coil about 40 miles below Trichinopoly, where a Lock of 9 feet fall, with a regulating basin for the highest rise of the river, has been constructed for the descent into the Munyaur, an irrigating stream branching from the Colleroon—The navigation then takes the course of this stream to Tripendaul, a distance of 25 miles, where a level Canal two miles in length communicates with the Colleroon, immediately above the lower Annicut. This canal has a regulating lock at the upper end, and a lock of 9 feet fall into the Colleroon at the other extremity—Crossing the Colleroon into the Vuddavaur, and pursuing the course of that channel to the great Veeranum Tank at Laulpett, and the descent which is met with, is obtained by a Lock allowing for 7 feet fall, besides the varying height of water in the Tank. From this a short canal of $\frac{1}{4}$ mile with a lock of two falls of 7 feet at its lower extremity, gives a descent into the Vellicul, a deep surplus channel falling into Cawn Saibs channel at the distance of 3 miles below Laulpett; after which there is no Lock till the mouth of the Vellaur is reached, where a Lock of 6 feet fall provides for the descent to the level of the sea—The Cauvery is navigable from Trichinopoly to Permaul Coil, with some intermissions, from June till December and the remainder of the line remains open sometimes till February. The streams are moderate in velocity, and for down traffic exceedingly easy and convenient—The Locks are built for Barges 48 feet in length, by 12 in breadth, and drawing 4 feet of water, or 4 basket boats of 12 feet diameter. It would be difficult and expensive to make good towing paths on this line, and in the Cauvery it is of course impracticable; it would therefore be exceedingly desirable to use steam for ascending; and

if this were introduced, I have no doubt the line would be crowded up and down with merchandize and Government stores, troops and passengers of all descriptions: Barges should be built to fit the Locks, and steam tug vessels of moderate power to take them up from the Coast to Trichinopoly. The long talked of coast canal, or sea going steamers would complete the line from the Presidency

Many bridges have been built in Tanjore within the last six years, the most important of which are the Vettaur bridge at Nagore, 12 arches of 30 feet span, and the Vennaur at Tanjore, 5 arches of 58 feet each; and besides these about 20 bridges of from 30 feet to 150 feet waterway. These, with many smaller tunnels, complete several most useful lines of road through a country hitherto locked up, during about 8 months in the year, from any possible communication through it, except in one or two main lines of road. It has always been my study, if possible, so to construct irrigation works as that they may afford communication over the streams on which they are built, and this has tended also to open roads and render accessible towns and Villages to which there had previously been no approach during the cultivating season.

I have also endeavoured to make the river and minor channel embankments passable roads, not only for the convenience of the public, but that they may be well examined and kept in order. I have no doubt that attention to those points has been of great general benefit to the country, not merely at no expense to the Government, but preventing many accidents, and thereby saving much in the repair of breaches. The bridges have been always designed on the most economical principles, consistent with stability. I have studiously avoided all ornament, and adopted arches seldom exceeding 30 feet span, which are easily managed, and are done with almost the least comparative quantity of Masonry. The whole population of the district is alive to the benefit they have derived from these communications; and I am sure I utter the unanimous voice of the whole district when I say that stopping the expenditure of the surplus Davastanum funds in this way has been a severe disappointment; and that if put to the vote, every hand would be held up for the disposal of these funds in the constructions of Bridges and other works for the public good. The funds do not belong to Government, and the Government desires not to appropriate them to state purposes, they belong to no individuals or particular communities, and few if any individuals are found willing to take upon themselves the charge of them with the Pagodas; they belong to the people, and the people are willing and anxious that they should be laid out in this way; and undoubtedly the indirect benefit which the state would obtain from the improved communications would be great, while the energies of the people would be diverted from their extravagant ceremonies, to the promotion of works of usefulness. The proposed bridge over the Cauvery at Trichinopoly is one of the most desirable works in this part of the country. It was planned and Estimated 6 years ago, and was approved and sanctioned by the Court of Directors,

but has never been built. The pagoda funds might well be employed in this work, and whether the welfare of the people, the wish of the East India Company, the interest of the state, the whims, fancies, or rational desires of every caste and class of the people are consulted, they must be so disposed of; one and all of these will most assuredly agree, that they can be applied to no more satisfactory purpose. I have carefully planned the bridge, marked out what I consider the best site for it, and I trust the work will yet be undertaken.

UPPER COLLEROON ANNICUT, }
10th March 1842. }

(Signed) H. C. COTTON, Major
Actg. Civil Engineer, 5th Division.

To

*The President and Members of the Board of
Revenue, in the Department of Public Works.*

GENTLEMEN,

I have the honor to inform you that, in conformity with the instructions of Government, I have examined the Colleroon Annicuts, and the Colleroon and Cauvery rivers, during the greater part of their courses from their separation to the sea, and now beg to forward the following report, for the purpose of being submitted to Government with your observations.

2. The great evil experienced previously to the construction of the upper Annicut, and which, as your Board is fully aware, formed the cause of constant and urgent complaint, was that the share of water which the Cauvery received was altogether inadequate for the proper irrigation of Tanjore, and was greatly diminishing, and in so regular and uniform a manner, that serious apprehensions were entertained by many that the greater part of the original or parent stream termed the Agunda Cauvery, would at no very distant period flow down the Colleroon, leaving the Cauvery little better than a bed of dry sand, except during the season of high freshes. This was the opinion of Sir James Caldwell, the first Engineer who examined the rivers in 1804, and the subsequent alteration, which continued to increase, in the relative condition of the two rivers, seemed likely to verify that experienced Officers prediction. The water in the Cauvery was becoming less, and the accumulation and deposit of sand in its bed increasing annually, while almost every season large tracts of cultivation were lost, from the supply proving insufficient to bring the crops to maturity, to the great injury of the people, and the diminution of the Government revenue.

3. Various measures were adopted to arrest the growing evil, and to obtain for the Cauvery its proper share of water, such as extending the point of separation of the two rivers further to the westward, in order to avoid the banks of sand which obstruct the head of the Cauvery, and by erecting annually temporary embankments of (in the language of the country "Corumboos") across the bed of the Colleroon, for the

purpose of turning the streams into the other river. These operations were always vehemently opposed by the inhabitants of the Trichinopoly district, who complained, and with reason, that their lands were thereby deprived of their just share of water, and at the time when it was most wanted, and they were besides only temporary and very imperfect, though expensive and troublesome expedients, requiring to be repeated several times every year, and gradually becoming more difficult of execution, and less efficient in their operation.

4. At last the upper Annicut was designed and constructed by Captain Arthur Cotton in 1837, as a permanent remedy, and it has fully realized all the benefits which were expected from it since its construction. The province of Tanjore has in general been amply supplied with water, and many high tracts of land which the channels of the Cauvery never reached are now abundantly irrigated and yield excellent crops of rice. But in accomplishing this valuable, and indeed indispensably necessary object, rather more has been done than was either intended or desired. The Annicut has in short reversed, to a certain extent, the former state of things—The Cauvery, instead of being robbed of its just proportion of water, is now beginning to receive more than is required for the irrigation of Tanjore, and than it has capacity to contain without danger of overflowing and destroying its banks and flooding the adjacent country.

5. In the course of the last year in particular, a very marked change has taken place in the bed of the Agunda Cauvery, immediately above the Annicut. Formerly the deep bed was on the north side of the river, and in low freshes and at periods when there was not much water, the whole stream would have flowed into the Colleroon, if not prevented by the temporary dams which were constructed to divert a portion of it into the Cauvery. Now, there is a great deposit or accumulation of sand formed across the head of the Colleroon in front of the Annicut, extending nearly a mile westward, and the whole of the water coming down the Agunda Cauvery at the present moment, runs into the Cauvery, and the Trichinopoly ryots are occupied, as those of Tanjore used to be, in turning, by means of Corumboos, a portion of it into the Colleroon, to preserve the irrigation of their lands, which lie on the north side of the river.

6. The first effect produced by this change is the deepening and widening of the head of entrance of the Cauvery, accompanied by a great accession of water at all times, and particularly in high freshes, and the consequent encroachment on, and undermining of its banks along the first six or eight miles of its course. During the high freshes of last July and August, as reported by Captain Lawford, the narrow and weak bank which divides the two rivers immediately below this separation was preserved with much difficulty and at considerable expense, and was at one time in some risk of being destroyed. The danger has not yet extended further than five or six miles from the Annicut, because the derangement is only beginning, and the safety sluices and Calingulahs, which were constructed in the bank of

the river, expressly for the purpose of allowing the superabundant water to escape into the Colleroon, have hitherto proved fully sufficient to answer that end. But if the alteration which has now begun be allowed to proceed unchecked, the head of the Cauvery will continue to enlarge and deepen, and will draw a greater share of water into it than its bed will be able to contain, and then frequent breaches and inundations will follow, particularly in the upper part of its course, where its banks are weakest, and where it is difficult to relieve them by safety Calingulahs.

7. The district of Tanjore itself has not hitherto been exposed to more danger from floods than it used to be, for the sluices and Calingulahs of discharge have, as already observed, been powerful enough to reduce sufficiently the volume of water in the Cauvery before it reaches that province, and to restore the equilibrium of the two rivers; and these safety works, if it were deemed expedient, might easily be multiplied and enlarged; but it is at the Annicut itself, or the separation of the rivers, where the remedy ought and can with most effect, be applied. By allowing the excess of water to escape through the banks at a distance from the point of separation, the river below, it is true, is relieved, but the banks above are not protected; on the contrary, they are exposed to more danger, for the tendency of that system is to draw a large share of water into the river, and thereby to deepen and enlarge its bed, and in the same proportion to encroach upon and endanger its banks. This is sufficiently established beyond all doubt by the effects of the last two years. The original and proper use of the sluices was to regulate the level of the bed of the Cauvery, by carrying off any accumulations of sand that might be deposited in it, and to this purpose it is desirable that they should be generally restricted. They afford, it is true, a ready and very convenient means of relieving the river in extraordinary floods, and on such occasions can be resorted to with great effect and advantage. By establishing at the Annicut the means of regulating the quantity of water to be turned into the Cauvery, the danger now apprehended, is prevented, while all that outlets in the banks can at best effect, is to cure the evil, which they in no inconsiderable degree assist in creating.

8. The object, therefore, now to be primarily aimed at, is by modifying and perfecting the Annicut, and extending it across the Cauvery, if hereafter found necessary, as I think it will be, to establish such a permanent command over the two rivers at their point of separation, as to be able at all times to regulate the distribution of water in all stages of the freshes, so that each shall receive its just proportion, and no more; and neither to be needlessly exposed to injury during the very high floods which occasionally occur, and which have never yet happened without causing more or less damage to the country.

9. This perfect command over the rivers it, will be readily understood, cannot be at once obtained, in consequence of the necessity of first rectifying the present partial derangement; and it will be safe as well as economical to proceed gradually, regulating each improve-

ment according to the measure of success which follows the preceding one, so as to avoid as far as possible, all risk of unnecessary labour and expense arising from hasty innovations which may not produce the desired effect.

10. I have carefully and attentively considered the whole subject, having previously examined the rivers and works above and below the Annicut, for which the period of the year and the state of the rivers are particularly favorable, the water being low enough to expose to full view the condition of the beds and banks, while enough remained to indicate distinctly the sets and directions of the currents, and the parts most exposed to danger. I have had also the advice and assistance of Captains Lawford and Bell, both of whom are well acquainted with the character of the rivers, and have had some experience in their management; and I have had an opportunity of consulting with Mr. Kindersley and Mr. Onslow the Collectors of Tanjore and Trichinopoly, who take a warm interest in the subject, and were good enough to meet me at the Annicut.

11. Before describing the alterations which appear to me to be required, I would wish to draw attention particularly to the necessity of keeping always in mind, in the treatment of the rivers, the chief or primary uses which each is intended to serve, in order that these purposes may be interfered with and disturbed as little as possible. The Colleroon is the principal draining river of the country, and should therefore be maintained clear and free from obstructions throughout its course to the sea, so as to be able to carry off with safety the superabundant water in high floods, and preserve the country from inundations. The Cauvery, on the contrary, is essentially an irrigating stream, and its capacity and level should be regulated by the extent and level of the country which it has to water, and the numerous branches and channels it has to supply. If these distinguishing properties are overlooked, there will be great risk of the drainage of the country being disturbed, and of serious and permanent mischief being often produced instead of good, which it may be very difficult as well as expensive afterwards to rectify.

12. The alterations and additional works which I consider necessary, and would now submit for your consideration are the following; *First*, The continuation of the Annicut across the small island which separates the south and centre portions of that work, as was originally intended, and only postponed from motives of economy; and I would recommend that its height be two feet less than that of the Annicut, but to be furnished with upright dam stones, to afford the means of readily raising it during low freshes, when the whole or greater part of the water is required to be turned into the Cauvery for the purposes of irrigation. *Secondly*, to lower 200 yards of the *centre* part of the annicut one foot, at the same time strengthening and extending its apron, which, in its present state, is not strong enough to resist the increased size and velocity of the stream which will be produced by this change. *Thirdly*, the construction of a powerful set of sluices at the southern extremity of the large island, and connected with the middle por-

tion of the Annicut, and *lastly*, an Annicut on a low level across the head of the Cauvery, a little lower in the centre than at the ends, to confine that river within its proper limits, and to give the stream a direction down the middle of its bed and clear of its banks.

13 The first object of the first three works is to clear the head of the Colleroon of the large bank of sand which has been deposited in front of the Annicut and to restore the head of the river to its former depth and capacity, so that it may again become the principal branch and carry off the large share of water during floods and high freshes, and thereby relieve the Cauvery from the danger with which it is now threatened.

14 The two first improvements may and ought to be completed this season, and will I expect produce an immediate and powerful effect on the head of the Colleroon, by allowing a much larger quantity of water to flow down that river during high freshes, and by relieving in the same proportion the Cauvery from the excess which is now beginning to be turned into it. This is the first and most urgent object to be gained, and one that cannot be postponed without increased risk of injury to the banks of the Cauvery, and the certainty of much expense. I would therefore earnestly recommend to your attention the expediency of early sanction being obtained for the accompanying three estimates, amounting in the aggregate to Rupees 24,938, 13 11, which provide for the expense of the improvement, and also, for a narrow wooden bridge, very necessary for the efficient management of the sluices of the Annicut, and which will at the same time prove a great convenience to the inhabitants of the neighbouring Villages, and to travellers generally; a considerable quantity of stones are required which must be quarried at a distance, the preparation and carriage of which will occupy some time, and it is essentially necessary for the stability of the works that they be completed as early as possible, in order that the masonry may have time to set and consolidate before the month of June, when the freshes usually begin.

15 The additional sluices I consider to be very important and very much required. They will have a powerful influence in maintaining at all times a deep channel down the Colleroon, will allow a considerable quantity of water and much sand to pass down the river during the south-west freshes, and will be particularly useful in carrying off a large share of the Agundah Cauvery in the north-east monsoon, when Tanjore is sometimes flooded by the local rains, and when it is consequently desirable to exclude all foreign addition to them. They cannot, however, be completed this year in sufficient time to be used during the next freshes, and they are not so urgently required as the former two works. I have not therefore considered it right to delay this report till the plans and estimates are prepared, which will require some time.

16 These three works will, in my opinion, render the Annicut perfect, but the control over the two rivers will not be complete till an Annicut is constructed across the head of the Cauvery to regulate permanently its capacity, and prevent the frequent alterations, which

take place in the size and direction of its stream, often from apparently very trivial causes that cannot be foreseen or guarded against, and which cause much damage to the banks of the river. I would therefore record my opinion strongly in favor of an Annicut across the Cauvery, as necessary for the proper distribution of the water of the parent stream, and equally so on the score of economy, by lessening the outlay that is now annually required to preserve the banks of that river in the vicinity of the annicut. The importance of the latter consideration will be apparent, when I mention that nearly 12,000 Rupees were expended last year in protecting the embankment between the Annicut and Trichinopoly by temporary works, which will require to be renewed every year at an increased expense, and probably with less effect, as long as the present state of things is allowed to continue. It must also be remembered, that at one time some apprehension was entertained of these works not proving sufficient for the protection of the embankment, though the freshes of this year were moderate.

17. The plans and estimates of the proposed Annicuts and of the additional Sluices in the Colleroon Annicut have not yet been prepared, and I am in consequence unable to state their cost accurately, but I may give an approximate statement of the probable expense of the whole of the proposed improvements, which will be sufficiently correct for the present purpose.

Extending the Annicut across the small island, and lowering the middle portion of the Annicut, as per accompanying estimates.	Rs. 24,938
A set of large Sluices in the Colleroon Annicut.	„ 15,000
An Annicut across the Cauvery.	„ 65,000
Total Rupees.	1,04,938

18. This amount, though considerable in itself, is insignificant when contrasted with the immense value and importance of the works and rivers for the benefit of which the improvements are proposed. // The country in the Trichinopoly, Tanjore, and South Arcot Collectories, watered by the Cauvery and Colleroon rivers, yields to the state an annual revenue of between thirty and forty Lacs of Rupees, and I entirely concur in the opinion of all who have had any thing to do with the rivers lately, that the two annicuts have been the means of preventing a great diminution in that revenue as well as much injury and distress to the people; for it is evident that if they had not been built, the value and usefulness of the rivers would before this time have been greatly reduced, and much of the water which is now applied with so much benefit to irrigation would have been running uselessly to the sea. In this belief I am fully borne out by Mr Kindersley the Principal Collector of Tanjore, whose long administration of the province, and intimate acquaintance with its wants and resources, entitle his opinion in such a question to much weight and attention.

19. Since the construction of the Annicuts, the produce of the Nunjay lands watered by the two rivers has

been considerably augmented, and has become far more uniform than at any former period, though the two years which succeeded their completion were particularly unfavorable; and I have no hesitation in saying that the benefit derived during these two years alone from the Annicuts, in preventing the extensive destruction of crops, which would otherwise have been caused by the want of water, was greater in amount, than the money that has been spent in their construction, and is now required to make them perfect. Their value and importance would have been better appreciated, if their construction had been postponed a few years, for the extensive losses and distress which two successive years of unfavorable seasons would have produced, at a time when it was impracticable even in ordinarily good years to obtain with great labour and expense sufficient water for the irrigation of the country, would have put their necessity and usefulness beyond all question.

20. Great attention has been paid to the irrigating works of Tanjore and to the improvement of the roads and communications; though much more is still required, particularly in the latter respect; and the fruits of this alteration are apparent in the improved state of the country and ameliorated circumstances of the people, which have progressively advanced since 1800 up to the present time, when the average produce of the Nunjah lands is thirty per cent more than at the former period.

21. The accompanying two statements which I have received from the Principal Collector, showing the progressive increase in the produce of the wet lands from 1802 to 1841, and in the number of houses in the district from 1818 to 1841, are well deserving of attention. In no other portion of this presidency will the effects of British administration appear in so advantageous a light, and the favorable result instead of being an argument for curtailing the outlay, as I have heard it sometimes stated, appears to me to afford the strongest possible grounds and encouragement for augmenting it, and for extending to other districts a similar measure of outlay and care, in fostering their hitherto neglected resources, and in advancing the prosperity of their inhabitants.

22. I was met at the Vellaur river in South Arcot by Captain Lawford, and with him visited the following places and works on our way to the upper Annicut. The site of the proposed Annicut across the Vellaur, the Veeranum tank, the Lulpett locks and canal, the Vudavaur channel, the lower Annicut and the irrigating channels from it, the locks and canal connecting the Munnyaur and Colleroon, the Permal Covil locks and canal, grand Annicut, and other safety works of discharge in the banks of the Cauvery. The site of the embankment which separates the Colleroon and Cauvery, and the deep holes in the bed of the river close to it, fully confirm the accuracy of Captain Lawford's reports to the Board during the late freshes, and are proofs of the difficulty that was experienced in resisting the force and encroachments of the currents, and of the grounds that existed for apprehending serious injury. This embankment will still require very great attention

and care, for it is much reduced in breadth and strength, and the full force of the stream sets directly upon it; and the danger will continue to increase till a sufficient command over the rivers at their point of separation is established. It is very desirable, I may venture I hope to suggest, that Captain Lawford should remain in the division from the knowledge he possesses of the character of the rivers, and if Captain Bell does not obtain the charge of another division, when relieved from his present duty, his employment in Tanjore would also be very advantageous.

I shall have the honor at an early period to submit

plans and estimates of the proposed sluices in the Colleroon Annicut, and of the Annicut across the Cauvery: in the mean time I have again to solicit your influence and good offices in obtaining the early sanction of Government for the estimates which accompany this report.

I have the honor to be, &c.
 (Signed) D. SIM, Lieut. Col.
 Member of the Board of Revenue,
 Dept. of Public Works.

TANJORE DISTRICT, }
 January, 1843. }

Progressive increase in the average of Gross Nunjah produce, in every 5 successive years from Fusly 1211 to 1250, in the Province of Tanjore.

Fusly.	Gross produce of the Nunjah Tarriff lands in Tanjore.	Total of every 5 years.	Average of every 5 years.	Increase in the average of each 5 years above the average of the preceding 5 years.
	Culls.	Culls.	Culls.	Culls.
1211	11,423,566	47,098,944	9,419,689	
1212	8,566,491			
1213	1,773,947			
1214	10,136,428			
1215	11,250,011			
1216	8,680,840	52,689,382	10,517,876	1,098,187
1217	11,120,623			
1218	11,315,289			
1219	11,240,690			
1220	10,231,938			
1221	10,244,095	57,282,337	11,456,457	938,591
1222	11,588,812			
1223	11,897,075			
1224	12,009,938			
1225	11,542,410			
1226	11,142,870	57,526,476	11,505,295	48,828
1227	11,560,725			
1228	11,412,055			
1229	11,645,299			
1230	11,765,595			
1231	11,126,938	61,575,311	12,315,062	609,767
1232	12,297,039			
1233	12,610,263			
1234	12,844,451			
1235	12,696,617			
1236	13,343,787	63,464,865	12,692,973	377,911
1237	12,724,142			
1238	12,200,668			
1239	12,403,994			
1240	12,792,272			
1241	13,251,973	65,850,625	13,170,125	477,152
1242	13,256,030			
1243	12,845,822			
1244	13,488,892			
1245	13,007,905			
1246	11,847,457	68,281,339	13,656,268	486,143
1247	13,847,210			
1248	14,021,435			
1249	14,185,207			
1250	14,380,030			

Statement shewing the number of houses in each year, in the Province of Tanjore from Fusly 1227 to 1251.

Fusly.	Houses.
1227	145,192
1228	145,409
1229	147,334
1230	149,887
1231	152,376
1232	163,404
1233	166,058
1234	158,226
1235	159,776
1236	166,116
1237	173,139
1238	162,121
1239	169,966
1240	195,723
1241	196,770
1242	197,354
1243	197,251
1244	197,945
1245	198,827
1246	201,887
1247	203,602
1248	206,488
1249	207,635
1250	209,074
1251	211,588

No. 112.

To

The Chief Secretary to Government.

Department of Public Works.

SIR,

1. I am directed by the Board of Revenue, with reference to the order of Government, as per margin, to submit for the purpose of being laid before the Most Noble the Governor in Council, the following report upon the works of irrigation in Trichinopoly, Tanjore, and South Arcot, subordinate to the Coleroon Annicuts, with a plan of the rivers in illustration of the same.

M.C.No. 49 13th
Jan. 1844 para 3.

2. The Coleroon Annicuts have been so fully and minutely described in the report of Colonel Sim their professional Member, that it is needless to allude but briefly to their history in the present report.

3. The design of the upper Annicut, which is situated adjacent to the head of the Cauvery, was to divert into that river an adequate share of the water of the main or Agunda Cauvery, the greater portion of which naturally flowed into the Coleroon, and was lost in the sea, without ever being applied to the purposes of irrigation.

4. The lower Annicut, though a very great and important work, must be considered as supplementary to the other, being designed to collect and raise to a sufficient level the reduced supplies of the Coleroon, which, flowing on a widely extended and low sandy bed, would without the aid of such a work, be almost wholly lost to the dependent cultivation during the low freshes.

5. At the time these great works were projected the entire subject of their probable effects upon the long established system of irrigation in the delta, of Tanjore and in the other parts of the valley of the Cauvery and Coleroon under their influence was most carefully considered by Captain A. T. Cotton. The distribution of the new supplies of water required, with some exceptions which will be hereafter described, no new arrangements. It would have been scarcely possible, had it been thought necessary, to disturb the existing system of the channels leading from the great sources of supply. But it was by no means necessary to make any changes, for the arrangement of the numberless channels both for supply and drainage was as perfect as could be desired. The only important want was a greater abundance of water, and this want it was shown at the time, and has been amply proved since, could be supplied in the simplest manner, and to the fullest extent, by the upper Annicut.

6. It was however obviously necessary to determine one great question arising out of the proposed construction of this work, namely the disposal of the surplus water passing into the Cauvery in high freshes, and this accordingly formed a principal topic of discussion, and was in consequence well provided for.

7. Before entering upon the details of this part of the subject, it will be proper to resume and follow up that of the distribution, showing the partial changes in old channels and the extensions of irrigation to new lands in different situations that have taken place in consequence of the construction of the Annicuts.

8. The first to be mentioned is the Iyen Voykal, a very considerable Rajah Voykal, or main channel, irrigating a large proportion of the lands of Trichinopoly on the left bank of the Coleroon. The head of this channel was formerly about seven or eight miles below the head of the Coleroon where the upper Annicut was afterwards established, and the jar of interests between the proprietors of its dependent cultivation and the people of Tanjore was incessant; since, whatever was done to improve the head of the Cauvery, necessarily increased the labours of the Trichinopoly royots in drawing to the Iyen Voykal the diminished waters of the Coleroon.

9. The construction of the Annicut at once settled these disputes, for the head of the Iyen Voykal being carried by a new cut to a part of the Coleroon bank above the Annicut, it enjoys equally with Tanjore the full benefit of that work, and is now regularly supplied far better than it ever was before. Several minor channels formerly branching from the Coleroon between its head and that of the Iyen Voykal are also now supplied from the new cut, and in like manner under the influence of the Annicut. The Parawully Voykal, another channel of equal capacity with the Iyen Voykal, has received the benefit of the Annicut without any change having been made in the position of its head.

10. The only ancient branch for irrigation from the right bank of the Coleroon is the Munnyar, the head of which being intermediate between the two Annicuts, is the only one eastward of the division of the Agunda Cauvery which is uninfluenced by either of those works. There is consequently a difficulty in obtaining direct supplies of water for this channel in low freshes, but this was foreseen and provided against in the following manner. Some time before the Annicuts were projected, a set of under sluices for regulating the bed of the Cauvery were constructed at Permal Covil, where the Munny flows between the Cauvery and Coleroon, and consequently first receives the discharge from the under sluices; its exit from the Munny being provided for by another surplus sluice which conveys it to the Coleroon. At this place it was therefore easy to throw supplies into the Munny from the Cauvery, and the under sluices were partially reformed to facilitate the discharge of water without sand, or of both, at pleasure.

11. Here closes the account of the new arrangements made for distribution in connexion with the upper Annicut, and it will be seen from inspection of the map how very small a portion of the grand system of rivers and channels has received any alteration.

12. The next considerable channel from the Coleroon is on the left bank, and is called the Vuddavaur, which supplies the principal part of the irrigation of the Chellumbrum and Manargoody Talooks in South

Arcot, and it is immediately below the head of this channel that the lower Annicut is established. At the same time, there being other considerable channels, as the Cawn Sahib and Comaratchy, the heads of which were below the site of the Annicut, it became necessary to supply them in the same manner as the Iyen Voykal and the other Trichinopoly channels above mentioned near the upper Annicut, for which purpose a new cut was made for the benefit of all and named the North Rajah Voykal. Its effect has been, as in the parallel case of the Trichinopoly channels, to supply them far more copiously and regularly than they ever were before.

13. In 1839, three years after the construction of the Annicuts, a further extension of the benefits of the lower work, long before designed, was planned in detail and submitted to the Board, and carried into effect in the following year. A new channel called the Chellumbrum Peria Voikal was taken off from a point near the junction of the North Rajah Voikal with the Cawn Sahib and carried on a high level so as to command a considerable extent of land long left waste in the Chellumbrum Talook. Other less important channels were excavated about the same time, the principal one being the Boorthengoody at the North end of the Vee-ranum Tank, into which the Vuddavaur falls. The general result is that nearly all the ground of the two Talooks is under the immediate command of the irrigation, while every channel is copiously supplied.

14. It may be here remarked, that the very great value of the lower Annicut is especially exemplified in the fact, that it is never found necessary to discharge water from the Cauvery for the supply of the extensive irrigation of these Talooks, and of that of the right bank of the Colleroon under the lower Annicut, which will presently be described, but the water collected at the lower Annicut is, in low freshes, only that which escapes in various ways at the upper work, combined with the surplusage (chiefly of the Trichinopoly lands) and other drainage falling in between the two. This would be almost all lost by spreading over a wide bed and by absorption in the sand but for the lower Annicut; which gathers it in one body, and thus saves for the cultivation a great supply, which no other means could render available.

15. On the right of the Colleroon there were formerly no regular channels of irrigation besides the Munny, and consequently no new arrangements were rendered necessary by the construction of the lower Annicut.

16. The irrigation east of the site of the lower Annicut was formerly obtained almost exclusively from surplus water, the only direct supply being from the Munny, which at such a distance from its source was small and precarious; and during high freshes from the Colleroon by means of sluices which at other times discharged the surplus of the fields into that river.

17. The actual cultivation was thus imperfectly supplied, and maintained with difficulty; and there was

a great extent of waste land, of which more than 9000 acres were fit for wet cultivation.

18. It was in consequence determined to throw in a direct supply to these lands from the lower Annicut, for which purpose a channel named the South Rajah Voykal was taken off on the right bank and carried to a junction with the Woosey and Seeterampilly Voykals at that time supplied from the Palavar and Woodiar, two considerable surplusses, and in high freshes from the Colleroon. The waters of the Palavar and Woodiar were by this arrangement appropriated exclusively to their other branches, the Kullamullyar and the Pooray Voykal. The Woosey Voykal, which formerly watered lands near the Colleroon, was diverted to the eastward and carried across the Palavar by an aqueduct, and the Seetarampilly became the main course of the South Rajah Voykal parallel to the Colleroon.

19. These works were executed in 1837, 1838 and 1839, and in 1840 a farther extension of the South Rajah Voykal was proposed, and at the same time a plan was submitted for carrying the united Munny and Palavar, which then terminated in a tank called the Punjamen sery, by a direct course to the Sea, with a view to the irrigation of waste land, and at the same time of affording a new outlet much wanted for the general drainage.

20. In 1841 this project was executed. The South Rajah Voykal was continued, still parallel to the Colleroon, and carried by an aqueduct across the Alinjyar, another considerable surplus for the benefit principally of the lands of Achaverram formerly supplied from the Palavar. The last mentioned channel or Munny was carried across an Oopenaur (or surplus into which salt water enters) by an embankment, direct to the Sea, and at the same time made to irrigate land between the Oopenaur and the Sea. Other minor arrangements were at the same time effected, and thus a great extent of land on both banks of the Colleroon was brought under the command of the lower Annicut, and is all abundantly supplied.

21. To return now to the subject of the disposal of surplus water.

22. Prior to 1829 the only outlet for surplus water from the Cauvery to the Colleroon was the ancient native work called the grand Annicut. But since that year there has been a considerable increase of the means of relief to the Cauvery. Of these, two, the twenty vent under sluices, and the 150 yards Calingula, are situated in the island of Seringham, above the division of the river into the Cauvery and Vennar; and four, the sluices in the grand Annicut, the Coiladdy Calingulah, the Vuddavagoody Calingulah and sluices, and the Permal Covil sluices are below the point of separation and therefore do not affect the Vennar. All these works except the Coiladdy Calingulah, which is the most powerful, were established before the construction of the upper Annicut, and in the project for that work were considered nearly sufficient for the relief of the Cauvery, it being calculated that the surface of the river

would be but little raised in high freshes, while the discharge from the Calingulahs would be proportionably increased.

23. Subsequently, the Coiladdy Calingulah was built, and the vents of the 20 vent sluices raised so as immensely to increase its power of discharge; and thus prepared, the river sustained some very severe freshes in 1841 without material injury.

24. The deepening of the Cauvery has however naturally followed the prolonged flow of a considerable body of water entirely cut off from the Colleroon, and it has been shown by Colonel Sim that this effect cannot possibly be remedied by works, whether sluices or Calingulahs in the banks, but only by a lowering of the Colleroon Annicut, which has already taken place, and by sluices in that work, combined with a dam across the head of the Cauvery to prevent it from deepening.

25. It has been observed that the principal works for the relief of the Cauvery are situated below the branching of the Vennar which supplies a nearly equal quantity of irrigation. They have been so placed in consequence of the land in the island of Seringham being in all parts where a work of discharge for the undivided river would be most useful, highly cultivated, and too valuable to be destroyed without very urgent reasons.

26. The Vennaur was formerly a very badly supplied river in comparison with the Cauvery, and it was at one time proposed to build a dam across the latter for the purpose of more equal distribution. This object has however been for the present accomplished by corumboos through the influence of the upper Annicut, and the Vennaur receives its full share. In high freshes the lands under this river and its branches suffer more than those dependant on the Cauvery from the want of the same means of relief, and from the circumstance that the Vennar being for many miles the southern boundary of the delta, receives all the drainage of the upland on the right bank as well as the surplus of the Trichinopoly lands watered from the higher Cauvery channels.

27. It may be proper here to observe that the Nullar, for altering the course of which an estimate is sanctioned in the Minutes of Consultation under reply, is affected, though remotely, by the state of the Vennaur, but this was always the case, and it was observed in the letter forwarding that estimate, the opening a new vent for the Nullar was a necessary pendent, not to the introduction of an increased body of water from the westward, but to the repair of the Talnoyer Cotagum which forced back the drainage.

28. The drainage of the two Talooks of Chellumbrum and Manargoody has always been attended with difficulty. The subject has been carefully considered, and considerable improvement already made, chiefly by straightening the course of the Colleroon near the Sea. Much however is yet required to be done to save this valuable district from the inundations to which it is subject, and which have sometimes covered the whole of the land in cultivation and ruined the crops.

29. Throughout Tanjore, with the exceptions above-

mentioned, no alteration with regard to the discharge of surplus or drainage has been made since the construction of the Annicuts. Nor are any at present in contemplation, but it is not thereby meant that none will be required at any future time. On the contrary it is absolutely certain that the irrigation cannot be maintained without considerable annual expense, often increased by events which it would be impossible to guard against, even if they could be foreseen. These arise from the very state of things by which the fertility of the delta is produced, namely the bed of alluvium of which it is composed, and its low level, placing it under the command of a copious irrigation; so that independently of the certain destruction caused by great inundations, the banks of the rivers and channels are continually injured by changes of direction in the currents, and what is of more importance, the heads of all the considerable channels require constant watching and expense to preserve them in their right position and in a proper state to receive their due proportion of water; the nature of the soil being such as often to render of much importance what may appear at first a trifling neglect or accident.

30. These remarks were true of the rivers in their original state, but it cannot be denied that they have greater force in consequence of the deepening of the head of the Cauvery by the increased supply of water turned into it, which of course leads to more severe action upon the banks, and to greater changes in the different heads of channels. The Cauvery Annicut is proposed to mitigate this mischief, and it is confidently hoped will be effectual in assisting to preserve a proper equilibrium, but it would be hazarding too much to say that the improvements may be viewed as final measures, and that further changes will not be required hereafter.

31. The plan also shows the line dotted red of canal navigation from the Cauvery to the Vellaur, terminating at Porto Novo.

31. At Permal Covil a communication by locks is made from the Cauvery to the Munny, and opposite the lower Annicut near Tripamandal from the Munny to the Colleroon, by a canal and other locks. The line is continued by the Vuddavaur to the Veeranum tank, from whence it descends by locks into the surplus channel leading from the Laulpett Calingulahs into the Cawn Sahib, and so on without interruption to near Porto Novo, where the last lock is placed at the junction of the Cawn Sahib with the Vellar.

32. This communication is practicable for about six months in the year, and promises to come into much use for the trade Sea wards, but the currents prevent it from being available for any return traffic, and the basket boats having discharged their loadings are abandoned, being first stripped of the hides which cover them, and which are carried back to the interior to be again employed for the next voyage.

I have the honor to be &c.

(Signed) J. H. BELL,

Actg. Sec. Board of Rev. D. P. W.

Madras, }
26th February 1844. }

No. 390.

To

G. D. Drury Esq.

Chief Secretary to Government

Department of Public Works.

SIR.

1. I am directed by the Board of Revenue to ac-
In Cons. 17th
June 1844. knowledge the Extract from minutes of
 consultation No 388 dated the 19th April
 1844, in which it is observed, that the report furnished
 from this Department under date the 26th of February
 last upon the works of irrigation in Trichinopoly, Tan-
 jore, and South Arcot is deemed satisfactory as a detailed
 history of the past, but does not meet the object which
 was contemplated of obtaining information of their
 prospective purposes; and that the Government before
 sanctioning the expenditure of public money in the
 future execution of Works connected with the Cauvery
 and Colleroon Rivers, desires to be made acquainted
 with the causes which occasion their necessity, and the
 consequences intended by them, the risk to be anti-
 cipated in their execution, and the full advantages to be
 derived to the state from their perfect completion; and
 in practical illustration of these views the Board of Re-
 venue in the Department of Public Works is called
 upon to report on the results which are expected to be
 produced by the Dam now proposed to be built on the
 Cauvery, and to state why they are unable to look for-
 ward with confidence to the sufficiency of the work in
 completely rectifying instead of partially mitigating the
 evils to be apprehended and now experienced by the
 deepening of the head of the River &c. &c.

2. The Board desire me to explain, that when they
 submitted the Plan and Estimate of the Dam across
 the Cauvery, they did not consider it necessary to occupy
 the time of Government with a recapitulation of the
 causes of the necessity and expected consequences of
 that work, because the Dam forms one of a series of
 improvements, the necessity and objects of which had
 been already explained in the Report addressed to
 them by their professional Member in the month of
 January 1843, and submitted for the consideration of
 the Most Noble the Governor in Council with their
 Secretary's letter dated 19th January 1843 No. 24. In
 that Report, the subject is discussed at great length by
 Lieutenant Colonel Sim, the necessity of the several
 works shewn, and all the advantages expected to be
 realized from their perfect completion given in detail.
 From that Report they take leave to quote the following
 passages before proceeding to reply to the observations
 in the minutes of council, in order to bring the subject
 more completely before Government.

"In accomplishing this valuable and indeed indis-
 pensably necessary object (turning a sufficient supply
 of water into the Cauvery) Lieutenant Colonel Sim
 observes, rather more has been done than was either
 intended or desired. The Annicut has in short reversed,
 to a certain extent, the former state of things. The
 Cauvery instead of being robbed of its just proportion
 of water is now beginning to receive more than is re-

quired for the irrigation of Tanjore, and than it has ca-
 pacity to contain; without danger of overflowing and
 destroying its banks and flooding the adjacent country."

"In the course of the last year 1842, in particular, a
 very marked change has taken place in the bed of the
 Agunda Cauvery, immediately above the Annicut.
 Formerly the deep bed was on the north side of the
 river, and in low freshes, and at periods when there was
 not much water, the whole stream would have flowed
 into the Colleroon, if not prevented by the temporary
 Dams which were constructed to divert a portion of it
 into the Cauvery. Now there is a great deposit or
 accumulation of sand formed across the head of the
 Colleroon in front of the Annicut, extending nearly a
 mile Westward, and the whole of the water coming
 down the Agunda Cauvery at the present moment,
 January 1843, runs into the Cauvery; and the Trichino-
 poly Ryots are occupied, as those of Tanjore used to
 be, in turning by means of Corumboos, a portion of it
 into the Colleroon, to preserve the irrigation of their
 lands which lie on the north side of the river."

"The first effect produced by this change is the
 deepening and widening of the head or entrance of the
 Cauvery, accompanied by a great accession of water at
 all times, and particularly in high freshes, and the
 consequent encroachment on, and undermining of its
 banks along the first six or eight miles of its course.
 During the high freshes of last July, and August,
 as reported by Captain Lawford, the narrow and weak
 bank which divides the two rivers immediately below
 their separation was preserved with much difficulty,
 and at considerable expense, and was at one time in
 some risk of being destroyed. If the alteration which
 has now begun, be allowed to proceed unchecked, the
 head of the Cauvery will continue to enlarge and
 deepen, and will draw a greater share of water into it
 than its bed will be able to contain, and then frequent
 breaches and inundations will follow, particularly in the
 upper part of its course, where the banks are weakest,
 and where it is difficult to relieve them by safety Calin-
 gulahs.

"The object therefore now to be primarily aimed at,
 is by modifying and perfecting the Annicut, and ex-
 tending it across the Cauvery, if hereafter found neces-
 sary, as I think it will be, to establish such a permanent
 command over the two rivers, at their point of separa-
 tion as to be able at all times to regulate the distribution
 of water in all stages of the freshes, so that each shall
 receive its just proportion, and no more."

"This perfect command over the rivers, it will be
 readily understood, cannot be at once obtained, in con-
 sequence of the necessity of first rectifying the present
 partial derangement, and it will be safe as well as eco-
 nomical, to proceed gradually, regulating each improve-
 ment according to the measure of success which follows
 the preceding one."

3. In the Report from which the above extracts are
 taken, Lieutenant Colonel Sim, who had just completed
 an inspection of the rivers and works, with the view of
 proposing remedies for such derangements as had been

attributed to the construction of the Annicut, gave his opinion that the following alterations and additions were desirable, and that they would answer the required purpose, approximately stating their expenses as follows.

Extending the Annicut across the small island, and lowering the middle portion of the Annicut,	Rs. 24,938
A set of large sluices in the Colleroon Annicut,	„ 15,000
An Annicut across the Cauvery,	„ 65,000

Total Rupees. . 1,04,938

4.—The first of these improvements were executed last year, and their effect is described by Captain Law-Letter ^{26th Sept. 1843} } ford to have been perfectly satisfactory. Con 23d Oct. do } The deposit of sand in front of the Colleroon Annicut has been sensibly diminished, and considerable relief afforded to the Cauvery in high floods by the greater quantity of water that now passes down the Colleroon. But the head of the Cauvery opening through fine sand and alluvium, which is easily swept away by the currents, continues to enlarge, and its bed to deepen, and thereby more water is still turned into it during the season of high freshes, than its bed can safely hold, as is observable from the erosion of its banks throughout a considerable portion of its course.

5.—It is this progressive enlargement of the head of the Cauvery, and the evils resulting from it, the Board beg to explain, which the proposed Dam is intended to arrest, by substituting a permanent unchangeable flooring or pavement of masonry across the bed of the river, at its separation from the Colleroon, for the present changeable and constantly shifting bed of moveable sand, which is affected by every flood, deepening and widening as the flood increases, and thereby admitting the largest quantity of water, just at the time that it is wished to exclude it. This is the primary and main object of the Dam, and the Board entertain no doubt of its effecting this object, if the work is substantially and properly built.

6.—Its direct influence, on the bed and banks of the river is chiefly local, but by diminishing the quantity of water in high floods, and giving a right direction to the stream, at the place where it now does most mischief, it will have indirectly a powerful influence in protecting the banks from further abrasion, by rendering the currents more controlable, and the river less liable to overflow. It will not however, and never was expected, to give that full measure of security to the banks which would be required to prevent the river from ever overflowing the country, for the Delta of Tanjore and the two south Talooks of south Arcot have always been subject to periodical inundations, some of which in former times were excessively injurious, and these will no doubt continue to recur occasionally, notwithstanding all that can be done to prevent them, but the Dam will unquestionably have the effect of diminishing their frequency, as well as the extent of injury when they do happen.

7.—The influence of the work on the general irrigation will be beneficial, in so far that it will reduce the quantity of water in the Cauvery in high freshes, the superabundance of which on such occasions is now a serious disadvantage; and it will contribute to promote the prosperity of the District and the security of the Public Revenue, like every work that improves the irrigation, for the more perfect the irrigation of a country is, the greater and less liable to fluctuation are the productive qualities of its soil.

8.—The Dam will not occasion any deposit of sand in the river, for being on a level with the natural bed, it offers no obstacle to the passage of the sand, and it will not disturb the current where the irrigating channels begin nor impede its entrance into them.

9.—With respect to the “risk to be anticipated in the execution of the work, the possibility of its failure, and the causes from which such contingency might arise,” the Board would respectfully observe, that a certain degree of risk which no forethought can provide against, is inseparable from all hydraulic works of this description. There is always some uncertainty as to the period and height of freshes in Tropical rivers, and no bridge or Dam can be built in them without the risk attendant on the possibility of a sudden flood occurring at a time when the ordinary course of the seasons would not lead to its being expected, and floods under such circumstances are always more or less injurious. But the Board have no reason to apprehend in the present case any thing beyond the usual risk to which, in common with all similar works, the Dam must be liable, and indeed it may be considered to be exempt from some of the risks to which such undertakings are exposed, in consequence of the valuable experience which has been acquired in the construction of the two Annicuts already built, and the celerity and efficiency with which all works in Tanjore and south Arcot are completed.

10.—Notwithstanding all the care that can be taken by the Board, and skill and forethought exercised by the Engineer Officers under its orders, failures and disappointments will sometimes unavoidably happen in the construction and effects of public works—Such accidents are not confined to India, but are common in Europe, where so many superior facilities and advantages exist, and the insufficiency of estimates furnished by European Engineers, of the highest ability and greatest experience, to complete extensive projects proposed by them, excites no surprize, in consequence of the acknowledged impracticability to foresee and provide for all contingencies that are met with in their execution—At this Presidency it is matter of surprize that the failures should be so few, rather than that there should be some, considering the great disadvantages under which both the Engineers who design the works, and the Collectors who usually execute them, labour, from the number of these works, the great distances of some of them, and their position in jungles and unhealthy parts of the country where labourers are collected with the utmost difficulty. The inadequate number of Engineer Officers is another serious evil, com-

bized with the impossibility often experienced in procuring properly qualified subordinate Agents to superintend the details of the works.

11.—In regard to prospective works, the Board direct me to explain, that the upper Annicut has not produced any material change in the general system of the irrigation of Tanjore. It has only corrected a great and increasing evil, by substituting an abundant for a deficient supply of water, and thereby furnished the means of enlarging and extending the old channels of irrigation, so as to augment the fertility of the land previously cultivated, and bring into cultivation tracts of country which have hitherto remained unproductive from want of water.

12.—In the distribution of the water of the Cauvery among the numerous irrigating channels which are fed by it, much difficulty with considerable expense has always been experienced, from causes which will hereafter be explained, in giving to each its proper share, and it has at different times been proposed to construct masonry works on the same principle as those at the separation of the Colleroon and Cauvery, but greatly inferior in size and expense, in order to regulate with more ease and certainty the proportion of water which should be given to each, and to put a stop to the troublesome changes that are constantly taking place at the head of these channels. Such works the Board think it right to state may hereafter be found necessary at the heads of the larger channels, such as the Vennar Arselaur Codamoorty &c. but these are not more required now than they were before the Annicut was built, and they may not be necessary for years to come. Such probable improvements cannot be considered as proceeding from the effects of the Annicut, for if required at all, they would have been so, if the Annicuts had never existed.

13.—The only work proposed by Lieutenant Colonel Sim for the perfection of the upper Annicut now remaining un sanctioned, is the set of large sluices, and which it is hoped may not be required, tho' it would be premature to speak on this point with absolute certainty, till the full effects of the improvements already completed, and those about to be undertaken, are clearly seen.

14.—The Board do not anticipate that any more extensive works will be required at the upper Annicut, but some slight alterations in the relative levels of the two Dams may be found advisable, as observed in Lieutenant Colonel Sim's letter of the 3d November 1843, in order to regulate, as accurately as can be done, the division of the water; and with this view the proposed Dam is on the first instance to be made intentionally rather low, in order that its height may be more easily and more accurately determined hereafter, as more correct information is derived from future experience.

15.—In the way of drainage, especially of the low lands near the coast, on the completeness of which the quantity and quality of the produce so greatly depend,

a good deal still remains to be done. Considerable tracts of low land recently brought under cultivation are liable to be flooded during the north-east monsoon, and the crops are often damaged; and the Annicuts, by turning more water into the District, have of course tended to render these floods more frequent and extensive. To this important branch of the subject the Board have given their attention, and measures are in progress of being adopted for perfecting the drainage and opening more ready outlets for the escape of the excess of water to the sea; but it is hoped that this will be effected without materially increasing the annual outlay of the District.

16.—Having thus afforded the information required by Government respecting the proposed Dam, and which the Board hope will be found satisfactory, they direct me to submit, with all deference and respect, a few observations on the rivers in Tanjore, for the purpose of shewing the impracticability of always foretelling with that absolute certainty which Government appear to expect, the precise effects which works intended for their management and for the improvement of the irrigation dependent on them will produce, and the impossibility of preventing the country from being flooded, and the occasional failure of works.

17.—The Board would in the first place notice, that there always have been occasional floods of very extraordinary height in these rivers, sometimes produced by the south-west freshes, but more frequently by the north-east monsoon, when from long and continued heavy falls of rain, a large portion of the District of Tanjore and the two south Talooks of south Arcot, are overflowed for several days, and considerable injury done to the crops.—This will not appear surprizing, when it is remembered that Tanjore is an alluvial plain extending 70 miles from east to west, with two rivers and many large irrigating channels, flowing through it, in shallow beds very little below the surface of the country, and subject periodically to floods from both the south west and north east monsoons, increased at times by heavy local rains. Such occasional inundations are more frequent in India than in Europe, but tho' of a more extensive character, they resemble those floods which occur in other countries, and which no human efforts or skill can prevent. In Tanjore, Trichinopoly, and south Arcot they have been far less injurious during the last fifteen years than they formerly used to be, not however from the effect of the Annicuts, for as has been repeatedly observed, they neither increase nor diminish the aggregate quantity of water in the two rivers on such occasions, but from the treatment of the rivers being now better understood, and from more attention having of late been given to preserve the artificial banks in good order.

18.—The changes in the currents which often prove injurious to the banks, have their rise frequently in accidental and apparently very insignificant causes of sudden origin, and which can neither be foreseen nor prevented. The beds of the rivers consist of very fine

sand, which in the dry weather is lifted and driven into banks by the high westerly winds that always precede the south-west freshes, and these often give the current a new direction. Sometimes a tuft of grass or a small shrub, the growth of a few months, becomes a nucleus around which a deposit of sand collects to produce the same effect. It will be easily understood that no single work like the proposed Dam can be effected to prevent such changes in the beds of rivers 100 miles in length, and that the only mode of managing rivers like the Coleroon and Cauvery, is to observe carefully the changes as they arise, and to apply timely local remedies to counteract them, and prevent their becoming permanent and injurious.

19. The agency of the proposed Dam, as already stated, will so far be directly beneficial throughout the whole course of the river, that by diminishing the quantity of water, and consequently the strength and rapidity of the currents, it will render them more controllable, and will at the same time diminish the frequency of floods, and their injurious effects when they do occur, but it will not, and never was expected to give full security to the banks, nor prevent the country from being sometimes overflowed.

20.—With respect to the Annicuts, the Board have found no reason to alter their opinion, that they were indispensably necessary, and that if they had not been built, a large portion of Tanjore would before now have entirely lost the means of irrigation, and the remainder of the District been very imperfectly supplied with water. Instead of the cultivation having been extended, the Public revenue increased, and the prosperity of the District promoted, as has on various occasions been made known to Government, the Board would have had the painful task to report annually a progressive decrease in the Public revenue, and deterioration of the resources and fertility of the province,

with the necessarily attendant impoverishment of the people. When the Annicuts were proposed, the evils arising from want of water were at their height. The prediction of the entire annihilation of the Cauvery river at no very distant period by Colonel Caldwell, the first Engineer who examined and reported on the changes and relative levels of the two rivers, appeared to be rapidly advancing to fulfilment. The question, as correctly stated by Mr. Kindersley the Principal Collector was not whether Tanjore should be converted into a garden, but whether it should be allowed to become a desert, by the ruin of its irrigation.

21.—In conclusion, the Board desire respectfully to add, that the works and alterations proposed for the improvement of the irrigation of Trichinopoly, Tanjore, and south-Arcot, have always received their most careful consideration, and been well digested before being laid before Government; and that in submitting them it has been their earnest desire to explain fully and clearly, the nature and principle of each work, the defects it was intended to cure, and the result anticipated from it, in proof of which they would refer to the frequent inspections of the rivers and works of irrigation of these Districts by the oldest and most experienced Engineers under their controul, and the numerous reports submitted to Government on the subject. It is gratifying to them to be able to state, as it will be satisfactory to Government to learn, that the general effect of the works has been most favorable on the revenue, on the prosperity of the country, and on the well being of the people, and that the irrigation derived from the Coleroon and Cauvery, tho' still susceptible of extension and improvement, instead of having deteriorated as was once predicted, has attained a degree of efficiency and perfection previously unknown, and which, even the most sanguine advocates of these works scarcely ventured to anticipate.

(Signed) S. Best,

Secretary to the Board of Revenue D. P. W.

**NOTES ON THE CONSTRUCTION OF SALOOCHENUM'S BRIDGE ACROSS THE TAM
BRAPOORNEY AT PALAMCOTTA IN THE DISTRICT OF TINNEVELLY,
BY LIEUTENANT W. H. HORSLEY, MADRAS ENGINEERS.**

The successful completion of the subscription bridge across the Tambrapoorney between the towns of Culladacoorchy and Ambasamoodrum in the year 1840, and the very great convenience afforded by it to the public, speedily attracted attention in the district, and, in the end, led to that over the same river at Palamcotta being built at the private expense of Saloochenum Moodeliar, Naib Sheristadar at Tinnevely.

As it fell to my lot to superintend the construction of this important work from first to last, and having the means at hand, it will naturally be expected that I should draw up a short account of the proceedings for insertion in the Corps Records, particularly as it is the most extensive work of the kind yet undertaken in Southern India. I will do my best, therefore, to lay before my brother Officers all that I think will prove interesting and instructive in the details of the building, touching slightly only on those points which are of common occurrence, and therefore well known to all.

The bridge, as now built, was designed by Captain Faber, my predecessor in the 8th Division, in 1840, and consists of eleven elliptical arches of 60 feet span and 17 feet versed sine, standing on ten piers averaging 10 feet in height and the same in thickness, and two abutments measuring 15 feet in thickness at the springing courses.

The breadth over the soffit of the arches is 27 feet, of which 24 feet are occupied by the roadway, and 1½ feet on each side by the parapets. The total length between the abutments is 760 feet, or from the extremities of the wings 930 feet. The style of architecture is similar to that of Waterloo bridge over the Thames at London. The upper and lower faces of the bridge are ornamented with rows of coupled doric columns standing on the ends of the piers and supporting an entablature and balcony above. The parapets are of open balustrade work finely polished with shell chunam, presenting an appearance, of white marble, and giving to the whole structure a grand and imposing effect.

Operations may be said to have commenced on or about the 10th December 1840, but very little was done till January 1841. Between this and the end of May following the whole of the piers and abutments were completed to the level of the springing courses.

The foundations of all but Nos. 6, 7 and 8 piers, reckoning from the left bank, rest on hard kunkar rock at the depth of 8 or 10 feet. Nos. 6, 7 and 8 being situated in the sandy part of the river's bed, with a constant depth of 3 or 4 feet of water, it was found necessary to sink 3 rows of wells (vide plate 13 fig. 1) of 4 feet inner, and 6 feet outer diameter, to the depth of 10 feet, where a firm clayey bottom was met with. The wells were then filled in with cubes of masonry (made to fit the inner diameter) and the spaces between with

rubble stone in cement to the surface of the water. On these, as a foundation, were laid three courses of rough stones from the Palamcotta Fort walls, faced with cut stone, and bound together with iron cramps, set in lead. Above these, again, came brick in chunam to the required height. Lines of wells were also sunk in front and rear between Nos. 6 and 9 piers, to act as retaining walls to the pavement or flooring, which it was thought advisable to lay down for the protection of the foundations.

Further progress was prevented by the occurrence of the usual freshes in the river, consequent upon the setting in of the south-west monsoon, in the beginning of June. It now became necessary to determine what description of centring should be used, on which to turn the arches early in the ensuing year. The estimate allowed for the usual cumbersome mass of brick work, supporting palmyra frames and over these again a thick stuffing of brick in mud. I was the more anxious to secure efficiency in this part of our work, from having been an eye witness of the uncertainty and risk attending the removal of the centrings of the Ambasamoodrum subscription bridge, before mentioned; where, from the want of proper means, much inconvenience was felt, and considerable loss accrued. It was at length determined, with the full consent of Saloochenum Moodeliar, that a better description of centring than that allowed for in the estimate should be made use of. The plan adopted consisted of four parallel frames of anjelly timber (procured from Cochin) supported on twenty piers of brick work built up to within one foot of the spring of the arch, with a wedge of the form shewn in plate 13 fig. 2 on the top of each pier. The frames were connected transversely by struts and braces, and on top by palmyra pieces supporting the stuffing or mould, formed of bricks and clay (1 foot in thickness all round, and agreeing exactly with the curve of the intrados. The timbers for five complete centrings arrived at Palamcotta in the month of December 1841, and were framed together on the spot without loss of time. The arch work commenced on the 22d of February 1842 from the left bank, with the hope of completing the eleven arches in one working season. The impracticability of this, however, was soon apparent. It was therefore decided that operations should cease for the year, after the completion of No. 6 and so much of No. 7 arch as would act as a counterpoise to the former on the removal of its centring. To support this portion of No. 7 arch, a semicircular arch (vide plate 13 fig. 3) was turned below it on the centring piers, and the space between built up in the form of a buttress of brick in chunam, to within 6 inches of the intrados of the former, and this intervening space filled with fine sand to separate the temporary from the permanent work. This plan answered exceedingly well.

In February 1843, the centring of the remaining five arches were set up in rotation from No. 7 to No. 11 on the right bank, and the arches themselves turned by the end of July. The arch bricks made use of in this work were of different forms and sizes, to suit the radii of the curve, and laid according to the English bond, headers and stretchers alternately. Extra sized bricks were also used to break the joints, as shewn in Plate 13. Fig. 3.

The chunam was composed of 1 part of slaked lime to $1\frac{1}{2}$ parts of clean river sand, mixed dry in the first instance, and then beaten in stone troughs with sticks in the usual manner; some portion of it was prepared in a circular stone trough with a heavy roller moved by bullocks, but the common method was found to answer best. For the arch work, the chunam, after being taken from the trough, was ground fine by the hand. Jagherry was used in the proportion of 1 lb to 1 para of slaked lime.

The period allowed (viz. 30 days from the time the key bricks were driven) for the mortar to set sufficiently, having expired, and every precaution been taken to prevent accident, either to the work, or those engaged in the operation of removing the centring, heavy blocks of wood were first slung in front of each wedge, and stops of equal length inserted in the openings between the wedge pieces, to secure their being driven uniformly. The total projection of the centre wedge piece being 10 inches, and the slope to the perpendicular height as 2 to 1, the first stops were cut to the length of 7 inches, which, with a small wedge of 1 inch in thickness, held close to it by a person placed there for the purpose, allowed the centre wedge piece to slide 2 inches, or 1 inch of perpendicular height. Thus much was driven at 7 A. M., beginning with the lines of wedges under the haunches, then those nearest to them on either side, and lastly those under the crown. When the whole were driven, an opening of nearly an inch was observed between the stuffing and intrados of the arch at the haunches, extending (but gradually decreasing in breadth) to the first upright, shewing that the arch had been relieved equally at these points. The crown sunk with the centring one inch. In this state it was left till the evening of the same day, when the second inch of the wedges was driven in the same order as above, stops of 5 inches in length with small wedges as before being used at this part of the operation. It was now found that the opening between the stuffing and intrados at the haunches had increased to nearly 2 inches and extended as far as the second upright towards the crown on either side. The third inch of the wedges was driven the following morning with equal good effect. The crown, however, continued to settle down with the centring, which, at this stage, amounted to 3 inches, again at 5 P. M. the fourth and fifth inches were driven in. This last caused a very perceptible opening between the stuffing and intrados at the crown,

shewing, in fact, that the arch was no longer supported by the centring. On the third morning we commenced removing the stuffing from beneath the crown (little or no alteration having taken place in the state of the arch during the night) and in the course of the day, the whole of this was removed, and the centring timbers taken down and brought into store. Further examination shewed that the crown had sunk exactly 5 inches and the haunches risen $\frac{1}{2}$ an inch. During the operation of striking the centring, the usual transverse cracks were observed over the haunches, but these were very trifling from the first, and eventually closed of themselves, leaving the arch as sound as possible throughout.

The plan I adopted in the first instance to ascertain the amount of settlement was the simple one of a frame work of wood made to fit the curve of the intrados as originally turned, and which, when placed against the face of the arch, after the centring had been removed, shewed how much it had sunk or risen at different places—Another method, was that of drawing tangents to the curve at the crown and over the haunches, and then measuring the ordinates of the curve formed by the settling of the arch (vide Plate 13. Fig. 5.) The result shewed a fall of 5 inches average at the crown, and a rise of $\frac{1}{2}$ inch in the centre of the haunch, diminishing on either side in equal proportions.

The spandrel arches side retaining walls, and blocking course, were completed during the months of August and September 1843, after which the road way was in part filled in and the bridge opened to the Public on the 7th November following, leaving the Balustrade and fine plaster work to be done in 1844. These latter operations proved more tedious and expensive than was at first anticipated, owing to the extra degree of care and attention bestowed upon them, at the express desire of Saloochenum Moodeliar. Instead of using Pottery for the balustrade, as is customary in India, I divided the balustrade into eight parts, and had moulds made for each part. These, when burnt, were put together in the same manner as pillar bricks, and afterwards plastered with chunam. The bridge and its approaches were fully completed by the end of October 1844 at a total cost of Rupees 51,986—of this sum Rupees 47,236 were expended in the construction of the bridge itself, and Rupees 4750 for raising the approaches. That on the right bank had to be raised 15 feet above the former level, involving also, the reconstruction of a small bridge across the Paulien channel stir- plus, the Parapets of which were formerly under water during high freshes. The roadway is now 3 feet above the level of the highest fresh ever known, that of 1827.

Polished granite slabs bearing an inscription in English and Tamil have been inserted in the centre of the bridge Parapets. The following is a copy of the English inscription.

THIS BRIDGE AND ITS APPROACHES WERE CONSTRUCTED
AT THE EXPENSE OF.

T. SOOLOCHENUM MOODELIAR
NAIB SHERISTADAR OF TINNEVELLY
HAVING BEEN DESIGNED BY

CAPTAIN C. E. FABER, Civil Engineer in 1840,
When E. P. THOMPSON, Esq. was Collector, and
C. T. BIRD Esq. Sub-Collector;

Commenced in Jan. 1841 and completed in Oct. 1844
Under the Superintendence of

LIEUTENANT W. H. HORSLEY, CIVIL ENGINEER
and during the Collectorships of
Sir HENRY C. MONTGOMERY Bart, AND
E. B. THOMAS, Esq.

Cast iron lamp posts with Copper lanterns and burners complete, have arrived from England, and will shortly be fixed in the Parapets of the Bridge. They are to be lighted with oil at the public expense.

Agreeably to the orders of the Honorable Court of Directors and Government, an obelisk of stone with suitable inscription in English and Tamil is about to be erected on the left bank of the river in the centre of the approach to the Bridge, to commemorate the munificent and public spirited act of Saloochenum Moodeliar in providing funds for the construction of this highly useful and important work.

To give some idea of the value of this Bridge to the community generally, I subjoin a memorandum of foot Passengers &c., who have passed over it during a period six months.

DATE.	People.	Bandies.	Cattle.
From 5th to 31st December 1843.	286677	4165	8786
„ 1st to 31st January 1844.	469083	8190	15298
„ 1st to 29th February 1844.	324102	5574	14796
„ 1st to 31st March 1844.	229725	5954	19740
„ 1st to 30th April 1844.	160512	4818	33633
„ 1st to 31st May 1844.	155083	399	3259
Total 5th December 1843 to 31st May 1844.	16,25,182	29,100	95,512

The above is the lowest computation. Others have passed unnoticed by night, and lately two Native In-

fantry Regiments, the 15th and 31st, with about 400 Bandies and 5000 people each.

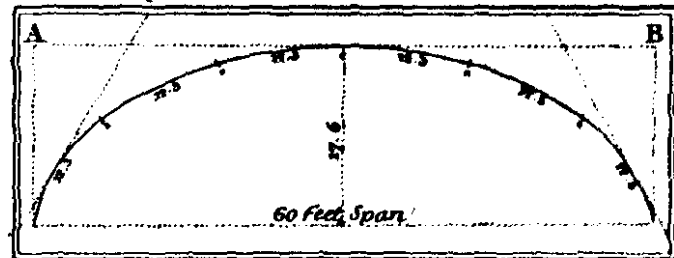
Palamcotta }
20th January 1845. }

Signed W. H. Horsley.

Method observed in striking the centring under No. 7 arch.

Before driving the wedges, it was necessary to remove the six inches of sand which intervened between the temporary buttress arch and the intrados of that portion of No 7 which had been built the previous year, as a counterpoise to No 6. This was easily effected with long pikes, and as soon as all was clear, the wedges were driven in 2 inches of their length, (the same method and order of striking being observed as in the case of No 1.) On the following morning two more inches were driven, giving the second inch of fall to the centring throughout, and again the same quantity in the evening. The fourth and fifth inches of fall followed on the third morning, and by the evening the whole of the stuffing, palmyra rafters, and centring timbers were removed. The cracks, (slight ones) which had shewn themselves in the extrados of the arch while building, closed entirely, and others appeared over the haunches, consequent upon the settlement at the crown. This latter was ascertained to have sunk 5 inches, a few hours only after the centring had been struck.

In order to ascertain the amount of settlement in different parts of the curve, I caused three straight lines to be drawn on the face of the arch, tangents to the intrados at the crown, and over the haunches, at the distance of 12½ feet from the springing course, and two vertical lines tangents to the curve at the latter point, and meeting the Horizontal line in A and B. thus.



On the removal of the centring, the tangents at the haunches were found to have risen, the original line having a convexity of ¼ inch in the centre of its length. The horizontal tangent to the intrados on the contrary had assumed a concave figure, its depression at the centre of the key brick being as near as possible, 5 inches, and decreasing gradually towards the extremities, or fixed points A and B.

MEMORANDUM ON THE OCCURRENCE OF WASTE IN THE OPERATIONS OF
COINAGE, BY CAPTAIN J. T. SMITH, F. R. S., F. R. S. N. A., &c. &c. &c.

1 As it is the professed object of our volume to record the experience of each Officer in his peculiar province, for the benefit of those who may not have had similar opportunities of observation, and as some of the practical subjects connected with the management of Mints are peculiarly foreign to the ordinary pursuits and experience of the Engineer, I am induced to make a record of the few facts which have come under my observation even during the short period of my connection with the Madras Mint, insignificant as they are, in the hope that they may not be without interest and usefulness to those who may be for the first time compelled to enter upon a study of the subject.

2 I am the more encouraged to enter upon these details because, though I am conscious of my inability to bring to light any new facts, still I am of opinion that some benefit, may be derived from a careful attention to those which are already well known; and as the object which I have in view in what I am about to bring forward, is the establishment of a principle which has not yet been recognised, and which I am of opinion may perhaps be considered of importance to the future economy and strict check over the complicated processes of the manufacture of coins, I trust that my endeavours to elucidate the subject, and to clear the way of some of the difficulties which impede the progress of the newly appointed Mint Master, may not be altogether unavailing.

3 The principle which I wish to establish is this, that in the ordinary processes of coining *there is no such thing as wastage, or loss.* I mention the ordinary processes of coining, because I wish to confine myself at present within those limits which strictly comprise matters of my own personal experience, and my acquaintance with the subject is of too recent a date to allow me to include the extraordinary duties which Mints are sometimes called upon to fulfil, more especially the refining of the precious metals, and their chemical separation from one another. During the four years that I have had charge of the Mint, little or nothing has been done in the way of these processes, so that there has been no opportunity for the thorough investigation of them; and therefore, though I feel convinced from the general reasoning which applies to all such processes equally, that the same result must upon a thorough investigation be found true regarding them also, still I feel it necessary on this occasion to limit my observations to those with which I feel myself more thoroughly conversant, and which, from their being of the most constant occurrence, are for practical purposes of the largest importance.

4 I am aware that the subject which I am now about to discuss is not brought under consideration for

the first time, and on the contrary that it has been a matter of attentive scrutiny and examination ever since Mints have been conducted under European agency. Nor am I ignorant that the question is supposed to have been decided in direct opposition to my views; and that the authorities vested with the controlling powers of various Mints have not only from time to time admitted the existence of unavoidable wastage, generally, but have even gone the length of reducing the principle to a regular system, and have assigned to each individual process its share in the general loss. I have also been fortunate enough to obtain access to the very valuable report, containing a masterly analysis of the subject, by the late James Prinsep, Esq., Assay Master of the Calcutta Mint, wherein a review is taken of an extensive series of experiments conducted under the superintendence of himself and the late Dr. Bannister, and also of a similar series in the Bombay Mint by Captain McGillivray, and a comparison made, whereby the results experienced in the two Mints are shown to be in strict accordance with one another.

5 The facts contained in the official papers above referred to are, without doubt, strictly correct, and the inferences drawn from them equally so, nevertheless I trust I shall be able to show that the proposition I advanced is still absolutely true, and not incompatible with these facts and inferences, although it is altogether at variance with the general deduction which has been drawn from them, and too long acted upon, viz. the inevitable necessity of wastage and loss in coining; and I think it will be shown that it is only in consequence of a partial view having been taken of all the truths connected with the subject, that this erroneous opinion has so long been allowed to remain in force.

6 On my first connection with the Mint my attention was forcibly drawn to this question. I observed that a large wastage had been year by year practically experienced in the Indian Mints;* that the regulations of some of them expressly provided for "unavoidable wastage in the operations of the coinage," and that in the official correspondence it was invariably treated as the cause of a real deficiency and a positive loss to the State. All this was quite unintelligible to me. Upon general principles the occurrence of unavoidable waste in the few simple processes to which I saw the metal subjected seemed to me to be unaccountable; and observing also the fact, that nothing in the shape of refuse was ever removed from the departments without undergoing a strict search for any particles of precious metal which might be contained in it, the quantity of which was estimated, and an allowance made in the accounts, it seemed to me to be quite impossible that there should still be any real deficiency, or any opening by which so large a quantity as that supposed to be annually dissipated, could be removed or lost sight of.

* This, must have amounted to upwards of a lac of rupees per annum in all the Mints a few years ago.

7 My reasons for these doubts will appear more clearly, if we for a moment turn our attention to the well known physical truth that matter is not destroyed; that there is no such thing in fact as *destruction* of matter of any kind.* This assertion may appear rash and unwarrantable to those who are unfamiliar with philosophical truths, but it is one so thoroughly established, and so fully known, that it would be a waste of time to attempt an argument in support of an admitted postulate. It is a truth equally universal as it is undeniable, that there exists no such thing as the annihilation of matter. A metal for instance, may be reduced to powder, or it may be dissolved, it may be converted into a salt, it may be changed into a hundred different forms, but still, after each or all these metamorphoses it remains undiminished. If proper means be used, every particle of the original metal may be restored to its primitive condition, without loss. All the efforts of the whole creation could not annihilate a single particle of it.

8 In bringing this fact into view, in connection with the practical manipulation of the precious metals in coinage, it is to be observed, that the only case in which a real practical loss could be the unavoidable accompaniment of any process, would be that in which the particles were either dissipated in such a manner that they were carried out of the premises and could not be collected again, (although they still existed) or they might be mixed up and confounded with so large a mass of heterogenous matter as to make it inexpedient, as a matter of economy, to extricate them. There is no opportunity for the first of these accidents to take place, there not being the smallest tendency whatever to dissipation of the metal in any one of the processes of coinage, except that of melting, and in that, as will be seen hereafter, no such thing occurs. In regard to the second, although it might be the occasion of a trifling waste practically† yet it is *not* one, in the sense in which we are now considering it, because, whether the particles so mixed up with other matter, be, or be not actually separated again, they are invariably estimated in value and allowance made for them; and it is a loss *over and above this*, supposed to be unavoidable, which I am now considering.

9 Before we proceed, let us for a moment pause and consider the above truths once more. We have established that, 1st. It is impossible for the precious metal entrusted to a Mint to be annihilated. 2d. That it is subject to no process by which it is irrecoverably dissipated,—and 3d. That even in respect to the trifling quantity which may be permitted to remain in the mass of refuse and dross, no part of the loss in question is sustained. There is therefore in these considerations nothing whatever to explain the large waste to be accounted for. It cannot therefore be

wondered, that it should have appeared to me incomprehensible.

10 There is also another principle which is of great importance in viewing this subject; and which, had it been applied as early as its truth was admitted, would long ago have removed the difficulties of it. This is, that all the manipulation in the world, and all the processes imaginable cannot alter the *value* of precious metal. It may be melted, laminated, pickled, stamped, It may have baser metal mixed with, or taken from it. It may be alligated, or refined, and its weight may be either increased, or diminished, by the addition or subtraction of alloy; but be the processes many or few, provided the original particles still remain, and have not been abstracted or dissipated in any way, the original value is still unaltered.

11 Coupling then this fact, with those given above, a clear apprehension will be formed of the difficulty which I felt at the outset of my experience, founded upon principles which my subsequent opportunities of investigating the subject have only confirmed. Seeing that there was no process by which silver or gold could be lost or dissipated, and remembering that all the operations of the coinage could not change the true value of metal once delivered to the Mint, I was naturally at a loss to comprehend how it was possible there could be an "unavoidable waste" in coining, and still less how it could possibly amount to the large sums commonly experienced and charged in Mint accounts.

12 The full investigation which it has been in my power to make into this important subject, has fully satisfied me of the truth of the proposition stated at the outset of this paper, though it is at the same time equally certain that all the wastages recorded in the experiments referred to above, and allowed in the practices of the different mints are by no means illusory. The explanation is to be found in the fact, that the wastages referred to are merely apparent, and apply simply to changes of the *weight* of the metal under manipulation, which are not necessarily alterations of its value, but which have been unavoidably treated as if they did involve that change, in consequence of the Mint accounts not being competent to make the proper compensations in fineness, which always accompany the losses of weight—owing to the absence of any means of detecting variations so minute as those which follow the different stages in the manufacture of coins. For want of this, it has been impossible ever to adjust the value of the out-turn of the Mint to the true standard it was supposed to conform to, and whenever very large losses have been experienced, this has most probably been one of the causes which has occasioned it.

* The Queen's Assay Master in the Royal Mint could not have intended to be understood *literally* when he said (Report on Mint Art 704) "but you may destroy gold or silver if the object be to destroy" as there is, in truth, no such thing as destruction by any created power. He doubtless meant that you might cause gold or silver to cease to be metals, in which sense they might be said to be destroyed; but this would be very different from annihilation; for whatever might be

the nature of the substance into which the metals might be changed, there is no doubt but they could be easily restored to their original condition.

† In the Madras Mint the value of the silver which is contained in the refuse at an annual settlement would not amount to more than 3 or 400 Rupees; the whole value of silver coined during the same period being 40 or 50 lacs of Rupees.

13 A like difficulty also, regarding the precise estimation of the value of bullion on receipt, has sometimes led to its being over-rated, and unduly paid for; and these two causes together constitute, I have no doubt, the chief reasons of the waste in every Mint; the losses which have been sustained being the result, either of the bullion being overpaid for in the first instance, or being over issued, in coins exceeding standard fineness, in the second, or by both these together.

14 It may perhaps be most satisfactory that I should in this place go through a detail of each successive operation of the manufacture of coins, and show the change which takes place in the metal, and the causes which are apt to give rise to real and apparent loss; to state the precautions which are necessary to guard against the former, and the means by which the compensation naturally arising from the increased fineness of the metal may be made to neutralize the latter; as I think I shall then be able to show more practically than by any mere general statements, how the truths which I advance may be verified; and reconcile the conclusions which I have drawn with the more obvious and plain realities of every days experience which have been hitherto acted upon.

15 There are no less than seven principal operations in the manufacture of silver coins (to which I shall confine myself) and these have their subdivisions. They are 1st Melting—2d Laminating—3d Cutting, sorting, and adjusting—4th Milling, or marking—5th Annealing—6th Cleaning—7th Stamping.

16 *Melting.* There is a greater probability in this process, that a real loss, an actual diminution of value should occur, than in any other. I have above stated that a change of value cannot possibly be effected, except by a literal abstraction of the precious metal, and we can easily understand why such is the case. If a pound of pure silver, for instance, were melted a thousand times, and if copper were added to and subtracted from it by successive portions. At every step of these processes, provided none of the particles of pure metal had been allowed to escape, the result of every true assay of the metal, whether in its coarse or fine condition, ought to be such as to make its value equal to that of a pound of pure silver. There is nothing in mere manipulation to alter value, unless, some of the precious particles are dissipated; but we might be inclined to suspect that this might occur during fusion. It is not impossible, one would think, that silver might be volatilized, and thus the precious metal be diminished in quantity. It is certain that if an alloy be melted, its weight after fusion is considerably reduced; but it is also equally certain that, practically, not a particle of silver escapes from the furnace.

17 This being the only point on which the smallest doubt could reasonably be entertained, I have given

it the most attentive examination. When I was in Calcutta in January 1842 and visited the Mint there I made particular enquiries as to the volatilization of silver. The very idea of such a thing seemed to be considered absurd, and I was assured that no such thing as volatilization of silver had ever been experienced. It was not the custom to sweep out the chimnies, because the volatilization of silver was out of the question, but I was told that when that metal was adulterated with mercury there was a loss, and particles of the mercury might be evaporated. This is true also in regard to lead, fumes of which escape from silver very frequently. But neither of these would at all change the value of the mass in fusion.

18 The same question has also been practically tested at Madras—and though no such thing as sweeping the chimnies for the purpose of recovering volatilized silver had ever been heard of previously, I determined upon having it done, in order to obtain decisive evidence upon a point of so much importance. The result was, that in the chimney of a furnace which had been in constant daily use for about 15 years, and in which many crores of rupees worth of bullion must have been melted, there were collected particles of silver which altogether weighed about 70 grains. This experiment taken in connection with the experience of the Calcutta Mint, seems to my mind to be quite conclusive as to the fact that there is no real loss in melting by any dissipation of the precious metal. We must therefore now enquire what other causes there may be for loss. A considerable quantity of metal may accidentally escape during the fusion, or be spilt in the act of pouring, which is lost for the time, either in the furnace amongst the charcoal, or dispersed over the floor of the melting room; but as every part of the room and also the furnaces are carefully cleaned of every atom of solid matter, and the whole of this cinder, charcoal, dust, and sweepings, is ground to impalpable powder, and the silver contained in it separated by a tedious and oft repeated washing, and the searching trial by intense ignition with a flux in the blast furnace, there is but a very trifling proportion* of it which escapes recovery, and that portion does not constitute any loss or occasion of waste in the accounts, its amount being estimated and an allowance made; the dross itself being sold by auction.

19 It is notorious, however, that when silver is melted for coinage, the weight after fusion is considerably less than before, even after making this recovery, and every allowance. It is admitted also that the metal undergoes refinement, and consequently that it has become purer in quality than it was. All that I wish to add is, that its value after fusion ought to be precisely equal to what it was originally, and that there is no necessary cause for wastage or loss; and this, because it is simply copper and nothing besides copper, or base metal, which is injured by the heat so as to be separated

* The value of the silver which remains in the melter's dross is usually about 100 Rupees, upon a coinage of 20 lacs.

from the alloy and lost in the refuse, whence it is not worth while to recover it. It is owing to the absence of any means of recognizing the minute changes of fineness in the silver alloy, and the consequent adoption of a system of account independent of them, that it has been impracticable to exhibit this truth, or to take advantage of it, in the manner indispensable to avoid waste; and the attention being therefore exclusively paid to that change in the metal which alone is palpable viz. in its weight, is one of the great causes of the real loss which I enquired into. I propose hereafter to detail the means by which this evil has been rectified; in the mean time I must invite attention to another.

20 When the Mint receives bullion, it is supposed to receive nothing but solid metal, which is charged to it according to its weight and actual fineness, but I found that these supposed conditions did not always exist, and that the bullion was not always made over to the Mint in the solid state. In some cases coins were received, which were always more or less dirty, and these were calculated in the accounts by multiplying the gross weight of dirt and silver by the average fineness of a sample melted for assay. The consequence manifestly was an unavoidable loss, corresponding with the amount of dirt which had been reckoned as silver, and the remedy was plain, viz. taking care to melt the coins always in future. In this way one of the principal causes of the previous loss was got rid of.

21 I am not aware of any other cause of waste which attaches to the operation of melting, taken *per se*, because when the out-turn is correctly estimated according to its actual weight and true fineness, the result always is equal in value to that of the metal put into the pot. This has been fully confirmed on the large scale by the experience of all the operations of the Madras Mint of late years; which indeed have proved not only that the melter's delivery may be to the full amount of the value charged against him, but even to a trifle more, owing to a cause which will be explained in the sequel.

22 But in order to make the comparison strictly, it is necessary that the melter's deliveries should be exactly assayed. It was formerly customary to allow all the ingots which were delivered within the acknowledged "remedy" to be passed into work indiscriminately, and to be reckoned in the accounts at what they were called "Standard"—but this involves a great uncertainty in the value of metal received from him. All the melter's ingots might for instance range in close proximity to the higher limit allowed by the remedy viz. B. 1 dwt. or they might all touch the lower prescribed boundary viz. W. 1 dwt. but in neither case would any difference be shown by the accounts. In order to an accurate comparison it is essentially necessary that the ingots should be assayed and reported at the nearest half dwt. to their true fineness, and that the melter be credited at the same, which is now invariably done in this Mint—and it is a system which not only carries with it the assur-

ance of a strict conformity with truth and exactness, but also possesses this capital advantage, that a total check is put to the acquisition of any benefit whatever by fraudulent debasement of the metal. When all that passes out of the melter's hands is carried to account at its true weight and fineness, it ceases to be his interest to take any steps to adulterate the mixture; whereas upon the former system, when all the ingots which were not so bad but that the Assay Master might pronounce them standard, were passed into work and credited in his account at the same value as those which were of the finest acceptable quality, it was evidently to his advantage that as few of the latter and as many of the former should be delivered as possible.

23 By the system of rating all the melter's deliveries at their precise worth, his honesty is placed beyond suspicion, because he has no interest in being otherwise. When the Mint Master knows that whatever is taken from the melter will be rated at its true value, he may be perfectly indifferent as to any danger of adulteration. The melter can by no process whatever change the value of the bullion in his possession, and he is called upon to re-deliver all that is entrusted to him, or pay for it. There ceases therefore to be any necessity for that complicated system of watching and supervision, which however ineffectual to check fraud, when there is no other preventive, must unavoidably have been resorted to were the above simple method of checking the accounts not discovered. As I have above not only shown that there is no real cause for waste in this department, but also stated the fact that no such thing is practically experienced, it is unnecessary to dwell longer upon it, I will therefore proceed to the next.

24 *Laminating.* In this department the experience of all Mints seems to be the same, viz. that no loss whatever is experienced. In fact there is no part of the process by which any waste could be accounted for, excepting it were by the removal of the oxide of copper which forms on the surface of the straps while annealing, which last process is performed two or three times during lamination. I observe by the notice of a late lecture given by Mr. Brande on the business of the Mint, that in the London Mint the annealing of the ingots is done out of the contact of the air, whereby the burning of the alloy is prevented. In other Mints where this is not the case, the annealing would give rise to a small gain or loss, according as the oxide of copper is removed from the straps before delivery, or not. If allowed to remain, there would be a certain increase of weight; if removed, a certain diminution, but in neither any alteration of *value*. And in both these cases the effect produced is an anticipation of those due to the subsequent processes of annealing and blanching, to which it must be referred; because if there have been a gain in this department, it is merely at the expence of an increased, and if there has been a loss, of a diminished waste by the effect of the acid in blanching the pieces; which last apparent waste will

be accounted for, and the compensation explained when we arrive at that process. As regards the process of lamination however the value of the metal is unchanged. No silver is dissipated, and if any particles are separated, they are collected together and restored.

25 *Cutting.* In Madras the cutting and adjusting are included in the same department with the laminating, there is no separate receipt and delivery. There is however obviously nothing in the process of cutting to alter the value of metal; nor can we imagine any reason why a riband of standard silver, after being cut into a million of pieces should not be the same value as before. The experience of different Mints varies as to the occurrence of a trifling increase or diminution of weight, that is apparent value, owing to the blanks being received and delivered with a greater or less quantity of oil adhering to them; but the circumstances giving rise to this increase or diminution have no interest whatever in connection with the value of the metal, which obviously cannot be affected in the slightest degree by the greater or less quantity of oil or grease attached to it. I am not aware of any other cause which can even effect any apparent change in its value. Small particles of metal are apt to be detached by the operation of the cutters, but these are of course collected together and delivered.

26 *Adjusting.* After the pieces have been cut they require to be separately weighed, and adjusted to the correct standard, or brought within the prescribed remedy. The correction is made at Madras by a second cutting, and as there is evidently nothing in the mere operation of weighing to alter value, the remarks above given as to the effects of cutting, apply equally to the adjustment, the pieces undergoing no other operation whatever. In most other Mints the adjustment is done by the use of a file, and a trifling apparent waste ensues, which Mr. Prinsep states to be chiefly due to the wiping off a portion of the oil previously gained. In so far as it is the effect of this, it is of course of no interest in our present enquiry. We may however perceive in the use of the file one very trifling opening for an alteration in the value of the metal, by the removal of the particles separated from it, which might to a very minute extent adhere imperceptibly to the persons of the men employed, and thus be irrecoverably carried off the premises; and that such a loss does in fact take place we cannot doubt, though it is probably, undeserving of the slightest notice. In Mr. Prinsep's report above referred to, the whole apparent loss chiefly attributable to the wiping off of oil, is stated to be at the rate of only about .0001, or $\frac{1}{10000}$ pie per cent. That part of it therefore which is due to the dispersion of the minute particles of the metal must be very insignificant. As it will be seen hereafter that this is the only opening whereby there seems to be any possibility for loss at all, it is necessary to be particular in pointing attention to the amount of it; and to add that whether it were more or less, it is not "unavoidable," as the Madras process of adjustment is unattended by

any waste. If therefore the use of the file should be attended by a loss which is worthy of any consideration, it ought to be abandoned, and the Madras method, which is also much cheaper, substituted for it.

27 I must not omit now to state, what I have been obliged to defer to this opportunity, in consequence of the three processes of laminating, cutting, and adjusting, being associated together in the Madras Mint, that as a matter of experience, no loss has ever been met with in any of them. It is however necessary to add, that until within the last year the results were not tested with so much minute accuracy as they have been since the year 1844, in consequence of my attention being occupied with other points of importance, and the apparent results previously obtained being so satisfactory, that there seemed to be no reason whatever for investigation. Up to the date mentioned, there was always a considerable *excess* in the out turn of the three processes, which without any minute enquiry was attributed to the grease adhering to the blanks and scissel. During the last settlement, however, I adopted the plan, in imitation of the system followed in Bombay, of making a daily trial of the exact proportion of weight due to the grease, by boiling a bag of blanks in a strong solution of caustic potash, and the difference of weight shown after drying, was deducted from all the deliveries both of coin and scissel, which were entered in the accounts only at the net weight of clean metal. The last half years settlement which has been conducted entirely on this plan, has still been favorable, and there has been no deficiency, but even a trifling apparent excess, due in my opinion to our having in spite of all our care somewhat underrated the grease.

28 *Milling.* The operation of milling is merely the raising up of the outer edge of the blank, by squeezing it between two dies, to make the rim smooth. The serrated edge of the coin is afterwards formed in stamping. In this operation it will be evident that there can be no change in the value of the metal. There is nothing whatever in the use of the machine, or in the result of the process to effect any change at all. In some Mints, where a large quantity of oil is used in milling, and this is afterwards cleaned off together with all that previously adhered to the blanks, there is an apparent loss arising from a diminution of the gross weight, by the removal of the oil which adhered to the pieces on receipt; but in this, as in the previous processes, the change is merely an apparent one, there being, as before stated, nothing whatever in the increase or diminution of weight arising from oil to affect the value of the metal in the slightest degree.

29 *Annealing.* The process of annealing is for the purpose of softening the blanks and making them more fit to receive the impression of the die. It also assists the operation of the acid in cleaning. The blanks are placed in a reverberatory furnace and brought to a red heat, after which they are cooled, either by immersion

in water, or by exposure to the air. The effect of this process is a slight increase of weight, owing to the combination of oxygen with the alloy in the metal; and as it is entirely superficial, it varies in its proportion according to the form and superficial area of the pieces exposed to its action. We have not made any experiments with minute accuracy on this point, as the pieces after leaving the laminating and adjusting department are counted on transfer, and thus passed from hand to hand by tale, so that trifling variations in the gross weight cease to be of any importance; but from the experiments which we have made, the difference of weight in Rupees has been shown to be about 3 annas $7\frac{1}{2}$ pie per mille, or $4\frac{1}{2}$ pie per cent. As this increase of weight is occasioned merely by the addition of a foreign substance (oxygen) to the metal, it cannot of course by any possibility be the cause of any loss of value.

30 It will place the subject in the clearest light however, if we view the results of this process and the next in conjunction, as respects the alteration of weight, I will therefore merely add on the subject of annealing, that in consequence of the effects of this and the subsequent process being entirely superficial, the apparent results are also greater in the small coins, in which the superficies bears so much larger a proportion to their weight than it does in the larger pieces. The explanation which will be given, however, showing the unchangeableness of their value, is equally applicable to them as to the rupee pieces, to which latter I only confine myself now, for the sake of perspicuity.

31 *Blanching.* The pieces which have been blackened by the action of the fire, giving rise to the oxidation of the copper alloy, are boiled in diluted sulphuric acid, by which the whole of the oxide of copper is removed, and they are brought to the beautiful frosted dead white appearance witnessed upon articles of plate and jewellery. The acid thus carries off not only the oxygen to which the increase of weight brought about by annealing is due, but with it the copper also; there is therefore a net loss of weight after the action of the acid, in consequence of the removal of a portion of the copper alloy, and the result of the most accurate experiments we have been able to make upon this point, taken in connection with the results of the actual deliveries upon the large scale to and from the department, show that it amounts upon an average to about $6\frac{1}{2}$ annas per mille or 7.8 pie per cent. I should mention, to avoid mistake, that this refers to a comparison between the weight of pieces free from all grease and oil, (that is in the condition in which they are received from the laminating and adjusting department, a deduction having been made, as above stated, to compensate for oil) and the same pieces when thoroughly clean and dry, and ready for delivery at the stamping presses. I mention it more particularly because I have reason to believe that it varies from the experience of other Mints—Of course the $6\frac{1}{2}$ annas loss is in addition to the loss of whatever increase of weight is effect-

ed by annealing, which indeed is rarely attended to, except as a matter of experiment, all the departments of milling, annealing, cleaning, and stamping, being associated together.

32 We have in Madras another process of cleaning which is peculiar to this Mint, whereby the frosting or bloom occasioned by the action of the acid is removed, and the pieces are slightly polished. The object of this is to enable them to take a better impression in Stamping, the Madras presses not having the circular movement, and to prevent the clogging of the dies, and it is effected by enclosing them in a barrel with paddy-husk and water, and causing it to revolve for about an hour, at the end of which time they are sufficiently clean for use. This process is attended with an apparent loss of about $3\frac{1}{2}$ annas per mille, or nearly 4 pie per cent; but as it consists almost wholly of silver, it is recovered from the contents of the barrel, and there is no final waste or difference of value. In the above statement this process is included in the result of actual practice, showing an apparent diminution of weight of $6\frac{1}{2}$ annas per mille upon the whole three processes, but as I believe the "churning" process is not the occasion of any part of this, owing to the completeness of the recovery, that statement will be equally true as applied to the remaining two processes.

33 The difference of weight of $6\frac{1}{2}$ annas above mentioned is solely a loss of the oxide of copper, for diluted sulphuric acid has very little solvent power on metallic silver. At all events, it is the only diminution of weight which ought to be allowed, because if there should be any solution of silver by the action of the acid, it ought to be recovered, by any one of the simple and easy processes for effecting that object, such as the use of copper sheets, solution of salt &c. If therefore the diminution be wholly a loss of copper, there has been no change in the intrinsic value of the pieces; their fineness must necessarily have increased, just in proportion as their weight has been diminished. There is therefore no occasion whatever for loss, as relates to value, even in this process—any more than in those which have preceded it.

34 *Stamping.* Before going further to dispose of the apparent loss of $6\frac{1}{2}$ annas per mille above mentioned it may be as well to say a few words about the last and finishing process in the manufacture of the coin, the Stamping. It is obvious from the nature of this process, as in respect to one or two others preceding it, that there is nothing whatever in it to alter the value of the metal; and in the exact experiments recorded by Mr. Prinsep no change whatever was shown. In the Madras Mint, this department being associated with the three last, no separate account has been taken, but we have every reason to concur in the result above quoted; and in the delivery of finished coins, the difference in weight of $6\frac{1}{2}$ annas per mille, which has been mentioned as the result of annealing and blanching, includes every thing up to the final delivery of the

finished coins. In disposing therefore, of that apparent loss of $6\frac{1}{2}$ annas, we account for every change to which the metal is subject, after its delivery from the laminating and adjusting departments; and, seeing that there is no loss whatever there, for every chance of waste subsequent to the delivery of the metal in ingots by the melter.

35 I have before shown how the mere fusion of the bullion cannot alter its value; and besides have stated, not only that it ought not, but that it does not effect the smallest change. That when proper precautions are taken, the true value of the ingots is fully equal to the value debited against the Mint for bullion, (and even more) and that it has been proved to be so, as a matter of fact, ever since the recommencement of this Mint. As the bullion is converted into standard metal without loss, so it passes through all the other processes, except the annealing and blanching, wherein it has been stated to be subject to a diminution of weight of about $6\frac{1}{2}$ annas per mille or 7.8 pie per cent. The produce of the Mint might therefore be delivered without any waste or deficiency, were it not for this apparent loss by diminution of weight. I have however explained, that as it is a loss exclusively of copper, the real value of the pieces is unchanged; the only difficulty is to devise a plan whereby, in spite of the imperfection of the science of assaying, the refinement occasioned by this abstraction of copper may be clearly and exactly shown, and a practical method adopted for the purpose of meeting it, in such a manner that the fineness of the resulting coins may be as nearly as possible *precisely* "standard."

36 According to the practice of most Mints, the coins on being examined by the *pix* are reported to be "standard," if within certain limits either way. The precise deviation which is to be allowed is, I believe, left more or less to the discretion of the Assay Master, when this system is followed, but the ordinary and proper limits are such, that they leave the value of the delivery uncertain to a most material extent, amounting to very nearly 7 per mille. I here allude to the uncertainty which must exist, from the impossibility of judging according to such a system, as to the true value of the delivery, when it is not known whether it is all of the highest or of the lowest allowable fineness. It is not probable that it would ever be universally either one or the other, but when the distance between the two extremes is so great as that above stated; a difference, which in the coinage of a large Mint like that of Calcutta, amounting as it does sometimes to 3 crores per annum, would make it *possible* that the value of the delivery might vary upwards of 2 lacs of rupees, it would be vain to expect any thing like an exact appreciation of its out-turn, and hopeless to attempt to show its uniform consistency in value within such narrow limits as those marked by the changes of fineness occasioned by the use of acid in blanching the coins.

37 But that this may be done by a different system I shall proceed to explain; and it is remarkable, as well as fortunate that the difference in practice which is essential to success is so very trifling. All that is necessary is, that in regard to the assay of coins as well as ingots, the report should be made to tell the exact fineness to the nearest half pennyweight, like the assay report of bullion, according to some invariable plan. It is not very material what the system of report is, but it should be followed with the most undeviating uniformity; and if so, an application of the actual average of all the assays of the coins (the more numerous the better) to their weight, will show their true value with very great precision; and if in addition to this an uniform system of valuing the bullion received by the Mint be also rigidly adhered to, it is possible not only to make an exact valuation of the out-turn, but to show very distinctly even the compensation for the apparent difference of value occasioned by the loss of weight in blanching.

38 I shall first proceed to give an example of the method by which the whole out-turn of the Mint is valued, and then show how the comparison between that value and the value of the blanks before blanching clearly indicates the refinement by the process.

Let us suppose then that the out-turn of the Mint has been 40 lacs of rupee pieces, and that there have been 500 assays made of them, of which the results were reported to be as follows:

B 1	B $\frac{1}{2}$	Standard	W $\frac{1}{2}$	W 1.
5	40	320	135	0.

39 In order to find the exact value by means of the above scale, we must remember that, if such a case should occur, (though it never does in Madras) every piece varying a full pennyweight from "standard" is to be reckoned as equal to two varying only $\frac{1}{2}$ dwt. and therefore in striking the balance in the above example in order to find the average, we have to set off 50 on the better side, against 135 on the worse, and the case then stands.

B $\frac{1}{2}$	Standard	W $\frac{1}{2}$.
50	320	135.

Now by cancelling 50 on each side, and supposing that as the deviations of fineness compensate for one another (in value) they may be reckoned as "standard" coins, and joined with them accordingly; there remains a surplus of 85 W $\frac{1}{2}$ pieces out of the original 500, showing that $\frac{17}{100}$ ths of the whole delivery, or 17 per cent were a half pennyweight below "standard." Taking therefore $\frac{17}{100}$ ths of the 40 lacs of pieces, and reckoning the difference between the worth of these had they been full standard, and what they are worth when only of the fineness of W $\frac{1}{2}$ dwt, we find the deduction to be Rs. 1545 7 3 $\frac{1}{2}$ and subtracting this from the 40 lacs of rupees, the remaining true value of the whole delivery is 39,98,454 8 8 $\frac{1}{2}$.

40 The above process, simple as it is, furnishes an

exact measure of the value of the out-turn of the Mint, and I have reason to believe that the result may be depended upon to considerable nicety, spite of any accidental errors in the assays upon which it is founded, which if there be no systematic cause of inaccuracy, compensate one another. It also supplies a distinct criterion, whereby to judge of the conformity of the coins with the standard prescribed by law. This will be best illustrated by the last example. It was seen that in the imaginary case there stated 17 per cent were found to be $W \frac{1}{2}$ dwt., the rest being standard. This is the same, in effect, as if the whole 40 lacs were $\frac{17}{100}$ ths of half a pennyweight below standard. And therefore $W \frac{17}{100}$ th dwt. or about $W \frac{1}{11}$ dwt. represents the true deviation of the whole coinage.

41 The same result would be equally shown, were we to arrive at the fraction by comparing the deduction made for worseness with the gross weight, but we must remember in doing so that $\frac{17}{100}$ ths of a dwt. is $\frac{17}{100}$ ths of $\frac{1}{11}$ th, or $\frac{1}{1100}$ th of the whole value, which agrees with the proportion of $1545 \quad 7 \quad 3\frac{1}{2}$
 $40 \quad 00 \quad 000.$

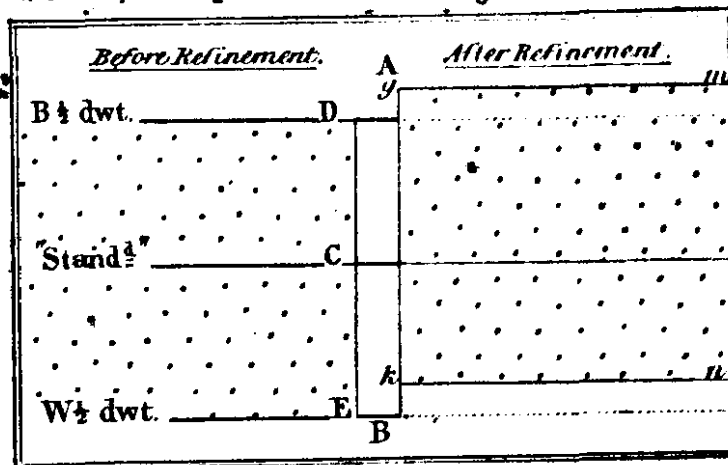
42 In order to make a strict comparison of the receipts and issues of a Mint it is absolutely necessary to calculate the value of the out-turn in this or some other equally exact manner. It is impossible to attain any thing like exactness, when the value of the out-turn is subject to an uncertainty so great, that in the transactions of a large Mint the true worth of the delivery might exceed or fall short of the nominal value assigned to it by a lac of rupees either way, in an extreme case, without its affecting the accounts. Even in the comparatively small operations of this Mint, the uncertainty might easily reach to 10 or 15,000 Rupees either way in a years transactions. And that system must be obviously incomplete, which at the same time that deviations in the gross weight of the out-turn are accounted for to the nearest *anna*, leaves thousands of rupees worth of value in the fineness wholly unregarded.

43 In order to understand clearly how the compensation for the loss of weight in blanching the coins is effected by the increased fineness, it is necessary to enter into some explanation. It might at first seem to be impossible, that a change of fineness which, in rupee pieces, does not probably exceed the $\frac{1}{11}$ th part of a pennyweight, could be shown by an assay which is unavoidably attended by some uncertainty in its results, and which consequently does not profess to mark changes of smaller amount than four or five times that magnitude; but if we take all the circumstances into consideration, we shall see that the difficulty is not so great as might be imagined, and we shall be able clearly to trace the mode of its solution.

44 Bullion passed into work is, in Madras, invariably such, as has been reported either "standard" or $W \frac{1}{2}$ dwt., but in consequence of the unavoidable uncertainties in the assay, above alluded to, it is by no means

sure what the exact fineness of metal reported under either denomination may be. To confine our view for the sake of perspicuity to one description only, the designation "standard" includes all finenesses of metal between $B \frac{1}{2}$ dwt. and $W \frac{1}{2}$ dwt., so that out of every thousand ingots reported of that fineness, many may be expected to be, or appear to be, very nearly $B \frac{1}{2}$ dwt. many very nearly $W \frac{1}{2}$ dwt. Now the effect of the acid, in removing a part of the copper, is to exalt the purity of the whole by a trifle, as above stated, about the $\frac{1}{11}$ th part of the $\frac{1}{2}$ dwt. and the result of the next examination of fineness by assay would be, that out of the whole thousand, all those whose apparent fineness had previously been any thing superior to $\frac{1}{11}$ ths of $\frac{1}{2}$ dwt. Br. would now be so raised in purity as to be reported $B \frac{1}{2}$ dwt; and this proportion of the whole would be more or less, the greater or less the actual refinement had been.

45 Perhaps this matter may be made more plain by reference to the subjoined diagram. Let A B be taken to represent a scale of the real fineness of metal, of which the point C represents the "standard" degree of purity, E the degree next below it, or $W \frac{1}{2}$ dwt. and D the next above, or $B \frac{1}{2}$ dwt. Let us suppose also that the numerous dots on the left hand side of A B represent the positions on this scale which a number of coins about to be blanching occupy, according to the fineness shown by assay as belonging to the metal from which they were cut. We must recollect that all which fall between D and E are reported "standard," but all which rise in the smallest degree above D, and from that to F, are reported $B \frac{1}{2}$ dwt. After the refinement which has been effected by the acid, the position of all the marks on the scale is raised as shown by the lines g m, k n, and by this means the whole of the marks which were highest on the scale, before the rise in their purity took place, are now above the mark D, and are therefore reported at the next higher fineness.



46 Just also as a part of those blanks which were previously reported "standard" are by the operation of the acid in the blanching raised to the fineness of $B \frac{1}{2}$ dwt. so are part of the rest, which were previously reported of the fineness $W \frac{1}{2}$ dwt. raised to the degree

"standard." These changes of course affect the average fineness of the whole mass of coins, and our experience shows that it does so to such an extent as to compensate for the loss of apparent weight; and the precision with which the effect of even small changes of fineness upon the value of large masses of coins may be shown by assaying, a process so uncertain in individual cases, may be considered very remarkable by those who have not been in the habit of viewing its results in this manner. By way of illustration, I shall here give an example taken from the actual practice of the Madras Mint.

47 During the 7th half yearly settlement viz. from Nov. 1844 to April 1845, the gross weight of the pieces passed into the cleaning (or blanching) room was 11,60,088 Tolas, and their real standard value, as calculated by rating those pieces only at full standard which were cut from standard ingots, and those at the fineness $W\frac{1}{2}$ dwt. which were cut from straps of that denomination, amounted to 11,59,481 Rs.—being 507 Rs. less. After the coins had been cleaned, the assays upon the six samples of all the finished coins were in accordance with the following abstract.

	$B\frac{1}{2}$	Stand.	$W\frac{1}{2}$
9,90,950 Single Rupees.	7	71	5
3,92,000 Quarter Rupees.	2	28	1
5,64,570 Double Annas.	6	63	2

48 Making the calculation in the manner before explained, it appears that the whole of these coins were on the average above standard; the Rupees to the extent of about $54\frac{1}{2}$ Rupees in value, the quarter Rupees by 7 Rupees, and the two anna pieces by 9 Rupees. Total of all three, $70\frac{1}{2}$ Rupees. It thus appears that the whole mass of coins, which before cleaning was 507 Rupees below standard in fineness, was after it 70 Rupees above, being an increase of 577 Rs. but the weight had been diminished by the process 483 tolas, so that the value of the $11\frac{1}{2}$ lacs of rupees worth of coins remained 11,59,675 Rs. being within less than 100 Rupees the same as before, rather more than a full compensation having taken place.

49 A difference even greater than this would not very materially affect the evidence which may be drawn from the above example as to the compensation which takes place in fineness for the loss of weight in cleaning coins, and I am of opinion that were the assays more numerous and the operations upon a larger scale, the accordance would be more close. I have only to add upon this part of the subject, that the experience of the Mint since 1841 fully confirms the view above taken, although in consequence of our having neglected to take into accurate consideration the effect of grease upon the blanks and scissel, the accordance cannot be so distinctly shown in the former as in the later settlements. In all however the effects of the refinement are abundantly plain, and in only one instance out of seven does it fall materially short of a full compensation, the difference in that case being occasion-

ed by a known cause, distinct from any circumstances affecting the question now under consideration.

50 I shall have occasion very shortly to state other facts which will make it evident that any trifling discrepancy, plus or minus, is of immaterial consequence in the accounts of a Mint. In the mean time I trust that it will be quite plain, both from the above reasoning, and from the experience which I have stated, that there is no cause for deficiency, even in the apparent waste attending the blanching of coins. It is necessary now to pass on, and show how the real waste, when it does take place in a Mint, is experienced; and how, in connection with the system of which a part has been above described, this source of deficiency may be obviated.

51 It has been already remarked, that when no means exist for the precise valuation of the out-turn of the Mint, it is impossible to secure an exact correspondence between its nominal and real value; and that by attention to mere weight alone, the most important element in the calculation is neglected. We have also seen, that throughout the whole of the processes there is none that necessary alters the value of the bullion, so that if the same be correctly calculated on receipt as well as issue, no material difference ought to be found. It might be sufficient therefore for a comparison of the Mint accounts, that the true bullion values of its receipts and issues should be taken; but something more is necessary if it be required, not merely that the department should fully acquit itself of the trust reposed in it, but that the State should suffer no loss. In order to effect this, it is essential that the true bullion worth of the coins should be closely adjusted to the "standard," and that their nominal and real values should be equal to one another; so that the Mint establishment should not, in consequence of the coins being finer than they ought to be, take credit for more than the State actually receives the benefit of.

52 This may be done with the utmost precision, according to the practice partly described above, and that with great simplicity. Nothing more is necessary than to attend to the results of the operation of cleaning, and the consequent out-turn of the finished coins, and to regulate the proportion of the different kinds of ingots passed into work accordingly. It has been above stated that only two kinds of ingots are ever taken from the melter, viz. "standard" and $W\frac{1}{2}$ dwt. and the reason of that will now be obvious. As the effect of the refinement in cleaning is to exalt the title of some of the pieces, it would necessarily follow that if no metal but that which was reported "standard" were taken, the out-turn would be composed of "standard" and $B\frac{1}{2}$ dwt. coins only, and consequently would, taking the average "en masse," be above "standard." In order to balance these there should be an equal number of pieces equally below "standard," that is $W\frac{1}{2}$ dwt. and it must be remembered that part of these also might be raised to the denomination "standard." All that is necessary, therefore, is to observe what relative proportion of these two

denominations will, after the various refinements occasioned by manipulation, yield about an equal number of $B\frac{1}{2}$ dwt. and $W\frac{1}{2}$ dwt. coins, and to take that proportion of "standard" and $W\frac{1}{2}$ dwt. ingots only from the melter, regulating his practice, as to the addition of alloy*, in such a manner that it shall uniformly turn out the proper ratio. As the process of assaying is more accurate in regard to finenesses near to "standard" than any other, and as the practice of the melting department is exclusively directed to the production of that, the prescribed quality of metal, it very rarely if ever happens, that the pieces exceed the $\frac{1}{2}$ dwt. either way, an accident which could only occur in consequence of an erroneous character having been attached to some of the ingots passed into work.

53 Indeed, if it be assumed that the assay reports are correctly made, it is evidently impossible that there can be any wide deviation in fineness at all; for as all the processes of manipulation tend to exalt the purity, and the only pieces varying from standard are those whose title is the *nearest* degree below it, it follows that all the changes which the latter undergo, tend to bring them nearer to perfection, and when the adjustment is made in the manner above pointed out, the result is in as close accordance with the "standard" as it is possible to be brought by any means, as long as the assay remedy, or limit of uncertainty, remains a $\frac{1}{2}$ dwt.† Thus the coins on being examined by the pix, show a large majority true "standard," and of the rest about an equal number above and below it; and the nominal and real values of the pieces correspond almost exactly. In this case, the compensation for the refinement and loss of weight in blanching is gained by the difference between the gross and standard weight of the ingots taken from the melter; for as part of them are of the fineness of $W\frac{1}{2}$ dwt, and the whole of the rest "standard," it follows that the gross weight of the pieces cut from them exceeds their true "standard" weight, at which last only the melter is credited, although he delivers without loss. On the final delivery by the Mint, however, the fineness of all the coins, on the average, has become true "standard," and therefore the standard weight has become equal to the gross; the difference which previously existed having been occasioned by the excess of copper which was removed by the acid,

* There is no danger whatever of the melter's going too far, or disobeying orders, for as explained in paras 10 and 23, no addition of alloy whatever could add to the *true value* of his deliveries; and as he is credited at that rate, and that only, his attempting to debase the metal would gain him no advantage, and on the contrary would lead to punishment for too great departure from "standard."

† Greater accuracy might be attained in coinage, and much benefit would ensue from the universal adoption in the Indian Mints of the decimal system of reporting the fineness of metal, that is reporting the "touch" as has long been practised in regard to gold. By referring to the division of the pound troy into pennyweights and half pennyweights the Assayer now reports to the $\frac{1}{16}$ th part, and it is intended that his reports should be uniformly accurate to that extent; but if a decimal notation were used, and the precise result were noted to the third place of decimals, or the $\frac{1}{1000}$ th part, it is not probable that the deviations would exceed their present magnitude, and the precision with which the duties of the Mint could be conducted, even admitting errors to exist to as great an extent as at present, would be much increased. But besides this reason, it is abundantly

an operation which occasioned an apparent loss, though the standard weight was unaltered.

54 Having now, as I trust clearly, shown that there is no real necessity for any material loss by the operations of coinage, and that consequently the out-turn ought to equal the receipt, I must proceed to notice an expression made in regard to the out-turn of the melting department, and to explain how it is that not only there ought to be no loss, but that even a real *surplus* of delivery, a net *excess* will be met with upon all the operations of the Mint. The cause of this is no doubt well known, but it is remarkable that no notice of it whatever is taken by the accounts of any Indian Mint that I am aware of. In fact, it is not to be expected that whilst the accounts of the department have usually recorded only a loss, much attention should have been paid to a circumstance which clearly pointed to an opposite result, however distinctly the fact of the existence of such a cause might be acknowledged. But I have little doubt that in every Mint, if the results of its operations be tested in the manner I propose, they will not only exhibit the truth of the proposition which I have advocated, but also prove the existence of a surplus hitherto unnoticed.

55 The cause of this unrecorded surplus is the difference between the "trade assay" and the real worth of bullion. It is the universal custom of all Assayers, inasmuch as it is impossible to obtain *perfection* in accuracy, to make their reports of the fineness of bullion to such a degree of minuteness only as they can be sure of. Just as, in the mere weighing of bodies, it is impossible to do more than to state the smallest fraction which the beam will indicate, leaving the minute remainder undefined; so in registering the fineness of an alloy, the final process of which is dependent upon the scale beam, the Assayer merely notes the smallest division which his beam will indicate truly, and the minute surplus remains untold; the universal rule being that the purchaser, that is the Government, and on its behalf the Mint, is allowed the benefit of it. It thus happens that on every occasion when bullion is assayed for delivery to the Mint, there is a trifling surplus, more or less, which is not carried to account and charged against it, and though upon each individual occasion it is quite impossible to say what the amount of this benefit is, be-

dantly desirable that something simpler than the complicated phraseology of ancient times should, in these days of enlightenment be introduced, were it only for the purpose of facilitating the labours of the Officers of Mint Committees, and in part clearing up the deep mist of obscurity in which all Mint questions are involved, and that chiefly by the use of these very terms of Assay. They were probably invented when the simple art of assaying was wrapped in profound mystery, and they certainly are well calculated to keep it so; but in the service of Government, and especially in this country, where every public Officer has too much real business to attend to, to have time to spare for mystical research, it is most desirable that as little needless obscurity should be allowed as possible. It really takes a great length of time to become thoroughly familiar with the terms $B\frac{1}{4}$ dwts. and $W\frac{3}{4}$ gr. so as at once to attach distinct meaning to them, but the corresponding terms of the decimal system viz. 97½ per cent of pure silver, and 75½ per cent of pure gold, are instantly and clearly intelligible to any one. It may therefore be easily perceived how great a stumbling block in the way of the comprehension of Mint papers would be at once removed, if the simple expedient of the decimal notation for assays were adopted.

cause it is owing to the very circumstance of the impossibility of stating this fractional excess with correctness, that it is omitted; still a very little consideration will prove, that in the long run of a vast number of such transactions the amount of gain arising from these indefinite fractions it is not only tangibly and actually realized, but is also capable of accurate calculation.

56 As I am aware that a good deal of difficulty has been occasionally felt in regard to this subject, more especially in distinctly understanding how it is possible that a correct calculation can be made of the sum of a series of fractions every one of which is doubtful, I subjoin some extracts from a memorandum written in explanation of the subject, which will I hope make it more clearly intelligible.

57 "The benefit by the assay remedy arises from the custom of reporting assays by $\frac{1}{4}$ dwts. only, and by never using a smaller weight. When the button which shows the proportion of pure silver in a bar is being weighed, as many $\frac{1}{4}$ dwts. are put into the scale as will almost, but not quite turn it, the excess of weight being always left on the side of the button, if there be any difference. If there be no difference, then there is no benefit, but as metal is assayed of every conceivable shade of fineness, and consequently the assay buttons are of an infinite variety of weights, intermediate between the stated divisions upon which the report is made, so there is in every case, excepting when it happens to fall *exactly* upon the precise $\frac{1}{4}$ dwt, a gain more or less, which is invariably given in favor of the Government. The amount of this gain is never ascertained, because it is not usual, and would take up too much time to put in fractional weights, and it would be useless to adopt the practice of doing so, because the process of cupellation is liable to errors which might cause variations, more or less in the fraction, and thus make its value when stated, incorrect. The fractional benefit is therefore always doubtful as to its precise value, but not so as to the fact of fractions in general being a decided and substantial benefit. If the merchant weighs goods by a scale which only turns with an ounce, and gives himself invariably the benefit of the turn of the scale, it is quite certain that in the long run he must gain, although the amount of gain in each transaction is quite uncertain.

58 "In assaying, it is impossible to say with certainty what the real benefit upon any one transaction is, because the errors in cupellation are so unavoidable that it is very probable that the particular button or buttons do *not* represent the ratio of pure silver in the bar exactly; but as there is no reason why those errors should make the buttons statedly either heavier or lighter, it is certain that in the long run, the heavy and light ones will be equally numerous; so that, as regards a large series, the accidental errors of cupellation will not affect the result, and the amount of benefit, as a whole, will be the same as if there had been no errors.

59 "But though the amount of the fraction in a single case cannot possibly be determined, that is no reason why the value of a very large series of them may not be determined with abundant precision. It is impossible to say how long any single man resident in London, of the age of 20 years will live, but the gross total of the years of life of any very large number, say 10,000 such men, may be calculated with the greatest precision, and why? Because we have the means of ascertaining the *average* age of each man with considerable exactness. I shall now be asked to explain, how I can obtain the average value of these uncertain fractions; I answer, by the well known rules of arithmetic and laws of chance.

60 "If a man throws a single die a vast number of times, the number of marks on the uppermost face of the die at any given throw, cannot possibly be foretold, but the total number of marks which will turn up in a million of throws, may be reckoned with certainty, thus. Since there is no reason whatever why any one face should be turned up, more than any other, it is certain, *in a very large series*, they will all do so about an equal number of times, and therefore, as the average number of marks on the six faces is $3\frac{1}{2}$, the total number thrown will be equal to $3\frac{1}{2}$ times; the number of throws. Again, if a million pebbles of every conceivable weight, between 1 lb. and 2 lbs be taken, although the actual weight of each individually may be unknown, the gross weight of the whole million may be calculated very nearly. For if the difference between the 1 lb. and 2 lbs. be supposed to be divided into tenths, it may be assumed with almost certainty that in a vast series, there will be about an equal proportion of the whole which will fall to each of these divisions; and therefore, as the average of all of them is $\frac{2}{10}$ ths, the average weight of all the pebbles would be $1\frac{1}{5}$ lbs; and the weight of the whole million, very nearly $1\frac{1}{5}$ million pounds.

61 "And so with regard to assays, if the difference between the dwt. and $\frac{1}{4}$ dwt. be supposed to be divided into 10 parts, it is probable that, in a very large series, the fractions of benefit will be equally numerous on all, and the average or mean value would therefore be $\frac{2}{10}$ ths or $\frac{1}{5}$ of $\frac{1}{4}$ dwt. that is $\frac{1}{20}$ dwt. which is equivalent to $1\frac{1}{2}$ per mille: but as, according to what is stated above, there are a certain number of cases in which, the weight of the button may be *exactly* the $\frac{1}{4}$ dwt, in which case no benefit is gained, a deduction has to be made from the above result to allow for them, and this deduction can only be learnt by experience, because it depends chiefly on the delicacy of the beam used by the assayer, and his personal habit in weighing. But it has been stated by the Officers of the Royal Mint,* that the average benefit is about $\frac{2}{10}$ ths of the complete fraction, thus making $\frac{1}{10}$ th the deduction for *exact* buttons; and if that ratio be assumed in this case, the result of the benefit of all the fractions would be $\frac{2}{10}$ ths of the $\frac{1}{4}$ dwt; and since the benefit of the full $\frac{1}{4}$ dwt. is 2. 27 per mille,

* Vide Mr. Beckwith's evidence before the Select Committee on the Royal Mint, Art. 788.

$\frac{2}{11}$ ths of that would be somewhat less than 1 per mille.

62 From this, I fear rather tedious investigation, it appears, that the average surplus which ought to be realized in every Mint which receives bullion debited against it at the "trade assay" ought to amount to nearly one rupee in every thousand. The experience of the Madras Mint has been quite in accordance with this expectation. We have not, however, always had a surplus so large; and in the course of 7 settlements, we on one occasion had none at all, being a few rupees (about 70) deficient; but circumstances occurred, which were well known at the time, to cause these results to be less favorable, and fully accounted for them in a manner which in no way interferes with the truth of the proposition advanced in this paper; and as it would be inexpedient to enter into a discussion of them in this place, I shall merely say that they have been such as are but seldom likely to be met with in most Mints, and that even spite of them, the gross results of the coinage of this Mint, since the commencement of the system in 1841, have given what will, I trust, be considered sufficient evidence of the truth of my arguments to entitle them to confidence; the net excess upon the coinage of 115 lacs of value, having been, when every thing is fairly calculated, rather more than 7000 Rupees, being at the rate of $\frac{2}{11}$ ths per mille.

63 The above statement shows the actual balance taken upon the whole coinage since August 1841, but if shorter periods only were examined, the comparative excess, would in some, be much greater. It is, however, not unreasonable to infer, that if all the processes of manipulation be conducted in a strictly uniform manner, and the valuation assigned to the bullion be equally so, its net produce or out-turn, would not be otherwise; and it might therefore be expected to be uniformly as favorable as we have experienced it to be in the best settlement; and I have been led to the conclusion, from the facts and reasoning above given, as well as from the improved regularity and increased produce of our later settlements, that a surplus of one per mille may be reasonably calculated upon in every Mint; an expectation, which will appear to be less unreasonable, when I remind the reader of the fact stated in evidence before the Committee of the House of Commons, that the gain arising from the same fractional difference between the "trade assay," and real value, in the coinage of gold in the Royal Mint, had actually amounted in 15 years to no less than 5 lacs of rupees,* or upwards of 33000 Rupees per annum.

64 It will be seen by what has been before stated, that the chief points essential to success in the adjustment of the accounts of the Mint, are, 1st to take care that in the valuation of bullion received, the true weight of *solid metal* actually handed over be charged for, and nothing more; 2dly that in the out-turn of pieces, the precise value of all the deliveries be ascer-

tained, by the average of as large a number of assays of six coins as possible; and 3dly that this value be made to correspond closely with the standard and nominal rate of the pieces, by the method of adjustment described in para 52. If this be done, it is not only true that there ought to be no waste or difference between the receipts and out-turn†, but as long as the unreported fractions in assay are thrown into the scale in favor of the Government, an excess ought to be exhibited, which may be estimated at nearly one per mille. A surplus which alone would amount in the transactions of all the Indian Mints, to between 30 and 40 thousand rupees per annum.

65 But the chief use which I think may be derived from the principle which I have endeavoured to establish, is the assistance which it is in its power to render towards the establishment of a simple and efficient system of check and controul over the executive operations of the Mint. Thus, in regard to the melter's accounts, when the attention is exclusively directed to the differences of *weight* only, which the metal undergoes by that process, the whole responsibility of the custody of the metal, must be necessarily dependent upon the vigilance of the watchmen who superintend the operations, and the honesty of the parties engaged in it; because it is impossible to distinguish between any deficiency which may be caused by fraud or speculation, and the uncertain, but unavoidable loss (of weight) which is the result of fusion; whereas, by referring to the simple fact that the real value of metal is not changed by the fire, and that consequently, the value of the out-turn in ingots must necessarily be equal to that of the bullion melted, the check is so certain and secure, that all the expense, trouble, and responsibility of watching the proceedings of the department, may with perfect safety be dispensed with. In Madras, the head melter gives security for the safe custody of the bullion entrusted to him, and with that precaution he cannot go wrong; for unless it were possible that there could be collusion with the Assay department, any attempt at fraud must instantly be detected. I may here mention, that he is not only expected to return the full value debited against him, but also that of the unreported fractions, alluded to in para 21.

66 And in the same manner that perfect security may be obtained by the Mint Master as to the proceedings of the melting department, without the necessity of a constant dependence upon the unrelaxing vigilance of his Superintendents, and the honesty of his workmen, so may the Officers of Government keep a strict and perfectly secure check over the operations of the whole Mint, without the smallest reference to the tedious and elaborate details which, for want of a simpler system, it is necessary to lay before them. Details, many of which are so intricate and obscure, that nothing but a long apprenticeship and familiarity with such subjects can render them intelligible. If it be once established that the out-turn of a Mint ought

* Vide Report of the Select Committee on the Royal Mint, Art. 1892.

† It deserves to be noticed, that suggestions were given by Mr. Prinsep with the view "to provide against any undue wastage, and yet to preserve the coin of full weight on its issue from the Mint." But these suggestions, from not asserting the principle now brought forward, did not extend to the root of the evil; and the consequence, I believe, is that they have not been successfully carried out in practice.

to be equal to its receipts, the whole mass of these details may be set aside for the single comparison between the receipt and out-turn.* I trust that I have succeeded in making it apparent that not only this is the case, but that even more than this may be depended upon; and it is merely necessary to add, that the only circumstances which I am aware of, as likely to cause the least fluctuation in the amount of the fractional surplus which may be looked for, are the chance of errors in assaying, or the failure on the part of the assayer to allow all the benefits which are calculated upon.

67 It might be a question whether the fractional gain above alluded to ought to be taken advantage of by the Government; but perhaps when it is understood that it is the universal and well known privilege of the purchaser in all countries, the question is not likely to be raised.† If, however, it be conceded that the Government rightly has this advantage, the fact of its possessing it, offers a strong argument in favor of the merchants being released from the charges incurred in melting their bullion, which I believe they are called upon to pay in some Mints; and the rule for the adoption of that most necessary, and in fact indispensable preliminary to any thing like a strict system of check in the Mint, might be made universal and imperative.

68 I have throughout this paper made no allusion to one, and I really believe the only one real cause of waste in Mints, worth speaking of, and that is speculation, and I have omitted it for obvious reasons; It does not come under the head of those causes of waste which are "unavoidable," but it is nevertheless serious, and requires much attention and care on the part of the executive Officers of the establishment. My object has been, rather to pave the way for the establishment of a system of check, by which the real losses by fraud and speculation might at last be discernible, and to view the subject in the light of the relation between Government and the Mint establishment, than to consider the duties of the Mint Officers in relation to their subordinates.

69 Few subjects require more constant attention than that of guarding against frauds and speculation, and there is hardly any one of the arrangements of the

department which it is more difficult to place on a satisfactory footing, than the measures which are necessary to keep up an unintermitting and secure check against these evils, owing to the great apathy, indifference, and dishonesty of the agents who must necessarily be employed in the service. The system to which I have been gradually endeavouring to bring matters since I have been in charge of the Madras Mint, has been that of the separation of the different working departments into distinct wards, completely enclosed on all sides, and with but one entrance. A gollah or watchman is stationed at this opening, whose duty it is to examine all who pass in and out of the ward, and he is accountable to the Superintendent of that department for the performance of the duty. Each Superintendent is separately responsible for the bullion received and delivered by his ward, so that he is in the general way accountable for the accuracy with which the search is carried on.

70 As a check upon the watchmen of the different departments, and for the security of the whole establishment, great pains are taken in the search of workmen at the great gate, or general entrance. The operation of search is twice gone through, the first time by servants of the establishment, who are promised a reward for each discovery, and threatened with dismissal in case of their passing over an attempted theft; and the second search is by expectant "oomeidwars," who are stimulated not only by the promise of the same reward as is held out to the other searchers, but also by the chance of succeeding to their situations, in case of the established servants being discharged for neglect.

71 Should any piece of bullion be discovered at the great gate, the watchman of the department to which the man upon whom it was detected belonged, would of course be accountable for having allowed him to pass, but no such case has yet occurred; the department gollahs have once or twice detected an attempt to secrete an old coin, but no piece of bullion or new coin has ever got as far as the great gate during my time. Other small coins have been frequently brought into the premises by ignorant parties, spite of the prohibition posted up on the outer wall against it, and these have been very often detected on their going out again,

* I hope it will not be supposed, that I would in the least degree advocate the details above mentioned being unattended to. The apparent wastages, as well as every incident peculiar to the manipulation of the bullion, must always be interesting to, and matter of the closest scrutiny by the proper Officer, the Mint Master; but I am decidedly of opinion that these matters are not only a burthensome tax upon the patience and attention of the Officers of Government, but that they absolutely frustrate the very object they are intended to bring about, by diverting enquiry from the points of real importance, and fixing it upon others which are of no moment at all, and the information regarding which is necessarily so

† There are reasons which make it desirable that the fractional gain should be given in the coins, either in whole or in part, and that the latter should in fact be somewhat above "standard;" and whenever the management and practice of the Indian Mints shall be reduced to an uniform system, a measure very desirable, but requiring much care, it will be a question for discussion whether it ought not to be a matter of regulation that it should be so; the duty of the Mints at present being, of course, to adhere as closely as possible to the prescribed standard. But even if this were done to the full extent, although the Government would thereby sacrifice the trifling benefit which they would otherwise derive from the fractional excess, there would be no alteration as to the distinctness of its exhibition by the Mint accounts; for the debit and credit in the Mint books being regulated by the true value of the receipts and deliveries, could not be affected by the proportion of silver put into the coins; and if the latter were issued of a somewhat finer quality than "standard," they would be charged in the Mint books at a rate somewhat above their nominal value, and a difference equal to the value of the unreported fractions, or such part of them as had been given in the coins, would exist between the credit allowed to the Mint by Government, and the nominal value of coins received from it.

incomplete, that the data given cease to be of any use whatever. For instance, while the apparent wastages in each room may be most closely scrutinised from time to time, and the accounts compared with one another and found to agree, they might nevertheless be altogether inaccurate and delusive, and afford no clue whatever to the proceedings of the department; trifling and unobserved alterations having been made in the manipulation, which without intending it, might have materially affected the results; changes such as are now referred to are constantly apt to take place from a variety of circumstances, and their influence can not be foreseen by any one, and must be wholly unknown to the Officers of Government.

but I do not recollect any thing worse having been ever brought to my notice; and as the general out-turn of the Mint is such, as to prove that there cannot be any very considerable loss in that way, I am inclined to hope that the difficulties of effecting the concealment, during a threefold examination, may be so great, and the punishment attending a discovery so alarming, as to have discouraged the attempts altogether.

72 I cannot conclude without stating one general principle which may be useful as a key to the consideration of all questions as to a real and apparent "waste." It is this; whatever the process may be which is suspected of being the cause of waste, one of two things must be true regarding it. Either it removes silver from the metal or coins, or it does not do so. If the

latter, then there is clearly no change or diminution of real value, as I have explained above. If the former, then the silver may be sought for and recovered from the refuse. When this truth is attentively considered, it cannot I think fail to be perceived, that no such thing as waste, unaccounted for, ought to exist, or to be suffered in any Mint; a proposition, the truth of which it has been my object to demonstrate by the facts and reasoning contained in this paper; and however feeble and imperfect my attempt may have proved to be, I trust that I may at least succeed in attracting attention to it, and that I may venture to look with full assurance for the confirmation and establishment of my views, by the researches of others better able than myself to do justice to the subject. J. T. S. 8th July 1845.

FAILURE OF A BRIDGE—The following extracts from a private letter from Captain Green, giving an account of the disastrous fall of a bridge of 70 feet span executed under his orders, an accident which was attended with a loss of the lives of 49 men, and the wounding of 21 more, will afford an example of the great difficulties and disadvantage under which Engineer Officers sometimes labour, in the management of public works at a distance from themselves, owing to the ignorance, carelessness, and indomitable conceit of the agents in whose hands they are compelled to trust the execution of their orders.—ED.

"The abstract of the case is this. Three years ago, I proposed to bridge a nullah near Mundium with an arch of 60 feet, and rise from spring to crown of 18 feet. One haunch was raised 4 feet, the other 2½, when a flood occurred and carried away the centring bodily. I raised the lower haunch to the height of the other, and left the work until after the monsoon. I was absent in Canara under the orders of the Madras Government, and had not seen and could not see what my people were doing. Matters were therefore suspended until I could take a personal share in them. On my return from the low country I saw and approved of the haunches, and all that had been done. Immediately after the monsoon, I got an order from the Governor General to make a very detailed report upon the Maunzerabad Ghaut, for the information of his Lordship in Council, and the Court of Directors. I went and contracted fever, and was obliged to go away on sick certificate to the Neilgherry hills. In the mean time the arch was turned, and so very slowly, that including the time occupied before the monsoon in raising the haunches 4 feet high, it was not keyed under 78 days. I had got no wedges to it, the centring being the common native one, and the monsoon, by the time it was keyed, was approaching; under these circumstances, I got Lieutenant Horsley's and Captain Bell's reports on uncentering the large arches they had made, and referred the question to Colonel Sim, whether I might not abridge the period of drying, after keying, which I had originally ordered, viz. 2 months; he wrote back, that considering the drying the bulk of the arch had experienced while under construction, the centring might safely be removed one month after keying, accordingly I issued, under certain specified conditions, an order to that effect to the surveyor. Major Pears having in the mean time examined the arch, and written me that

it was apparently quite dry enough, and on the whole a good piece of brick work. An order to the Amildar, and to the maistry, was inclosed in that of the Surveyor, which he was to give to them when from personal examination he was prepared to proceed with the uncentering. Notwithstanding this permission to proceed with the uncentering, he kept it up for 2 months after keying, and even then would not have taken it down, had I not sent a peremptory order to that effect, which I did on hearing that a fresh had carried away the side posts, and dismantled the centring 15 feet from the spring on each side, measured along the curve. The arch only being thus supported by the crown, and cracks appearing above the haunches where the curve of the ellipse begins to quicken. The instructions for uncentering were carefully followed out, the cracks closed, and the arch struck me on my way down from Ootacamund, as a good job.

The Surveyor and Maistry appeared to me to act with remarkable caution, and some degree of skill, and on meeting with a nullah 2 years after, of 70 feet wide, the idea of spanning it with a 70 feet arch immediately occurred to me. However I determined to have an adequate semi-conjugate axis, and therefore allowed one third of the span.

The 70 feet arch was turned in 23 days, rather sharper work than before, and twice was the Surveyor ordered to leave the centring up for 2 months, and twice was the same order written to the Maistry. The centring rested on 27 pairs of wedges 3 feet long, and these were ordered to be driven in 3 inches after keying, however, they would not move. Colonel Underwood told me the same things happened to his centring for the Adyaur bridge:

One month after keying, I ordered the Maistry to make a

passage through the stuffing, wide enough to let him get in under the crown, and examine how far the drying had proceeded. He reported that the opening half a yard wide had been commenced but that it was too damp to be proceeded with. He had not therefore bored it right through from one side to the other. I was about 200 miles off by the tappal route, and the day this report reached me, the arch had been thrown down into the bed of the river!

The explanation of this transaction is this, that the Surveyor was applied to by * * * to know what instructions Captain Green had given him regarding the centring, his reply was given in these words "I heard nothing particular from Captain Green about removing the centring of the arch, more than to examine the state of dryness of the arch, and to report the same to him. But as I consider any time after the expiration of a month is sufficient guarantee to operate with the withdrawing of the centring, I consequently purpose to do so on the 20th, or within the end of the month, if there be no fall of rain within that date. The last 2 days have been cloudy and threatening, and there is every probability of getting rain shortly." The foregoing was dated on the 15th, on the night of which rain fell very heavily upon the arch, and again on the following day. " * * * instead of seizing upon the fellow as a mad man who had avowed his intention of acting upon his own judgment in this important matter, or at all events sending off to him a caution to take care he did nothing without instructions, wrote as follows to the Surveyor. I am sure you may take down the centring (!) 35 days drying, such weather as we have had, must be enough for any arch."

They accordingly set to work to uncentre on the 22d March, and did it so hurriedly, unequally, and unskilfully, that the equilibrium was destroyed and the arch ruptured. It was a beautiful piece of work, the materials admirable, and extremely well put together.

Upon going to look at it, I found the haunches about 8 feet high uninjured. They had removed the stuffing from nearly every part but that from which it should have been first taken, viz.

under the crown, where they left it! They also pulled down the centring posts from both sides, but not from the middle. The arch was allowed to sink every where except at the crown. Notwithstanding this insane proceeding, the arch did not collapse until late at night. It was right good stuff to stand such unfair treatment so long, for 70 men were at it all day, and not a crack was to be seen up to the last moment." 13th May 1845.

Extract from a letter to Captain Green from the Secretary to the Mysore Commission.

"After an attentive consideration of the whole subject, the Commissioner observes that no precaution would seem to have been omitted by you to ensure the complete success of the undertaking; while your comprehensive and frequent instructions to the Assistant Surveyor and the Maistry entrusted with it appear to him to have embraced every point, and provided for every contingency."

"The supply of materials and workmen by the superintendent was timely, abundant, and good, and had the Assistant Surveyor persevered to the end with the commendable attention and conformity to your orders, with which he entered upon and continued in the work up to the period of the completion of the arch, instead of allowing himself to be led astray from those orders by a false and overweening estimate of own his abilities, the Commissioner has not a doubt that the work would have been completed, as successfully, as creditably to all parties concerned in the design and execution of it."

"When called upon for his defence Mr. K. has not only utterly failed to vindicate his own conduct, but he has made a discreditable attempt to implicate others in the destruction of the work, which was solely occasioned by his own incapacity and rash disregard of orders; an act which has involved the sacrifice of many human lives which ought of itself to prove a source of bitter reflection to Mr. K. as the fruits of his disobedience."

CORRESPONDENCE AND JOURNALS CONNECTED WITH THE OPERATIONS OF
THE ARMY IN SCINDE FROM 1840 TO 1844.—BY (CAPTAIN) MAJOR R. HENDERSON,
ENGINEERS; *Honorary Aid-De-Camp to the Governor General.*

To
The Adjutant,

Madras Sappers and Miners.

BANGALORE.

SIR,

I have the honor to report for the information of the Officer Commanding the Corps, that the detail of my company as per margin, were present under my command in the action which took place on the 17th instant, near the village of Katree, where the force under the personal Command of Major General Sir C. Napier was advancing upon Hyderabad.

2. Lieutenants
1. A. Apothecary
2. Corporals
2. J-madars
2. Havildars
3. Nalgues
48. Privates
1. Bugler

We left our encampment near the town of Mitaree at 6. A. M. of the 17th instant. In the column of route, the place assigned to us was at the head of a working party, consisting of my men and 100 Infantry of the line, in front of the advance guard. We had to make a practicable road for Artillery across several irrigation canals, when having proceeded to a village distant from Mitaree about 6 miles, we became aware that the enemy were near and intended to oppose our progress. The whole of the working party and advanced guard, including two guns, were immediately thrown forward, the guns being in the centre occupying the village, and the Infantry extending to the right and left. The position of my detail was on the right where we lined a portion of a bank close to the dry bed of the river Foolaylee, on the other side of which was a thick forest or Shikargah. The main body was immediately halted, and the General proceeded in advance with a Regiment of Irregular Horse, for the purpose of discovering the enemy and reconnoitering his position.

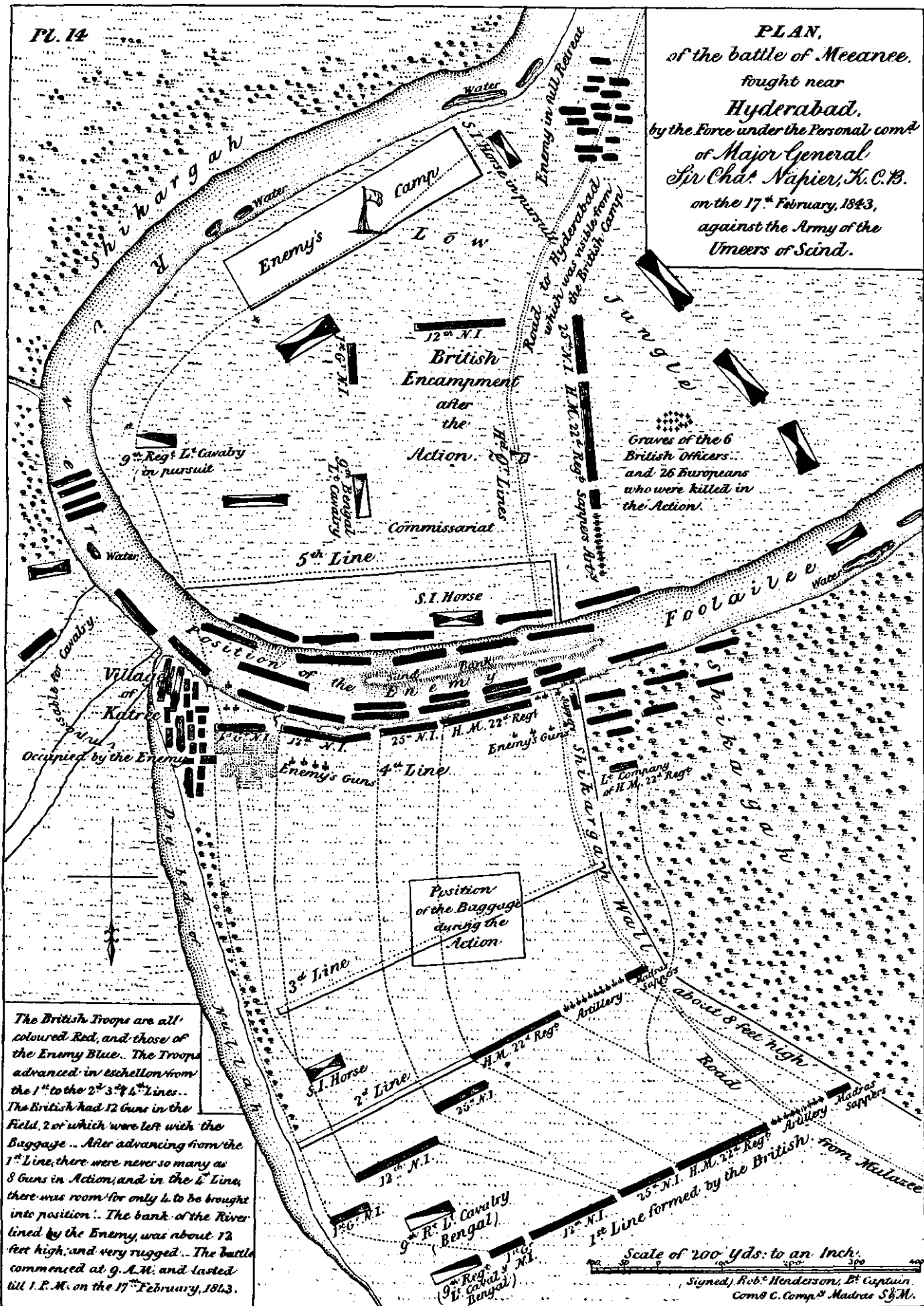
We had not been long in this position when we heard the sound of the enemy's guns, who had opened their fire upon the Irregular Horse, and shortly afterwards an order was brought for the Infantry of the working party to join their respective Regiments, and for the Sappers to remain with the Artillery, which was ordered to advance. The road lay along the bank of the river Foolaylee, and the services of the Sappers were required several times to enable the guns, especially those of the Camel Battery to pass, at last the whole of the Artillery consisting of one horse and mule, and one Camel Battery, were brought into position. The Sap-

pers were posted on the right of the Artillery at the extremity of the line. The Infantry were formed in line on the left of the Artillery and about 30 paces in rear, when the action commenced on our side by a cannonade of round shot from our guns, at a distance about 1000 or 1100 yards from the enemy's position. I should here mention that whilst our troops were being brought into position, the enemy kept up a fire upon us from two points, which proved to be the right and left of their position.

After a few rounds from each gun, the whole line advanced for about 300 yards, when the Artillery again opened, and after this, skirmishers were thrown out and the whole advanced to a third position about 300 yards in advance, when the guns were again brought into action with canister and shrapnell. The next advance was that of the whole line to the bank of the dry bed of the river Foolaylee, where the enemy were in great force, and a desperate conflict ensued.

The enemy having fired a volley with their matchlocks, threw them down, and with sword and shield rushed up the bank, under which they had hitherto been concealed, and penetrated into the ranks of the Infantry, where they were slaughtered. For some time the issue of the contest appeared to be very doubtful, as the men who advanced fought with desperation, and were evidently the flower of the enemy's army, and resolved not to give way; but they could not stand against the murderous fire of British musquetry, and at last they fell in heaps, while those that took to flight were pursued by the Cavalry, which now crossed the river near the village of Katree. Whilst this was going on towards the left, the Sappers assisted in getting the guns into position in the broken ground on the right, in which direction the enemy were rushing into the Shikargah, with the intention of availing themselves of its cover to turn our position, and many of them approached so close under cover of the wall as to annoy the Artillery greatly. Some of the gunners were shot at their guns, who were on the left of the Artillery. Those of the Sappers who were armed, immediately fired over the wall at the enemy, and those with working tools commenced destroying the top of the wall in order to get a better fire over it. This had the desired effect, and the Artillery no longer annoyed by the enemy's matchlocks, poured such a destructive fire in the direction of the Shikargah, that the enemy abandoned their intention and the rout was now complete. They fled in all directions, pursued by our Cavalry; every gun they had

PLAN,
of the battle of Meeranee,
fought near
Hyderabad,
by the Force under the Personal command
of Major General
Sir Chas. Napier, K. C. B.
on the 17th February, 1843,
against the Army of the
Umeeers of Scind.



The British Troops are all coloured Red, and those of the Enemy Blue. The Troops advanced in echelon from the 1st to the 2nd 3rd 4th 5th Lines. The British had 12 Guns in the Field, 2 of which were left with the Buggage. After advancing from the 1st Line, there were never so many as 8 Guns in Action, and in the 4th Line there was room for only 4 to be brought into position. The bank of the River lined by the Enemy, was about 12 feet high, and very rugged. The battle commenced at 9 A.M. and lasted till 1 P.M. on the 17th February, 1843.

was taken, their ammunition was left on the field, their camp was left standing, and in it was found their treasure, stores, and other valuable property, the whole of which fell into our hands. The Infantry crossed the river and the Artillery followed, taking up position No. 5 on the south bank, and the guns again opened on the right upon a large body of the enemy's horse, who made their appearance in that direction, but after a few rounds they all moved off. The firing now ceased, the day was ours, the Cavalry returned from the pursuit, our baggage was brought up in the rear, and we pitched our camp close to the spot where the enemy had left their tents.

After the battle was over, our men were still kept employed, as we were ordered to destroy the enemy's ammunition and gun carriages, which we effected in the bed of the river Foolaylee.

The number of the enemy is calculated at 21,000 men, at the least, and they had 14 pieces of artillery which fell into our hands. We halted on the 18th in our camp close to the scene of action, on which day the Meers delivered themselves up to Sir C. Napier. On the 19th we arrived at Hyderabad, where the army collected 10 more guns, besides large quantities of grain and other property.

On the 21st British colours were hoisted on the highest tower of the Fort of Hyderabad, and all public property inside was seized, including treasure, stores, jewels, arms and from 80 to 90 guns of all calibres.

It affords me great pleasure to record and lay before the Officer Commanding the Corps the valuable assistance I received from Lieutenant Outlaw, and 2d Lieutenant Boileau, attached to the company who were present with the men during the whole of the day, encouraging them by their own personal example in whatever service was required to be performed. The men behaved with great gallantry, and performed with great endurance the arduous services they were called upon to perform during the long and eventful day. The Officer Commanding will observe, that most of my men were called upon to take part in a most severe action without arms to defend themselves, as they merely carried their working tools. I would also beg to remark that the bayonet-knife at the end of the Fuzil, with which the men were partially armed, appears to be a most inefficient weapon, if not a great incumbrance, as it was found almost impossible to make it penetrate through the clothes generally worn by the enemy opposed to us.

I beg to annex an extract from a memorandum prepared at the desire of Major General Sir C. J. Napier, of the manner in which I became possessed of one of the enemy's standards. Having recovered the flag and other ornaments, I beg permission from the Officer Commanding to present it to the Head Quarters of the Corps, and take the opportunity of recommending to his notice Jemadar Tonderoyen as an excellent Officer and well deserving of promotion.

The accompanying sketch will show the nature of

the country where the battle was fought, and serve to illustrate the foregoing remarks.

I have the honor to be,

Sir,

Your most obedient servant,

ROB. HENDERSON, BT. CAPT.

FORT HYDERABAD. } Commanding C. Company,
25th February, 1843. } Sappers and Miners.

To

The Adjutant,

Madras Sappers and Miners

BANGALORE.

SIR,

1 Agreeably to my letter of the 11th Instant, I have the honor to forward for the information of the Officer commanding the Corps, the following particulars of the employment of the company under my command, connected with the action of the 24th ultimo, when Meer Shere Muhammud's force was completely routed by the force under the personal command of Major General Sir Charles Napier K. C. B.

2 On the 22d of March a portion of my company was ordered out to cut down the bank of the river Foolaylee on the Hyderabad side, so as to form an easy descent for Artillery. On the evening of the 23d we formed part of a force consisting, besides of two Regiments of Native Infantry, and a heavy battery of two 8 inch Howitzers, who were sent forward to take possession of the portion of the bank of the river which we had already prepared, and we remained there during the night. Early in the morning of the 24th this advanced force crossed the river, and we had scarcely formed on the opposite side, when Major General Sir Charles Napier appeared at the head of the main body and re-versed, which had marched out from the Camp at Hyderabad, the whole force then advanced in order of battle; my Company being at the head of the advance Guard to cut down the banks of nullahs and make the road passable for Artillery. We had proceeded about 3 miles, when the General discovered that the enemy were in position, and moved toward them with the Scinde Irregular Horse. Shortly after this, the enemy opened their fire of Artillery, and the main body was ordered to follow in column the direction taken by the General. The enemy's cannonade continued during our advance, and the British line took up its first position at about 1200 yards from the enemy (as shewn in the accompanying plan) and within range of their Artillery. Here a bold reconnaissance of the enemy's position was undertaken by Major Waddington Commanding Engineer, who rode along their whole front at a distance of about 300 yards. During the advance I received orders to make a slight detour from the column, in order to make a nullah passable for the heavy Battery, and as it was found that considerable assistance was necessary to bring these guns into action, and great expectations were formed as to their effect upon the enemy, we

remained attached to them. At the request of the Officer commanding the Artillery (Major Lloyd) I ordered the company to form sub-divisions, one to each gun, and thus we were enabled not only to give assistance when the Battery was advancing, but also in limbering and unlimbering in action, this operation being a very heavy one, and not easily performed by the European gunners of the Battery.

3 When the troops had formed in the first position, our Artillery opened upon the enemy; but as the effect of the shells from the 8 inch Howitzers did not at that distance equal the expectations of the General, he ordered the line to advance about 500 yards to the second position. The enemy keeping up a smart fire of Artillery from 11 guns during the whole time.

4 From the second line a heavy cannonade was opened from each of our Batteries, which continued for about an hour. Several of the enemy's tumbrils of ammunition were exploded by our shells, and in one of these explosions the dismembered remains of those who suffered were plainly discernible. Shortly after this there was an evident commotion amongst the enemy, and a movement towards their right. The General now gave the order for the Infantry to advance. This was done in the most gallant style, and as the line moved by Echelon of Regiments from the left, H. M.'s 22nd was the first to close with the enemy, who were now found to occupy one of the strongest positions that it was possible for an army to take up; viz. a double canal running along their front, each canal being from 30 to 40 feet wide at top, and provided with an embankment on each side—forming in fact a front of two deep ditches and 4 parapets, the ditch and parapet together in many places exceeding 25 feet in height. Besides these, there were other similar canals running on their rear and on their left, whilst their right rested on the village of Nareejah, the exterior walls of which were pierced with loopholes, and in the vicinity were several breastworks newly thrown up.

5 The gallant 22nd Regiment advanced against the most formidable opposition in the most steady and determined manner. As soon as they were within range, the enemy opened a matchlock fire upon them from behind their intrenchments, which much resembled the roll of British musketry. The Regiment suffered under it but advanced steadily, reserving their fire according to orders, till within 40 paces when they poured in a volley, and ascending the first embankment continued their exterminating fire, till they were enabled to surmount the formidable obstacles opposed to them, and then wheeling their right shoulders forward drove the enemy before them.

6 Meanwhile the 25th and 21st Regiments of Bombay N. I. were advancing in the most gallant manner under similar opposition, though in a less degree, and forming on the Right of H. M.'s 22nd Regiment, these three regiments drove the enemy back into the village, where they were exposed to a heavy fire from the Horse

Artillery, which had by this time dashed forward under matchlock fire and brought their guns into position on the top of the first embankment. At last the enemy were obliged to quit the village, when they were pursued by the Cavalry, which completed the route at the right of the enemy's line.

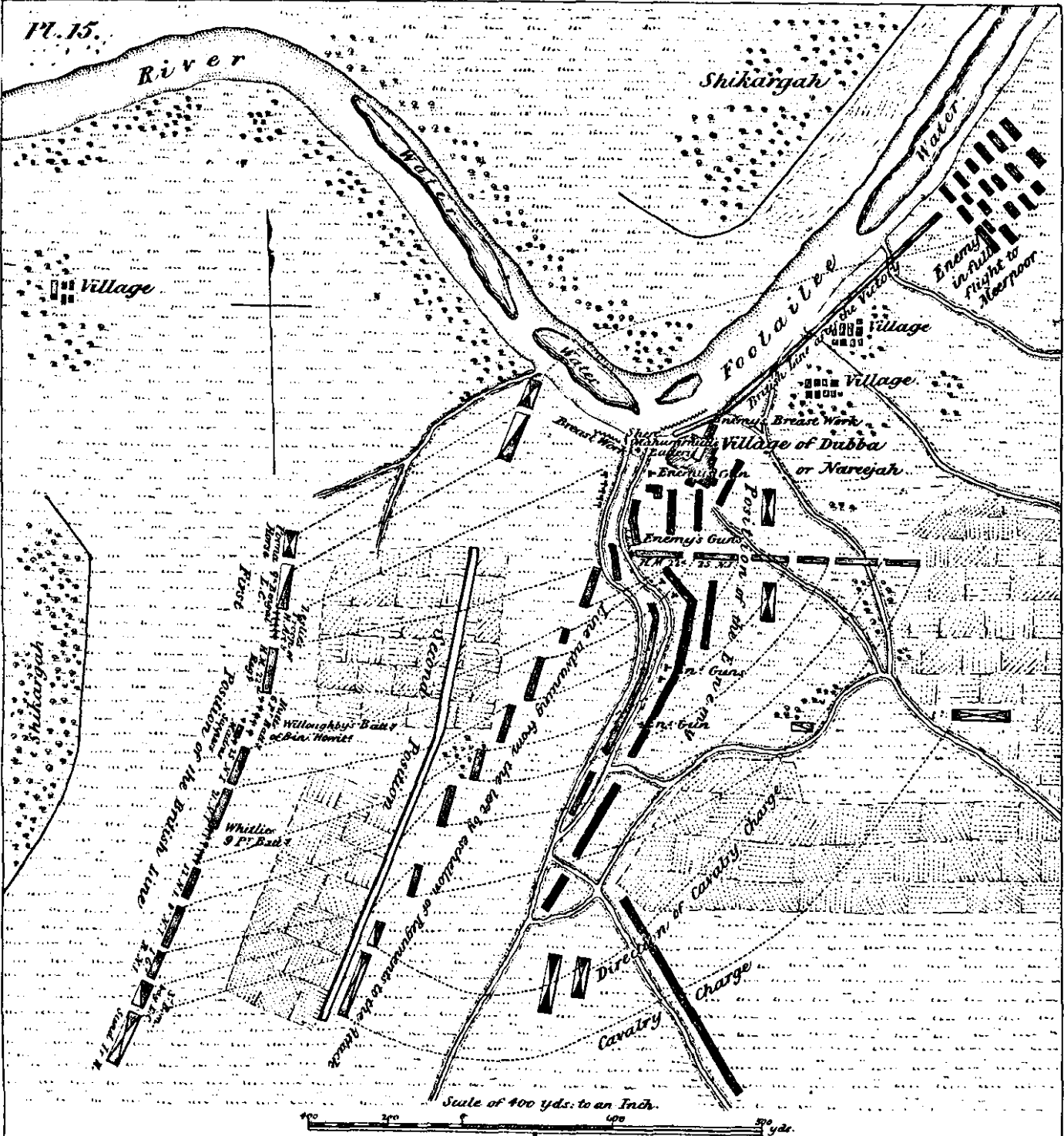
7 Whilst this was going on towards our left, the right of our line was also actively engaged. When the commotion and movement of the enemy towards their right, alluded to in the 4th para, was perceived, and while the Infantry was advancing, it was discovered that some of the enemy had taken to flight towards their left. The 3rd Bombay Light Cavalry and Scinde Horse immediately charged in the most gallant manner, and many of the fugitives fell under the sabres of these distinguished Regiments.

8 The other 3 Regiments of Native Infantry (12th, 8th and 1st Grenadiers) continued their advance and crossed the canals as they came up, but our Cavalry being amongst the enemy in their front, they were soon compelled to cease firing. Opposition now soon ceased. The field was our own—and the whole force, after the victory, formed line along the bank of the Foolaylee, as shewn in the plan. The last operation of the day was to encamp on the ground in front of the enemy's position, the front of our camp being nearly in the same line as the 2nd position of the British force.

9 With regard to my company; after the Infantry was ordered to advance, the Artillery could no longer play. I therefore formed the men up, and leaving them under Lieutenant Outlaw with the Artillery, I proceeded on and crossed the canals. Lieutenants Outlaw and Boileau soon followed me with the Company, as it was found that the Artillery were not to advance over the canals. But by this time the enemy began to take to flight in all directions, and as the Artillery were ordered to form line on the bank of the Foolaylee, we returned to assist the heavy Battery over difficult ground, and after a short halt for the refreshment of the troops, we marched with the rest of the force to our encampment.

10 In my letter of the 11th Inst., I mentioned the great assistance I received from Lieutenant Outlaw, and 2nd Lieutenant Boileau, and the excellent conduct of Jemadar Tonderoyen, and all the European and Native Non-commissioned Officers and Privates under my command. I have only to add that Corporal McDonough was wounded in the foot by a matchlock ball, and that his bearing on the occasion was very soldier-like.

11 On the 25th we halted on the field of battle, and on the 26th marched to Ali Yar Ka Tanda, and thence to Meerpoor, Shere Muhummud's capital, of which we took possession. After this we formed part of a force sent on to take possession of Omerkote, where some opposition was expected, but the small garrison (25 men) after a short parley came out and laid down their arms before Major Woodburn 25th Bombay N. I. who commanded. We then entered the fort (on the 4th of April) in which we found 9 guns. The British flag was



PLAN
of the Battle of Hyderabad
fought on the 24th March, 1813.
Between the Force under
Major Gen^l. Sir Chas. Napier, K.C.B.
and
The Belooch Army of
Sheer Sheer Mahummud Khan
or
Marpoor in
Lower Scind.

The British Troops are all coloured Red, those of
the Enemy Blue. The British Force was about
5000 men, that of the enemy about 20,000.
The British had 17 Guns, and the Enemy eleven.
The Enemy lost at least 1200 in killed and
wounded, and the British loss was 267 including
2 European Officers killed, and 13 wounded, one
of the latter mortally. The Battle commenced at
8, and ended about ½ past 11. A. M.

Surveyed by B^o Capt^o Henderson
Assisted by 2^d Lieut^o Boileau } Madras Eng^{rs}

hoisted on the highest tower, and having left a small garrison in the place, we returned to Hyderabad, where we arrived on the 11th Instant.

12 During a day's halt at Oomerkote I was ordered to make a survey of the fort. A copy of the Plan and report which accompanied it, shall be forwarded to the Officer commanding the corps.

I have the honor to be,

Sir,

Your most obedient servant,

ROB. HENDERSON, BT. CAPT.

FORT HYDERABAD,) Commanding C. Company
20th April 1843.) Sappers and Miners.

Journal of march to, and operations at Emaumgurh from the 6th to the 16th January 1843.

6th January.—At 2 A. M. a detachment of Sir C. Napier's force consisting of 300 H. M. 22d Regt. 224. Pdr. Howitzers, Captain Whittlie's Camel Battery, 200 Scinde Irregular Horse, and 30 Madras Sappers and Miners marched from Deeja-kote, every Officer and man being mounted on a camel. We continued our march till 1 1/2 P. M. when we found that we had perambulated 22 1/2 miles. Direction varying between east and south. The country passed over was almost a desert, except that there were a few shrubs here and there. No forage whatever was to be obtained for the horses, so that it was necessary to send back 150 of the S. I. Horse to Deejakote. The place we arrived at, consisting of a few huts, with 3 wells of water, was called "Choonknee."

January 7th.—We marched at 6 A. M. and went ten miles to a tank of brackish water, near a village named "Doomb." The country as before.

January 8th.—We marched 11 miles in a S E. direction to some water within a mile of a village called "Tujjul." No supplies to be obtained, and nothing but tamarisk and other shrubs which the Camels devour,

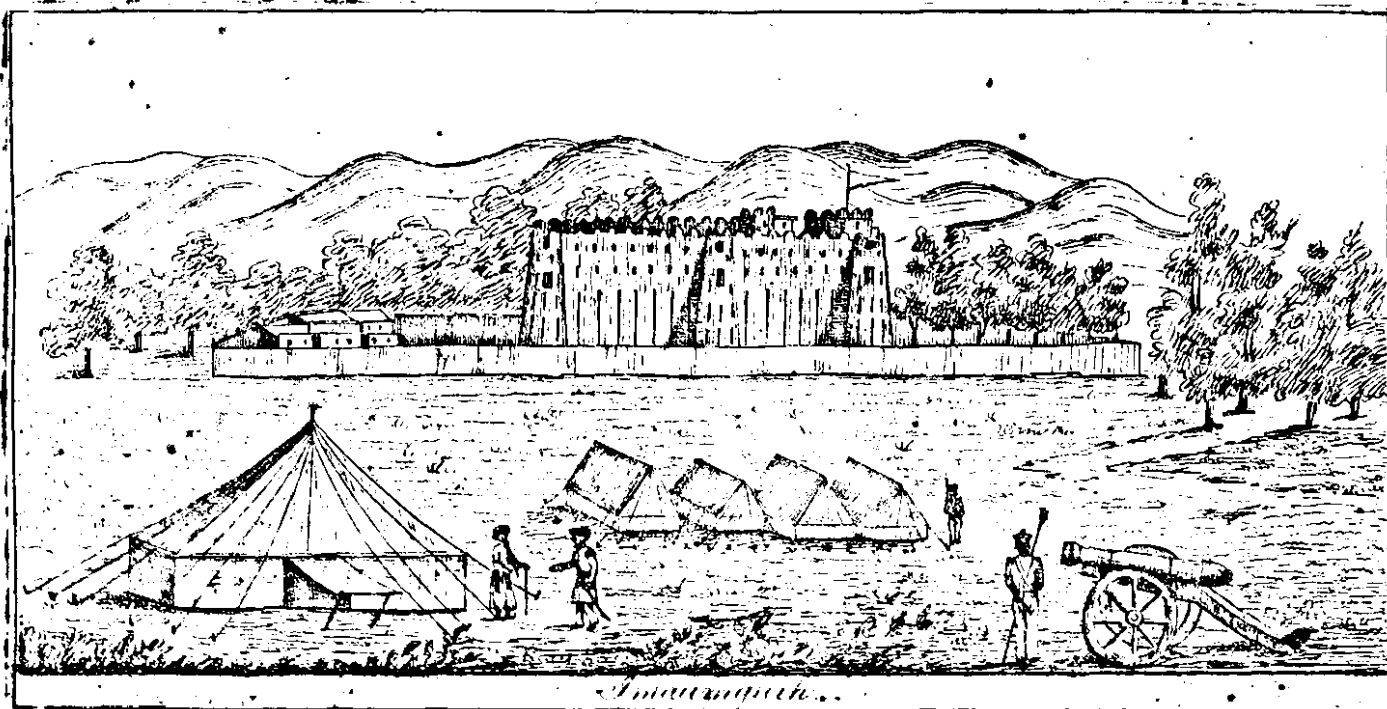
but nothing for the horses. The last mile of this march was along the dry bed of the Narra river; the sand was so heavy that Captain Whittlie was obliged to place 14 Camels to draw each gun.

January 9th.—We marched 12 miles to a place called "Luk," it consists of merely a few huts, formed in the shape of the Esquimaux snow-huts, but entirely deserted. Here are 3 small wells with pretty good water.

January 10th.—We marched 11 miles in an E. S. E. direction to a place called "Mittree," consisting of a few huts as before. This march we crossed a succession of steep heavy sand-hills, which we could not turn, as the hills formed basons between them, so that no sooner is one surmounted than another has to be crossed immediately in its front. A company of Europeans was attached to each gun, and the drag-ropes were in requisition during the greater part of this march. Here we found one well, which was soon drawn dry.

January 11th.—We were employed about two hours this morning in making the road up a single hill; the sand as before was extremely heavy. We marched to "Puddree" distant 8 1/2 miles. Here was one well with brackish water.

January 12th.—Road as yesterday. We marched 6 1/2 miles and arrived at "Emaumgurh," a neat looking fort (for dimensions See Pl. 16) situated in the middle of a bason or valley, commanded by sand-hills. The entrance is through a gate on the eastern side of an outer enclosure mud-wall, about 12 feet high, in the form of a rectangle; in this enclosure was a good well with sweet water, a few stable huts, and two small vaulted Powder Magazines, one of which was found nearly full of loose powder. The entrance was then through a strong well-flanked gate in a redoubt attached to the fort, which served to cover another gate situated about mid-way, on the eastern side of the fort. These gates were both of very good material, well bound with iron; and were commanded by lines of fire from loop-holes in every direction.



On entering the fort no means of access to the parapets could be immediately discovered, for the stair-cases leading to them are narrow, and are in the interior walls of the fort (See Plan.) On surmounting them, are vaulted galleries communicating all round the fort, from which through loop-holes a fire could be obtained to the very foot of the walls. Over these galleries is a roadway with a wall on each side, 5 feet high to the front, and 8 feet high on the inner side; that to the front alone was loop-holed. There was a tower at each angle of the fort, and one mid-way on the western side. Three

small guns, numerous wall-pieces, jezails &c. were found mounted on the walls. Large quantities of coarse powder were discovered stowed away in chambers in the towers, whose floors were on the same level as those of the vaulted galleries.

The whole of the masonry of the fort was of burnt bricks in chunam, except a few of the interior layers which were in mud. The walls and towers were 40 feet high, and the large tower (See Plan) 50 feet high.

The nature of the rampart and parapet walls will be seen by examining the section through V. W.

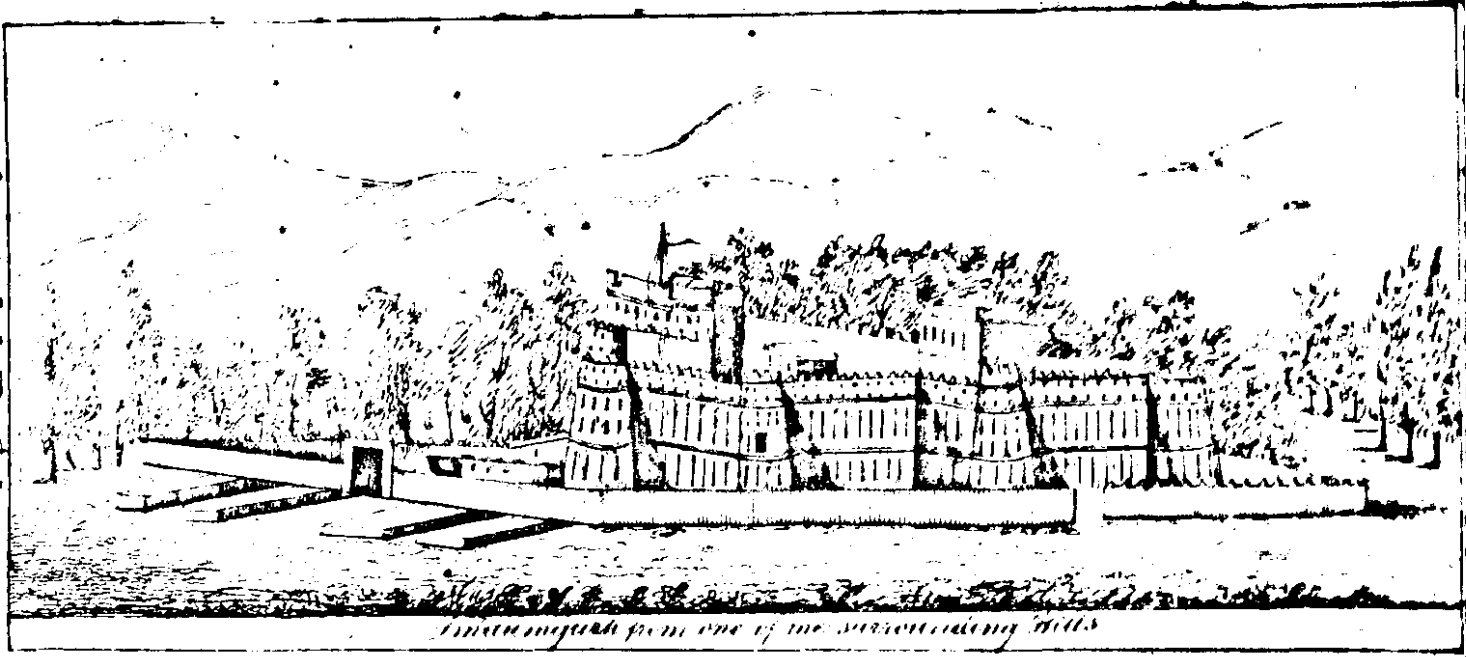


Illustration from one of the surrounding hills

January 13th.—The Sappers went down to the fort at day-break, and were employed in making 7 mines (7 feet apart from centre to centre) under the exterior wall of the northern curtain; this was found to be rather a dangerous operation, as the wall gave way; the mines however were driven under the wall through its entire depth or thickness. Some shafts were commenced in the galleries and towers, upon which a working party from H. M.'s 22nd Regiment was employed. They also removed the powder, which had been found in the fort, to a safe distance. In the afternoon the work ceased as Captain Whittlie's two 24 Pdr. Howitzers played into the fort, in order to ascertain with what effect his shells would act upon the vaulted galleries &c. Several shells passed through the walls and burst within the galleries.

January 14th.—The shafts which were commenced yesterday were carried down to the depth of 8 or 9 feet and chambers were made. Whittlie's guns again practised with good effect. In the afternoon we commenced to charge and explode the mines. In the 7 chambers marked A. A. A. &c. in Plan) were placed 238 lbs. of country powder i. e. 34 lbs. in each; the line of least resistance was 3½ feet. Tamping of sand. This was

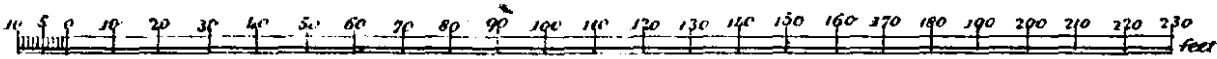
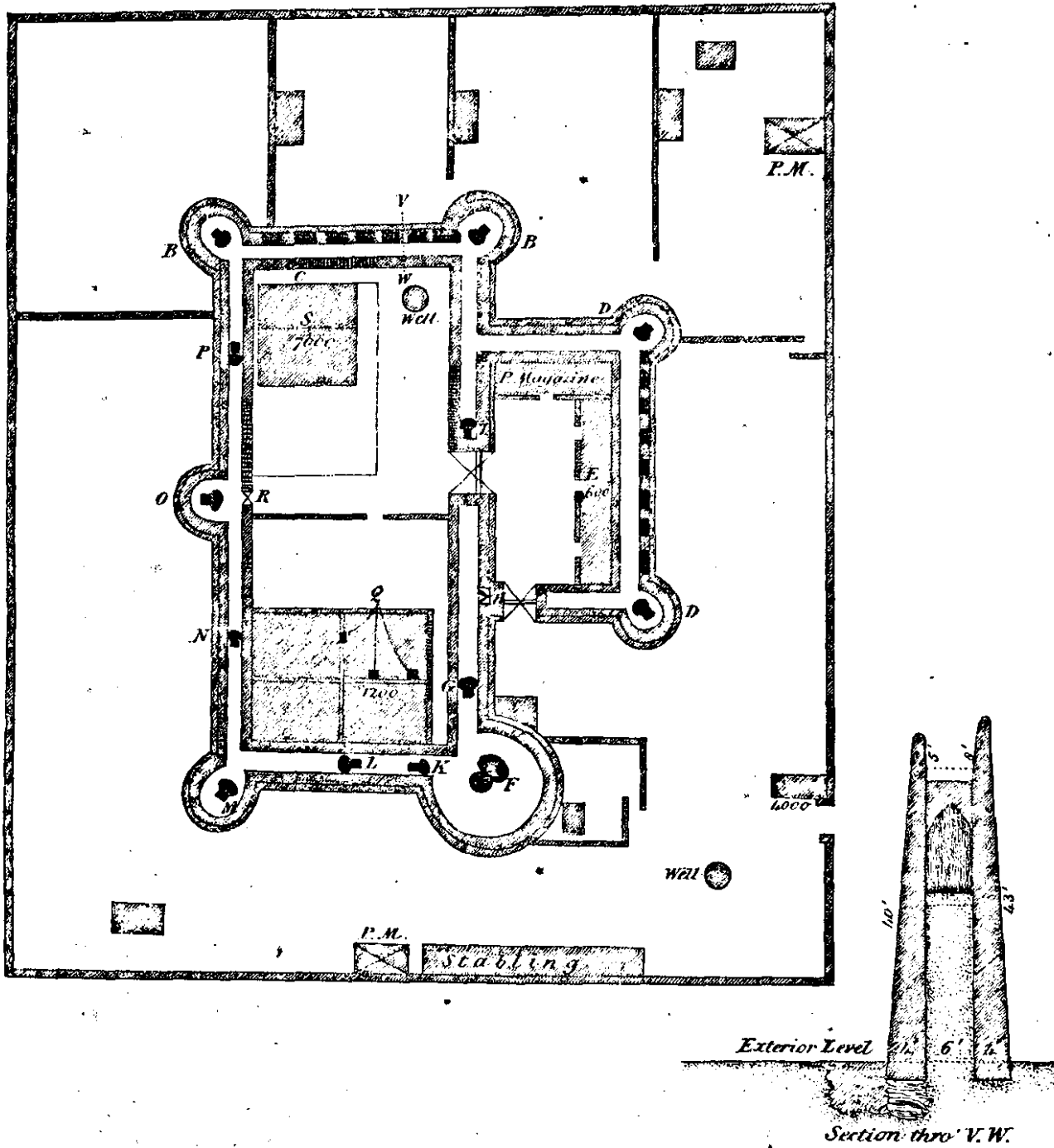
quite experimental, as we were not yet acquainted with the strength of the country powder found in the fort. There were 3 foci of ignition, fired simultaneously, tho' they did not act so. The effect was, that the exterior wall was very much shaken and cracked, but did not fall. After this, it was resolved to prove the comparative strengths of the Europe and country powder, and for this purpose 3½ feet circular shafts were sunk in the towers B. B. the shafts were about 9 feet deep, and the line of least resistance was 8 feet. In one was lodged a charge of 100 lbs. of Europe powder, and in the other 300 lbs. of country: on being fired, the effect in both was as nearly as possible the same, viz. moderate demolition; the intermediate curtain wall still remained standing. After this, in order to shake down this curtain, 300 lbs. of country powder lightly tamped were placed in the narrow stair-case C in the interior wall of the curtain and fired; the effect was, as desired, that nearly the whole of the curtain fell.

It may here be noted, that after this we always used three times as much country powder as we should have used of Europe.

Our mines were all fired by means of a hose one inch in diameter, at the end of which was inserted a piece of

PLAN
of the
FORT of EMAUMGURH.

*Shewing the position of the Mines
formed for its demolition between the 12th & 17th January, 1843.*



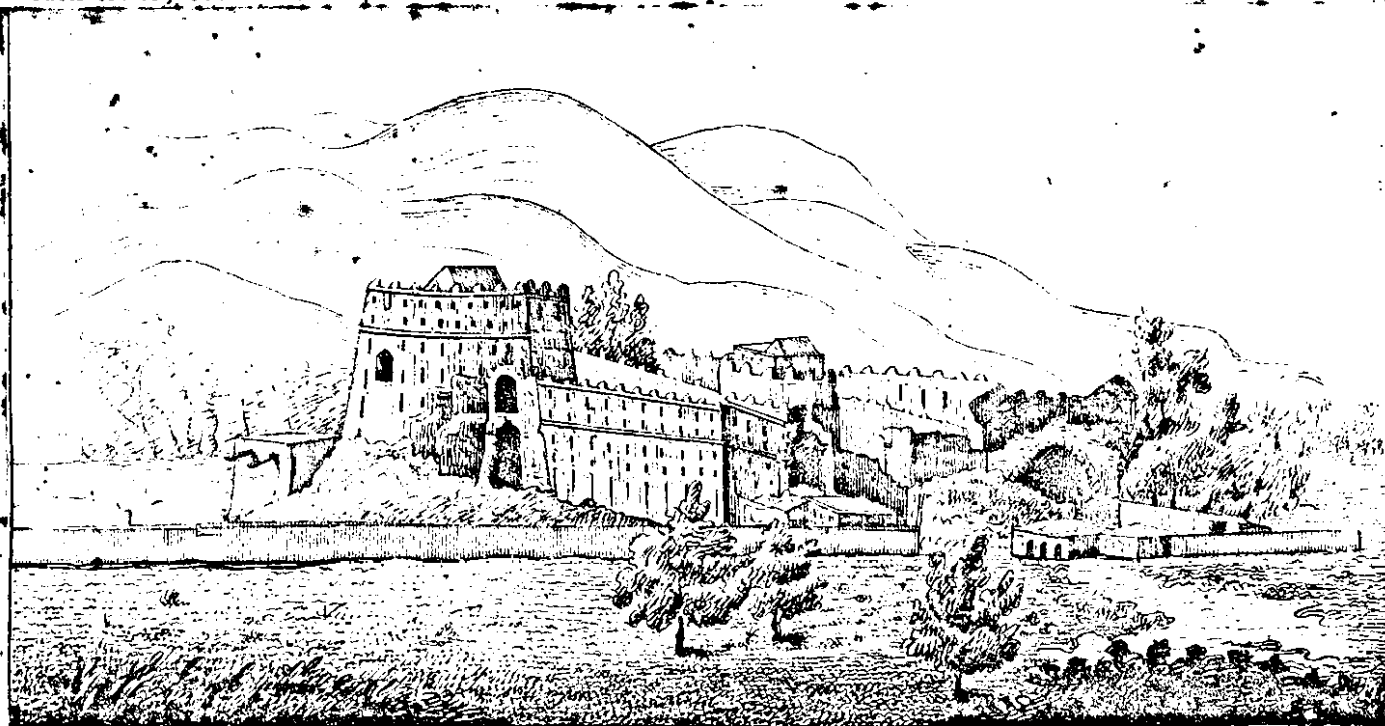
Scale for Plan ... 10 feet to an Inch.
Scale for Section ... 20 feet to an Inch

portfire, which was carefully secured by means of moist clay.

No slow-match was used, except at first, to communicate fire to the portfire, but this was afterwards superseded, as we found portfire created a much more speedy, and perhaps quite as safe, communication.

Our attention was next turned to the destruction of the redoubt, and shafts were sunk (as before) in the towers D. D. and 300 lbs. of country powder lodged in each tower; 600 lbs. were placed in a lower room of

the granary E, and were lightly tamped, while 8 mines (7 feet apart from centre to centre) were dug under the exterior curtain wall between the towers D. D. In each of these were lodged 50 lbs. of country powder, and fired from four foci of ignition, though not simultaneously; at the same time were fired D. D. and E. one or two of the mines under the wall were choked so that a portion of the curtain remained, while the towers D. D. and the house E. were destroyed with moderate, yet complete demolition.



Sketch of Inaugurk after the first days work.

January 15th.— Captain Whittlie's guns again practised. The rubbish of last night's explosions was cleared from behind the redoubt gate, and the gate was strongly barricaded within; 100 lbs. of English powder were placed in a Mussuk or bag of leather, and hung upon the spikes on the outer side of the gate; it was fired by means of a piece of portfire carefully inserted; the effect was, that the gate was thrown down upon its back, and one leaf of it was broken into two parts, as also was the thick beam which had been placed behind it. The arch of the gateway however remained standing. The gate, as it had fallen with its sharp pointed spikes upwards, would have considerably obstructed the passage of a storming party, were not the precaution of

carrying sand-bags to throw down upon it resorted to. The mines K, F, G, H, I, L, M, N, O, P, Q, and R, were then loaded.

Mine.	L.L.R.	Charge Country Powder.	Mine.	L.L.R.	Charge Country Powder.
K	"	100 lbs.	L	6½ feet	350 lbs.
F	16 feet.	1800*	M	8 "	350 "
G	6½ "	200	N	6½ "	200 "
H	"	150	O	7 "	250 "
I	6 "	150	P	6½ "	150 "

* This charge was calculated for 2400 lbs. of powder, but when 1800 lbs. had been put in, it was found that to have placed the remaining 600 lbs. would have obliged us to enlarge the chamber to such a degree, as would have placed the workmen in great danger, as they must necessarily have worked under the foundation of a heavy pillar supporting the roof of a house in the tower; as it was indeed, some of the charge was laid in the bottom of the shaft, but to restore in a measure this deficiency, the tamping of this shaft was built up with loose bricks to the very ceiling of the room wherein the shaft was sunk, and the small mine K. intermediately placed between F. and L. was made to assist in the demolition of the large tower.

The mine L. was overloaded by error; otherwise it will be seen that about 1-4th and sometimes 1-5th L. L. R.^s was used. It is not however intended that these operations should be taken as data upon which to found others, as circumstances rendered some irregularities necessary in our case.

In the house Q. placed 1200 lbs. powder loosely tamped, and 100 lbs. in the stair-case R. The mines K. F. G. H. I. were fired simultaneously with the mines L. M. N. O. P. and with the mines Q. R. The mine M. alone was choked, but the effect of the explosion of the others was that nearly the whole of the fort was demolished. M. was afterwards fired alone, and the tower fell.

Orders were given for the destruction of the rest of the powder found in the fort; accordingly 7000 lbs. were placed in the room S. This was fired, and was a truly magnificent explosion; not a vestige of the house was to be seen, the adjoining well was filled up, and bits of walls which had remained were shaken down.

There being still about 4000 lbs. of gunpowder left, this was collected just within the gate of the outer enclosure wall. Only 1½ feet of hose remained, and our last 3 inches of portfire was inserted into it, the former having been first placed into the mouth of one of the powder dubbars.

This was fired by Lieut. E. Brown of the Bengal Engineers (all the other Engineer Officers being present as they were on all other occasions) and the explosion surpassed in appearance the last one, heightened as this was by the darkness of the night. Several combustibles were ignited, and the conflagration lasted for about an hour afterwards.

January 16th.—We left Emaumgurh at day-break on route to Peer-Aboo Bukur, where we rejoined the force.

ARCHD. BOILEAU, 2d. Lt.
Asst. Field Engineer.

CAMP HYDERABAD SCINDE. }
17th November 1843. }

The Engineer Officers present on the above expedition were:—Major Waddington Bombay Establishment, Commanding Engineer; Brevet Captain R. Henderson Madras Establishment, Field Engineer; 1st Lieutenant E. J. Brown Bengal Establishment, Secretary to the Government of Scinde;—and 2d Lieutenant A. J. M. Boileau Madras Establishment, Assistant Field Engineer.

ROB. HENDERSON, CAPT.
Late Field Engineer in Scinde.

No. 1.

Statement of the services of the C. Company Madras Sappers and Miners in Scinde and the neighbouring countries, during the late War, from the 27th Nov. 1840 to the 25th of March 1844.

From the accompanying tabular statement, it will be seen that the Company commenced its march from Bel-

gaum on the 9th November 1840, and embarked at Vitoria direct for Kuratchee. Shortly after its arrival at the latter place, it was sent to join the Scinde field force at Quetta; a march of 500 miles. On the way the men were usefully employed in destroying the defences of the town of Kujuck, after it had been evacuated by the inhabitants; a small British force having failed in an attempt to storm the place by the gateway. They proceeded through the Bolan Pass alone, with only 46 muskets, the smallest body of British troops that ever passed through this defile (60 miles in length) by deliberate marches; and when it is considered that one-third only of the Company was armed, the rest of the men carrying merely working tools, and that they were encumbered with extra camels to carry the stores attached to a party of Sappers and Miners, there cannot be a doubt that in such an isolated situation, and in the midst of mountains which afford every advantage to an active and daring enemy, every man of the Company ought to have carried a firelock. Shortly after its arrival at Quetta, the Company was sent to Mobe, Moostung, Teeres &c. to make the road practicable for Artillery in the direction of Khelat; and a detachment accompanied a force which proceeded to Nooshky. In October 1841 the Company returned to the plains by the Bolan Pass, along with the Head Quarters of the force, with the exception of a Jemadar and 22 men, who accompanied a Battery of European Artillery, and 2 Companies of H. M.'s 41st Regiment, this detachment having been ordered to explore the country in the direct line from Quetta to the seaport of Soumeanee, and thence to that of Kuratchee. The Head Quarters of the Company continued with the field force at Seebee and Dadur, whilst its detachments extended all over the country from Seebee to Kuratchee, employed in various public works, as specified in the memorandum. Meanwhile the insurrection at Cabool broke out, and in April 1842 the Company proceeded above the Pass a second time, still leaving detachments throughout Kutchee and Scinde. From the Head Quarters of the Company at Quetta a party was sent forward with General England to Candahar, whose services are sketched in statement No. 2. After remaining above the Pass till September, the Company returned to the plains of Kutchee with General England's retiring army. This movement was effected in 3 columns, which followed each other after 3 or 4 days interval, and we were accordingly divided into 3 corresponding detachments, one to each column. At last the detachments of the Company assembled at Sukkur (with the exception of that with General Nott's force) and we crossed the Indus to Roree with the force under Major General Sir Charles Napier. This force quitted Roree in January 1843, and in the same month a detachment composed chiefly of European Artillery, H. M.'s 22nd Regiment,

and 30 men of my Company all mounted on Camels, proceeded 100 miles into the desert to Maumghur, and there we were employed in effecting the complete demolition of the fort, and the destruction of a large quantity of gunpowder found in it. We rejoined the main body of the force on the 16th January, and marched on with it towards Hyderabad, making the road practicable for Artillery as we advanced, a very necessary operation in Lower Scinde where there are no made roads, and the country is greatly intersected by canals of irrigation. On the 17th of February the battle of Meeanee was fought, and the services of the Company on that occasion were favourably noticed by Sir Charles Napier in his despatch. A plan and report of the employment of the Company on that day were forwarded officially to the Chief Engineer. On the 20th of February, we marched out of camp with a small force to take formidable possession of the fort of Hyderabad, and assisted in erecting a flag staff and hoisting the British flag upon the top of its highest tower. After this, we were employed in repairing and altering the fort, and the detachment that accompanied General Nott to Cabool, having now joined us from Ferozepore, the whole Company was present in the battle of Hyderabad on the 24th March, when its services were again favourably noticed in the General's despatch, and a report was forwarded as before to the Chief Engineer. Thus the men under my command in the short space of 5 weeks, were called upon to take part in two battles, one of which, was perhaps the most severe ever fought in India, when two-thirds of them were without arms to defend themselves! surely this is a convincing proof that the Corps should be fully armed. In the battle of Meeanee, each musket was of service.

After the battle, we marched 100 miles into the desert along with a detachment under Major Woodburn, and were present at the surrender of the fort of Oomerkote. We then returned to Hyderabad in the beginning of April, and from that time till the 25th of March in the following year, when we quitted the country, the detachments of the Company were sent to all the principal stations in Lower Scinde, and employed in various public works, such as building a fort, erecting barracks for Europeans and Natives, constructing a stone pier in Kuratchee harbour &c. with the exception of a short period, when a Naigue's party accompanied a force under Major General Simpson, 2nd in command in Scinde, in an expedition, on which occasion the General expressed in a note to Lieutenant Outlaw, his high approbation of the services of the Naigue and his party.

On the Company quitting Scinde, the following G. O. was issued by his Excellency Major General Sir Charles Napier G. C. B. Governor of Scinde.

General Orders by His Excellency Major General Sir C. J. Napier, G. C. B. Governor of Scinde.

Head Quarters, Kurrachee, 25th March 1844.

"Captain Henderson and Officers, Non-commissioned Officers and Privates of the Madras Sappers and Miners,—you have earned laurels in Sind—No troops have more honorably conducted themselves—Associated in all the glories of the Bombay Army, you leave this country regretted by your companions.—you have served under my immediate command for a year and half—your labours during our march into the desert were greater than those of any other troops, and were undergone with spirit. You did your duty

bravely in the battles of Meeanee and Hyderabad. In the former of these two actions, you were conspicuously placed, and nobly acquitted yourselves. I regret to lose you, but justice to you after your hard service has made me send you to your own homes, where an honorable reception awaits you. Go where you will, you will be attended with my sincere regards, and my heartfelt respect.

"To my friend Captain Henderson I have given a letter for the Commander in Chief of the Madras Army, that His Lordship may be aware of your worth."

The following Officers served with the C. Company of Sappers and Miners in Scinde Viz :

Rank.	Names.	Corps.	Remarks.
Bt. Capt.	R. Henderson,	Engineers.	Returned with the Company to India.
Lieutenant.	T. F. V. Outlaw,	26th Regt. N.I.	Left Scinde on S. C. & died at Bombay.
1st. Lieut.	Orr,	Engineers.	Left Scinde on S. C. & ultimately proceeded to Europe.
2nd. Lieut.	A. J. M. Boileau,	Engineers.	Do. Do.
Asst. Surg.	Carlow,	Medical Dept	Died at Kotra.

No. 2.

Statement of the Services of a Detachment from the C. Company Madras Sappers and Miners in Affghanistan &c.

The party of 1 Havildar 1 Naigue and 28 Privates left Quetta on the 26th April 1842 with General England's force, and was present at the second affair of Hukulzie on the 29th April, when the enemy were driven from the heights which they had occupied. It then proceeded on to the Kojuk mountains, where the force was again opposed, to Candahar, and joined General Nott's army. From Candahar, the party accompanied the force that relieved Khelat-i-Ghiljee, and after destroying the fort and buildings, (erected by the British) returned to Candahar. From the 18th to the 29th of June, the detachment was employed in destroying several forts of the enemy in the surrounding country, and on the 10th of August, marched with the force towards Cabool. The party was present in the General action with Shumshooden on the 30th of August, and on the 5th September, after having been engaged in the action before Ghuznee, they were employed during the night in preparing mines to breach the walls, which though got ready, were not required, as the fort was found to be evacuated in the morning. The party was afterwards employed for two days in ruining the defences, it then marched with the army and arrived at Cabool on the 17th September, having destroyed a fort on the road. At Cabool, they were variously employed, but chiefly in opening up a channel to supply the camp with water, which had been cut off by the enemy. On the 12th October the whole army quitted Cabool, and was daily engaged with the enemy, till its arrival at Jalalabad on the 25th Idem. The party reached Ferozepoor on the 23rd December, and quitted that place by land for Sukkur on the 5th January 1844, in order to open the road for Leslie's troop of Horse Artillery. From Sukkur the detachment came down the Indus in boats to Hyderabad, and having re-joined Head Quarters, the whole of the Company was present in the battle of the 24th March 1843, from which time its services are included in statement No. 1.

R. HENDERSON, CAPT.

Late Commanding C. Company Sappers and Miners.

Tabular Statement of the services of the C. Company Madras Sappers and Miners in Scinde, Afghanistan, and the territories of the Khan of Kelat, from the 9th November 1840, to the 25th March 1844.

Year and Month.	Head Quarters where stationed.	How employed at Head Quarters.	Officers present at Head Quarters.	No. of Detachments, and at what places.	Detachments how employed.	Officers Detached.	Officer Commanding the Detachment.
1840 Nov.	Quitted Belgaum on the 9th, and arrived at Vingorla on the 13th; Embarked for Scinde on the 27th.	"	Lt. Outlaw.	None.	"	None.	Lieut. Outlaw.
Dec.	Arrived at Kuratchee on the 4th, and quitted it on the 17th, to join Major General Brooks' force in advance.	In repairing a landing place at Kuratchee, and making a trough for horses to drink from.	Lt. Outlaw.	None.	"	None.	Lieut. Outlaw.
1841 January.	Marched through Lower and Upper Scinde to Bagh in Kutchee.	In clearing the ground where the Force was encamped.	Lt. Outlaw.	No. 1 Sukkur.	No. 1 Detached to Sukkur in charge of 500 Government horses.	None.	Lieut. Outlaw.
February	Marched from Bagh to Dadur, from Dadur to Bagh, and from Bagh to Kujjuck.	In destroying the fort of Kujjuck, after it had been evacuated by the enemy.	Lt. Outlaw.	No. 1 Mungul Ka Shurb.	No. 1 Left in charge of Engineer stores.	None.	Lieut. Outlaw.
March.	Marched from Kujjuck to Dadur, and from Dadur through the Bolan Pass to Quetta.	In making roads for the passage of the column on the march.	Lt. Outlaw.	None.	"	None.	Lieut. Outlaw.
April.	Marched from Quetta to Mobee.	Making the Nishpah Pass, on the road from Quetta to Moostung and Kelat.	Lt. Outlaw.	Quetta.	In charge of Engineer Stores.	None.	Lieut. Outlaw.
May.	Mobee.	As in last Month.	Lt. Outlaw.	No. 1 Nooshky. No. 2 Quetta.	No. 1 Employed in making roads for the passage of Artillery &c. No. 2 In repairing the Lines at Quetta.	Lieut. Orr at Nooshky, Lt. Boileau at Quetta.	Lieut. Outlaw.
June.	Teeree and Moostung.	Making a road from Mobee to Moostung.	Lt. Outlaw.	No. 1. Nooshky. No. 2. Quetta.	No. 1 Employed as in last Month. No. 2 As in last Month.	Lieut. Orr at Nooshky, Lt. Boileau at Quetta.	Lieut. Outlaw.
July.	Marched from Moostung to Quetta.	In repairing the lines and building a Magazine at Quetta.	Lieut's Outlaw, Orr, and Boileau.	None.	"	None.	Lieut. Outlaw.
August.	Quetta.	As in last Month.	Lts. Outlaw, Orr & Boileau.	None.	"	None.	Lieut. Outlaw.
Sept.	Quetta.	As in last Month.	Lieut's Outlaw, Orr, and Boileau.	No. 1. En route to Kuratchee via Kelat and Soumeanee.	No. 1. In making roads for the passage of Artillery.	Jemadar Ramen to Kuratchee.	Lieut. Outlaw.

Statement by Major Henderson.

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Year and Month.	Head Quarters where stationed.	How employed at Head Quarters.	Officers present at Head Quarters.	No. of Detachments and at what places.	Detachments how employed.	Officers Detached.	Officer Commanding the Detachment.
1841 Oct.	On the March from Quetta to Dadur.	Marching with General England's force.	Lieuts. Outlaw and Boileau.	No. 1. En route to Kuratchee via Kelat and Soumeanea.	No. 1. In making roads for the passage of Artillery.	Jemadar Ramen.	Lieut. Outlaw.
Nov.	Dadur.	Making bridges and roads.	Captain Henderson, and Lt. Outlaw.	No. 1 Seebee. No. 2 Bagh. No. 3 Kuratchee	No. 1 On survey duty. No. 2 On survey duty. No. 3 On public works.	Capt. Henderson, Civil duty at Seebee. Lt. Boileau on survey duty to Bagh. Jemadar Ramen at Kuratchee.	Capt Henderson.
Dec.	Seebee.	Repairing the Fort at Seebee.	Lieut's Outlaw and Boileau.	No. 1 Naree Pass No. 2 Kuratchee No. 3 Dadur.	No. 1 In making a Dam. 2. On Public works. 3. In constructing roads.	Capt. Henderson at the Naree pass. Jemadar Ramen at Kuratchee.	Lieut. Outlaw.
1842 Jan.	Seebee.	As in last Month.	Lieut's Outlaw and Boileau.	No. 1 Kunda. No. 2 Kuratchee No. 3 Dadur.	No. 1 Employed under Captain Henderson in excavating a tank. No. 2 On public works. No. 3 In constructing roads.	Capt. Henderson at Kunda on Civil duty Jemadar Ramen at Kuratchee.	Lieut. Outlaw.
Feb.	On the march to Sukkur.	Marching.	Capt. Henderson.	No. 1 Seebee. No. 2 Kuratchee No. 3 Shikarpoor No. 4 Sukkur. No. 5 Dadur. No. 6 Meerpor No. 7 Kokur.	No. 1 Employed in repairing the Fort of Seebee. No. 2 Left Kuratchee on the 6th and arrived at Shikarpoor on the 27th. No. 3 In building barracks. No. 4 Constructing Public works. No. 5 Making roads. No. 6 and 7 Building Government Bungalows.	Lieut's Outlaw and Boileau at Seebee, Jemadar Ramen at Kuratchee, Jemadar Tonderoyen at Shikarpoor.	Capt Henderson.
March.	On the march from Sukkur to Quetta.	Marching.	Capt. Henderson.	No. 1 Seebee. No. 2 Shikarpoor No. 3 Dadur. No. 4 Sukkur.	No. 1 In repairing the fort of Seebee. No. 2 In building Barracks. No. 3 In constructing a breast-work at Dadur. No. 4 In building barracks.	Lieut. Boileau at Seebee, Lt. Outlaw at Dadur, Jemadars Ramen and Tonderoyen at Shikarpoor.	Capt Henderson.
April.	Arrived at Quetta on the 4th.	In constructing fortifications at Quetta.	Capt. Henderson.	No. 1 Seebee. No. 2 Shikarpoor No. 3 Dadur. No. 4 Sukkur. No. 5 Candahar.	No. 1 In repairing the Fort at Seebee. No. 2 Building lines for Sepoys No. 3 Constructing a Breastwork. No. 4 Building barracks No. 5 With Major General England's Force at the 2nd Affair of Hykulzie on the 28th April 1842.	Lieut. Outlaw at Dadur. Lt. Boileau at Seebee, Jemadars Ramen and Tonderoyen at Shikarpoor.	Capt Henderson.
May and June.	Quetta.	In constructing fortifications.	Capt. Henderson, Lieut's Outlaw and Boileau.	No. 1 Shikarpoor No. 2 Sukkur. No. 3 Candahar	Nos. 1 and 2 Employed in building Lines for Sepoys &c. No. 3 With Major General England's force.	None.	Capt Henderson.
July and August.	Quetta.	In constructing a breast-work and repairing the Fort of Quetta.	Capt. Henderson.	No. 1 Shikarpoor No. 2 Sukkur. No. 3 Candahar. No. 4 Dusht-i-Bedoulut.	Nos. 1 & 2 In building European barrack No. 3 With Maj. Gen. Nott's force. No. 4 In sinking a well.	Lieut's Outlaw and Boileau at the Dusht-i-Bedoulut.	Capt Henderson.

Year and Month.	Head Quarters where stationed.	How employed at Head Quarters.	Officers present at Head Quarters.	No. of Detachments, and at what places.	Detachments how employed.	Officers Detached.	Officer Commanding the Detachment.
1842 Sept.	Quetta.	In repairing the Fort of Quetta.	Capt. Henderson and Lieut. Boileau.	No. 1 Shikarpoor No. 2 Sukkur. No. 3 on the March. No. 4 on the March.	Nos. 1 & 2 In building Lines. No. 3 In marching with General Nott's Army in Cabool. No. 4 In marching with 1st division Scinde F. F. to Sukkur.	Lieut. Outlaw marching with 1st division General England's force to Sukkur.	Capt Henderson.
October.	Shikarpoor.	In surveying the city and cantonments of Shikarpoor.	Capt. Henderson.	No. 1 Sukkur. No. 2 On the March. No. 4 On the March.	No. 1 in making landing places on the River Indus, and repairing roads. No. 2 marching with Genl. Nott's Army in Cabool. No. 3 Marching from Quetta to Sukkur.	Lieut. Outlaw at Sukkur. Lt. Boileau on the March from Quetta to Sukkur.	Capt Henderson.
Nov.	Shikarpoor.	As in last Month.	Capt. Henderson.	No. 1 Sukkur. No. 2 On the March. No. 3 Between Sukkur and Shikarpoor.	No. 1 As in last month. No. 2 As in last month. No. 3 Employed on survey duty under Lieutenant Boileau.	Lieut. Outlaw at Sukkur, Lt. Boileau surveying the country between Sukkur & Shikarpoor.	Capt Henderson.
Dec.	Sukkur.	In Surveying the cantonment of Sukkur, and in blasting rock to improve the roads.	Capt. Henderson, Lts. Outlaw and Boileau.	No. 1 On the March.	No. 1 Marching with Genl. Nott's army to Cabool.	None.	
1843 January.	Marching with Major General Sir C. J. Napier's force.	In making roads for the passage of Artillery and troops. Capt. Henderson & Lieut. Boileau were employed with 30 men of the company in destroying the fort of Imaumgurbh by mining.	Capt. Henderson, Lts. Outlaw, and Boileau.	No. 1 with Genl. Nott's Army.	No. 1 Marching with General Nott's Army.	None.	Capt Henderson.
Feb.	As in last month.	In making roads for Artillery, and present in the battle of Meeanee on the 17th February.	Capt. Henderson, Lts. Outlaw, and Boileau.	No. 1 As above.	No. 1 As above.	None.	Capt Henderson.
March.	Hyderabad.	In surveying and repairing the Fort of Hyderabad; and present at the battle of Hyderabad on the 24th March.	As above.	None—The detachment that accompanied Genl. Nott's army having arrived before the battle of Hyderabad.	"	None.	Capt Henderson.
April.	Marched to Omerkote, and returned to Hyderabad and Kotree.	Marched into the desert and was present at the surrender of the Fort of Omerkote on the 4th April	Capt. Henderson.	No. 1 Hyderabad. No. 2 In the intrenched camp.	No. 1 In repairing the Fort of Hyderabad. Building barracks in the intrenched camp.	Lieut. Outlaw and Boileau at Hyderabad.	Capt Henderson.
May.	Kotree. On the right bank of the Indus.	In constructing a fort.	Capt. Henderson.	No. 1 Hyderabad. No. 2 Intrenched camp. No. 3 Ali Yar Ka Tanda.	No. 1 As in last month. No. 2 As in last month. No. 3 In making bridges between Hyderabad and the intrenched camp.	Lieut. Outlaw at Hyderabad. Lieut. Boileau at Ali Yar Ka Tanda.	Capt Henderson.

Year and Month.	Head Quarters where stationed.	How employed at Head Quarters.	Officers present at Head Quarters.	No. of Detachments, and at what places.	Detachments how employed.	Officers Detached.	Officer Commanding the Detachment.
1843 June.	Kotree.	As in last month.	Capt. Henderson.	No. 1 Intrenched camp. No. 2 Ali Yar Ka Tanda. No. 3 Mahomed Khan Ka Tanda.	No. 1 In building barracks. No. 2 Repairing the fort of Ali Yar Ka Tanda. No. 3 In constructing barracks.	Lieut. Outlaw, Mahomed Khan Ka Tanda.	Capt. Henderson.
July, August, and September.	Mahomed Khan Ka Tanda.	In building barracks.	Lieut. Outlaw	No. 1 Intrenched camp. No. 2 Ali Yar Ka Tanda. No. 3 Kotree.	No. 1 In constructing a road from the Fort to the intrenched camp. No. 2 Repairing the Fort of Ali Yar Ka Tanda. No. 3 In constructing a fort	Capt. Henderson S. O. commanding corps of Sappers and Miners at Kotree.	Capt. Henderson.
October.	Mahomed Khan Ka Tanda.	As in last month.	Lieut. Outlaw	No. 1 Intrenched camp. No. 2 Ali Yar Ka Tanda. No. 3 Kotree.	Nos. 1, 2 and 3 respectively as in last month.	Capt. Henderson at Kuratchee.	Capt. Henderson.
November.	Hyderabad.	In constructing roads and building barracks	Lieut. Outlaw	No. 1 Intrenched camp. No. 2 Kotree. No. 3 With General Simpson's Force. No. 4 Kuratchee.	No. 1 In making a road from the fort to the intrenched camp. No. 2 In constructing a fort. No. 3 Repairing roads for the passage of Artillery. No. 4 In making roads and constructing a stone Pier.	Capt. Henderson at Kuratchee, Lieut. Boileau in-trenched camp	Capt. Henderson.
December.	Kuratchee.	In making roads and constructing a stone Pier.	Lieut. Outlaw	No. 1 Kotree.	No. 1 In constructing a Fort.	Capt. Henderson returned to Kotree.	Capt. Henderson.
1844 January, February, & March	As in last month.	As above.	As above.	Do.	Do.	Do.	Capt. Henderson.

The Company embarked at Kuratchee for Bombay on board the Steamer Nemesis on the 25th of March.

R. HENDERSON, CAPTAIN.

Late Commanding Detachment of Sappers and Miners in Scinde.

WULLOORPOLLEM SLUICE VOL. I. P. 34.—Statement of the produce of the land under the Pulleiroo, previous and subsequent to the excavation of that channel in the Masulipatam District.

Average revenue of 5 years previous to the excavation of the Pulleiroo, being from Fusly 1242 to 1286.....	Rupees. 9,516
Average revenue of 5 years subsequent to the excavation of the Pulleiroo, being from Fusly 1247 to 1251.....	33,918
Estimated revenue of the Pulleiroo for Fusly 1251.....	36,544
Estimated capabilities of the land that may be brought under cultivation.....	1,39,683

E. B. JUNE 1845.

REPORT ON THE STRAITS WHICH SEPARATE THE RAMNAD PROVINCE IN THE PENINSULA OF INDIA FROM THE ISLAND OF CEYLON.

The distance between point Ramen, or Tonitory, in the Ramnad province, and the opposite coast of Ceylon, is about 62 miles. In the intervening space are situated the islands of Ramisseram and Manar, separated from each other by the bank called Adam's Bridge, and from the coasts of Ramnad and Ceylon, by the narrow channels or straits of Paumban and Manar.

The Manar channel is about a mile in breadth, and separates the island of Manar from Ceylon. It is navigable for small Dhonies only, and country boats. The island of Manar, which is a dependency of Ceylon, extends about 20 miles across the straits in a north-west direction. At its west end commences the bank called Adam's Bridge, which runs about 30 miles, also in north west direction to the island of Ramisseram. This island is about 10 miles in length, and is separated from the coast of Ceylon by the channel of Paumban, $1\frac{1}{2}$ mile in width.

The Manar channel was surveyed, under instructions from the Ceylon Government, by the late Captain Dawson of the Royal Engineers, and Mr. Stewart the Master Attendant of Colombo, who described it as a long narrow and very winding channel, having about 6 feet of water in the shallowest parts, with the exception of a bar opposite to its south end, on which there is not more than 3 or 4 feet of water. This channel, from the account given of it by the Officers who surveyed it, does not appear to be capable of any material improvement.

The sand bank called Adam's Bridge, is a very extraordinary formation. It is only about a quarter of a mile in breadth, and consists entirely of sand, partly above, and partly below water, collected apparently by the surf and currents, and unsupported, as far as could be ascertained, by rock. The east end of it was pierced by the Ceylon Officers to the depth of 30 feet, and nothing found but sand. On each side of the bank, at the distance of $2\frac{1}{2}$ or 3 miles, the sea is six fathoms deep, and quite free from obstructions of every kind.

There are three principal openings or channels across the bank. One near the island of Manar called the Tal Manar passage; the second 8 miles farther to the west, and the third about 11 miles from the island of Ramisseram, termed the Tannycoody passage. This last was examined and surveyed on the present occasion. It is narrow in the centre, and 30 feet deep, with broad curved bars opposite to its two ends, on which there is not more than 5 or 6 feet of water. The bank between it and Ramisseram is entire, and several feet above water. The Tal Manar passage was examined by the Ceylon Officers, and resembles exactly that of Tannycoody, but is not so deep, there being only about 3 feet of water on its north bar.

The intermediate opening was not examined, but from

its appearance, as well as from the description given of it by the fishermen who frequent the place, there can be no doubt of its corresponding very nearly with the other two. It is said to be rather deeper than the Tal Manar passage, but not quite so deep as that of Tannycoody.

In the vicinity of the Tal Manar and Tannycoody openings, the bank is visible above water for several miles, intersected by only a few narrow openings, but towards its centre it is chiefly covered with water, and very little sand is to be seen; though from the surf breaking exactly on the line of the bank, the depth of water cannot exceed two or three feet.

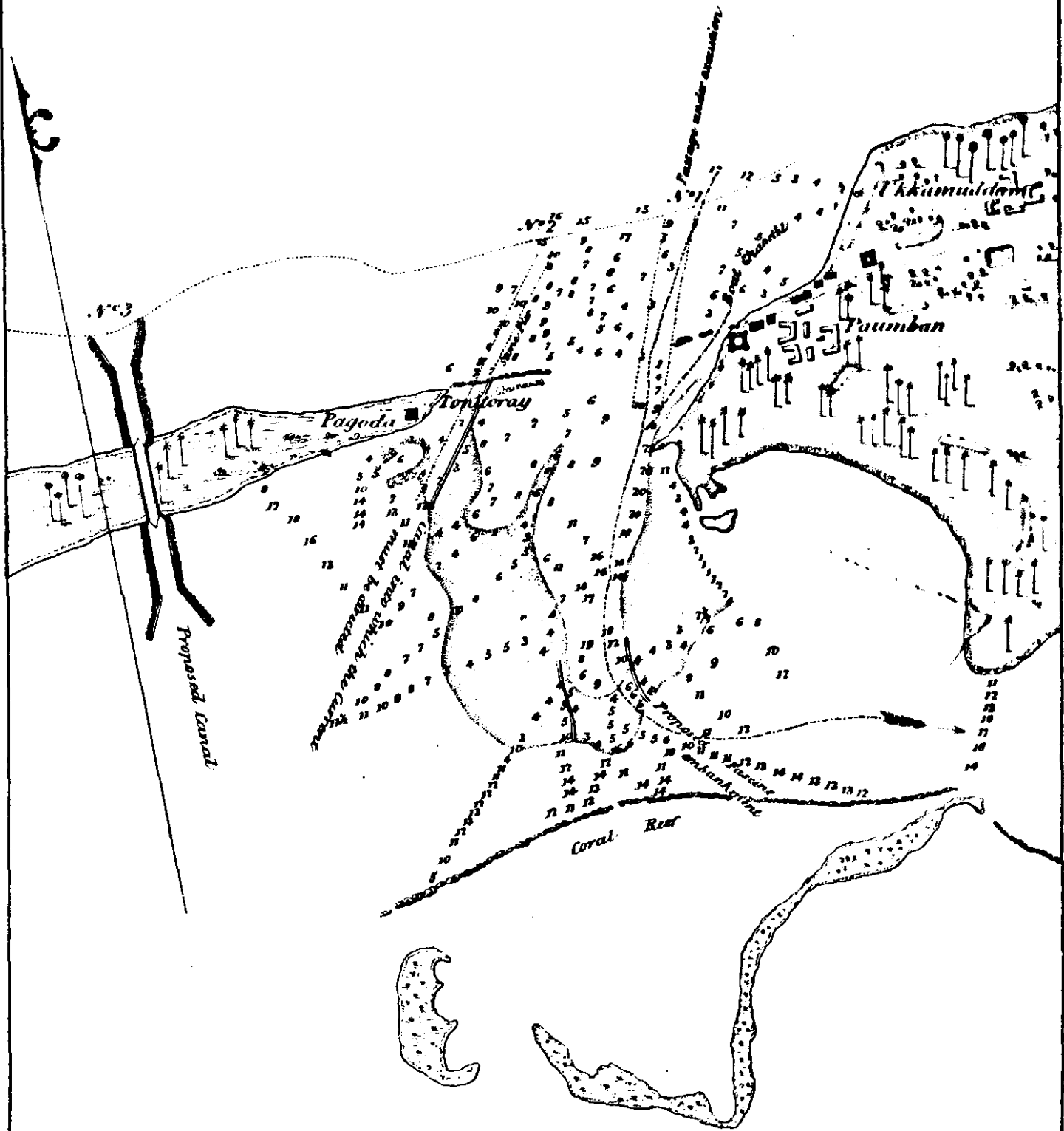
During both monsoons, on the lee side of the bank, to the distance of from half a mile to a mile, there are a great number of irregular shifting sand banks scattered about, on which there is from 2 to 4 feet of water, with passages between them eight or nine feet deep. The weather side, on the contrary, particularly towards the end of the monsoon, is in a great measure clear of such banks, and the surf breaks on its shore nearly in a straight continued line. When the monsoon changes, the strength and prevailing direction of the current changes too, and the loose sand of which the shifting banks are composed, on what was the lee side, being stirred up by the surf and sea, is swept by the current through the channels, and deposited on the opposite side, partly on the bars, and partly in loose detached heaps along the bank. These deposits appear to be further increased, by the sand thrown up on the weather shore by the surf, which as soon as it becomes dry, is carried by the wind across the bank into the sea on the other side. It was observed, when the wind was tolerably strong, that a continued stream of sand was swept across the bank into the sea on the lee side. The beach of Adam's Bridge therefore, to the distance of about a mile on both sides, is continually changing and shifting. On the weather side, it is generally clear, except immediately opposite to the channels, where there are always projecting bars, while on the opposite side, there are many loose banks scattered about, and constantly varying in position and extent, as the monsoon advances, and according to the state of the sea and weather.

During both monsoons, rather a high surf breaks on the weather side of the bank, but the south-west monsoon produces much the highest surf, accompanied by a long heavy swell. During part of the north-east monsoon, the surf breaks on both sides of the bank.

Dhonies in ballast, and fishing boats, occasionally pass through the openings in fine weather, but the passage is attended with some difficulty and danger, and is not common.

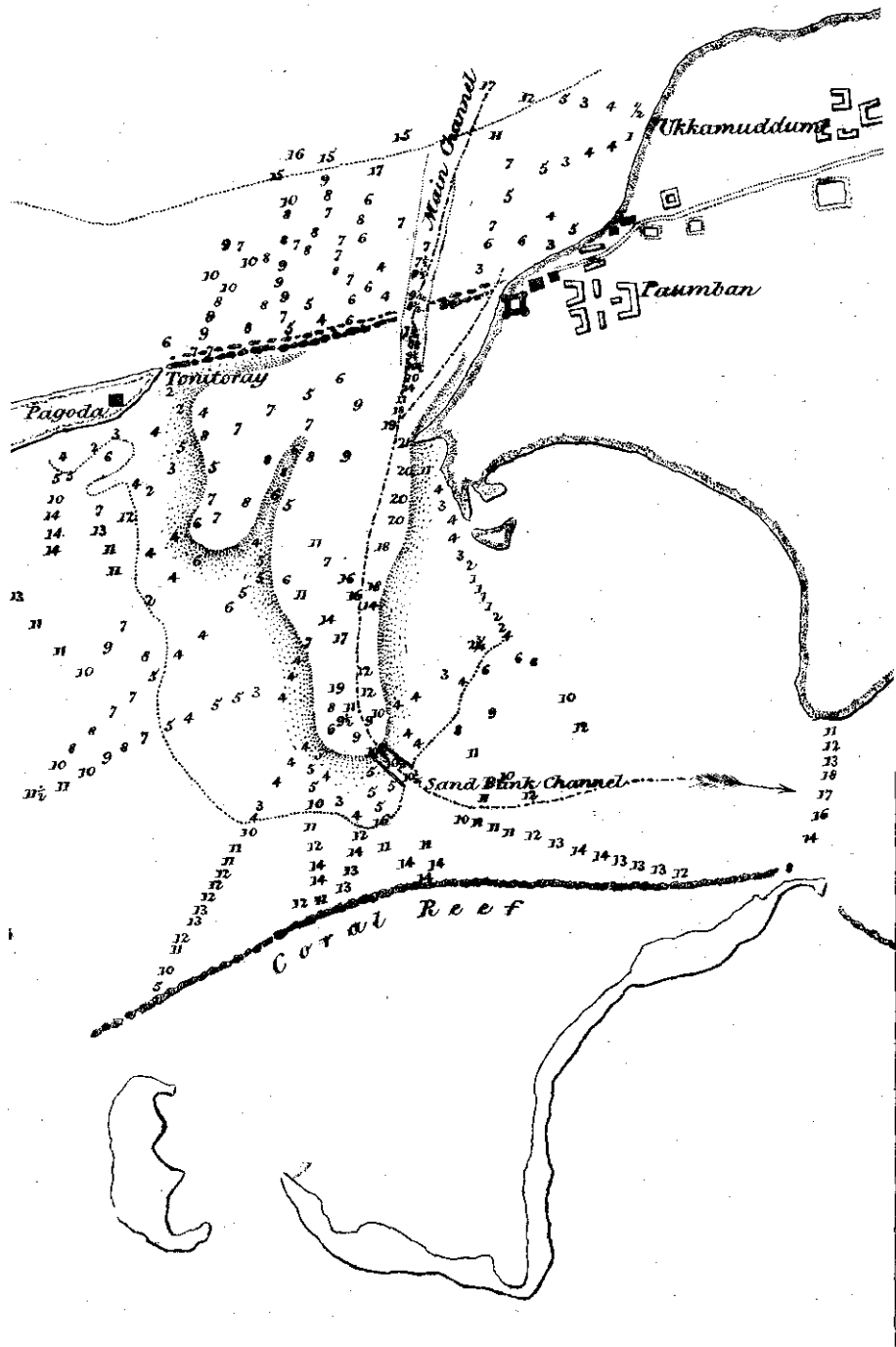
There is an account, I was informed, given in the records of the Dutch government of Ceylon, of a Dutch

*Sketch
showing the different plans proposed for opening a Passage thro'
Samban Straits, in 1829.*



Scale of 1/4 Miles to an Inch





fleet, having on one occasion escaped from a Danish fleet, by passing through the channels of Adam's Bridge. If this be authentic, either some of the channels must have been deeper in former days, or the ships must have been of a small size. It is probable indeed, that the depth and extent of the openings are constantly changing, from the effect of the current and surf, and the quantity of loose sand about the bank, and that they will not be found of the same size for any length of time. They appear to be affected by every change in the weather, the currents and surf, and most likely vary considerably in depth in different seasons.

If it be possible to obtain any where through the straits, a channel sufficiently deep for all classes of ships, it must, I think, be sought for in some part of this bank, and even here the practicability of opening such a channel, and of keeping it open, is very doubtful. A strong double bulwark of stones across the bank, extending into deep water on both sides, with a narrow opening of 100 or 200 feet, might, I think, with reason, be expected to accomplish the object. The velocity of the current would probably keep a narrow-fixed channel of that description always sufficiently deep, and sweep off any sand that might be carried into it, either by the sea or by the wind, and as the bulwark would extend into deep water, beyond the shifting sands, and the influence of the surf, there would be little risk, I think, of its ends being filled or choked with sand. The danger to be chiefly apprehended, is the formation of bars opposite to the ends of the channel, similar to what are now found in front of the natural openings, particularly on the south side, where, from the superior strength of the south-west monsoon, and heavy swell, sand banks are always the largest and most numerous, but of this, I think, there would not be much danger, the quantity of sand carried through the channel, from its being beyond the influence of the surf would probably not be very great, and as the current would be rapid, and extend into deep water, it is likely that what did pass through it would be dissipated and disappear.

The cost of such a work, would however be very great indeed, and could only be justified by its being considered an object of high national importance to have a passage sufficiently deep in time of war for the largest vessels. In the event of a struggle for the superiority at sea with an European enemy, the advantages of such a channel would be invaluable, but it is doubtful whether the benefits which commerce would derive from it, great as they undoubtedly would be, would warrant an undertaking, the expense of which, under the most favorable circumstances, must be very large, and the success from a variety of causes, which neither can be foreseen nor guarded against, uncertain.

There remains to be considered, the Paumban channel, or straits between Ramisseram and the Ramnad coast, which affords perhaps the only prospect of a moderately deep channel, such as would benefit commerce generally, and the coasting trade of India in particular, without the necessity of incurring a very large or disproportionate expenditure.

The examination of the Paumban passage, has accordingly, and in conformity with the instructions of Government, occupied the whole of the attention and time of the Officers deputed for the purpose of surveying the straits, with the exception of a few days devoted to the inspection of Adam's Bridge.

The obstacles to be overcome at Paumban, are a dam or ledge of rock extending from the island of Ramisseram to point Ramen or Tonitory, on the opposite coast of Ramnad, and an irregular sand bank, a little to the south of it, the exact situation and shape of which will be readily understood, from an inspection of the accompanying maps, on which the dam and sand bank, with the soundings in their vicinity, are minutely and accurately expressed.

The dam is 2250 yards in length, and runs east and west. It is bounded by two parallel ridges of rock about 140 yards apart. The north ridge is considerably the highest, and is termed the first or great dam. It is in most places visible at low water, though no where sufficiently connected to prevent entirely at any time the passage of the water. The line of the south ridge or dam, can also be distinctly traced at low water, but only a few detached rocks on it, even then appear above water. The whole or greater part of the space between these two ridges is filled up by large irregular masses of rock, in various positions, but generally in directions nearly parallel to the principal ridges, and usually several feet lower than them.

The continuation of the rock or dam, can be readily traced on the main land and island of Ramisseram, in its natural position, and in uniform layers, having a small inclination to the south, preserving exactly the same direction, but on both sides several feet higher than the dam.

The ridges which form the dam, are very much broken and displaced, and now consist of large flat masses of rock, seldom more than two or three feet in thickness. Their shattered state, and the break or chasm which they form in the general height of the stratum of rock, clearly indicate that the island of Ramisseram was at one time connected with the main land, and that it has been separated in the first instance by the sea, during storms, breaking over and bursting the chain of rocks which joined them, and afterwards by the water undermining, and displacing the broken fragments.

This supposition is confirmed by the records of the pagoda of Ramisseram, which relate, that until the early part of the fifteenth century, the island was connected with the continent by a narrow neck of land, and that the Sawmy of Ramisseram was carried across to the main land thrice every year on particular festivals. During the reign of Achoodapah Naig, Rajah of Madura, about A. D. 1480, a small break was made in the land, which formed the junction, by a violent storm, but as there was no great depth of water in it, travellers continued to cross on foot, till the time of his successor Vessovanda Naig, when the breach was much enlarged by a second storm.

The opening was filled up and repaired, to facilitate the passage of the pilgrims to the pagoda of Ramisseram, and the repairs lasted about 10 years, when a third hurricane destroyed them, and greatly extended the breach, after which no attempt was made to fill up the chasm.

Since then, every succeeding storm, has assisted in destroying and undermining the dam, and the inhabitants believe that its destruction is still proceeding, and that fifteen or twenty years make a sensible alteration in it. They state, that a storm occurs generally once in that period, and always displaces, and washes away a portion of the rock.

Besides the ridges of rock which constitute the dam, and which, as already stated, are about 140 yards in breadth, rocks and stones mixed with sand from the bottom, to a distance of about 800 yards on the north side of the dam, and 200 yards on the south side. Beyond 800 yards, the bottom to the north consists of mud and clay, with 14 feet of water, and on the south side beyond the rocks, it is soft mud and sand.

From a careful examination of the ground on the north side of the dam, by means of iron probes, and from the appearance of the beach on the Ramisseram and Ramnad coasts, it is probable that no connected layers or beds of rock extend further than 150 or 200 yards from the dam, and that beyond that distance, the bottom consists of detached fragments of rock and stone, mixed with hard gravel and sand. The bottom on the south side is similar, being composed partly of beds of rock, and partly of loose fragments.

The ledges of rock which form the dam, and the strata on both sides have been pierced and blasted in a great many places, and considerable quantities of the rock removed, for the purpose of ascertaining its quality and depth, and the nature of the ground beneath. The rock of the dam is considerably harder, as well as thicker, than what is found on either side, but the whole is soft and easily pierced and broken. It appears to be a sand stone of a soft description, and generally in an advanced stage of decay, varying in thickness from $1\frac{1}{2}$ to 4 feet, and resting on a bed of rough gravel. It is hardest at the surface, and becomes softer and coarser towards the bottom, which had indeed more the appearance of indurated gravel than of rock. The rock to the north and south of the dam, seldom exceeds $1\frac{1}{2}$ or 2 feet in thickness, and is in a very decayed state.

The several strata are found in their natural position on the island of Ramisseram, and on the opposite coast, and a number of wells having been sunk through them by the inhabitants, the quality and thickness of the rock are easily examined there, and correspond exactly with the preceding description.

In the dam, there are two channels, one about 500 yards from the eastern end, which is termed the large channel or river, and through which alone vessels at present pass. The small channel is 300 yards from the west end of the dam, it has only 3 feet of water on it,

is very narrow, and full of rocks, and in consequence, only used by canoes and boats.

The principal passage is about 50 yards broad, and is of very irregular depth, with a rocky bottom. In some places, it is not more than two and a half feet deep at low water, but there is a very winding narrow channel through it, just sufficiently broad for the passage of a dhoney, which is no where less than $5\frac{1}{2}$ feet deep at high water ordinary tides. This channel, from its very winding course, and little depth of water, is exceedingly inconvenient, and occasions great delay, and considerable expense, to all vessels passing through it. There is often a rapid current and heavy swell, and unless in very moderate weather, no vessel drawing more than 4 or $4\frac{1}{2}$ feet of water ventures through it, and in rough or stormy weather, it is often for several days altogether impassable.

The passage has always been confined to dhonies and other small vessels, chiefly belonging to native merchants. These, when coming from the northward, anchor at eleven or twelve hundred yards from the east end of the dam, in 16 feet of water on soft mud. There, they unship cargo, till their draught of water is reduced to 4 or 5 feet, according to the state of the weather, and then drop, or warp through the channel, as the wind or current are favorable or otherwise. After passing the channel, they anchor a second time, about 400 yards below the dam, in 12 feet water, and re-ship cargo till they draw about 6 feet. They then proceed to the southward, and cross the sand bank already referred to, about 2,700 yards below the dam, and on which there is not more than 7 feet of water when the tide is full. As soon as they cross the bank, they anchor for the third time to re-ship the remainder of their cargo, and then continue their voyage.

These operations usually occupy three or four days, even under the most favorable circumstances, and when the weather is stormy, the detention is considerably greater, for the Pilots will not then undertake to carry any vessel through the passage, and if this happens during the north-east monsoon, the vessels are obliged to remain at anchor to the north of the dam, in an open situation, exposed to the risk of being driven on the rocks to lee-ward. Moreover, when ten or twelve dhonies arrive together, which often is the case, the last are occasionally detained for a very considerable period. For, as they can only pass when the weather is moderate, and then only three or four during one tide, owing to the crookedness of the channel, it may happen that the whole number are unable to get through, while the wind and sea continue moderate, and then the last arrivals are obliged to wait ten or twelve days longer, for another interval of fine weather.

The expense attending the passage of the channel, and the bank below it, varies from 10 to 40 Rupees, according to the size of the vessel, and when the detention and risk of damage are taken into the account, the whole must form a very heavy burden on the coasting trade of the country, and greatly retard its extension and improvement.

The removal therefore of the existing difficulties and obstructions, and the improvement of the channel, so as to facilitate the passage of the vessels which now use it, and at the same time to admit of its being navigated by ships of a larger size and superior description, is an undertaking of much importance, and highly deserving of attention.

From the preceding remarks, and from an inspection of the Chart, it will be seen, that the removal of the rock which obstructs the channel, though that alone would be an improvement of much value, would not remove the whole of the difficulties at present experienced in navigating the Paumban channel, for, after passing through the rocks, there still remains a sand bank to be crossed, on which there is not more than 7 feet of water at high water ordinary tides.

The removal of this bank, it is to be feared, may prove a very difficult part of the undertaking; at all events, the success of any measures adopted for the purpose, is much more uncertain than if rock formed the obstruction, for where that is met with its removal can always be calculated on with certainty, though the expense may in some cases be great.

The bank, it is probable, consists chiefly of the earth and sand which composed the narrow neck of land that formerly connected the main land and island of Ramisseram, and of the sand washed out of the deep channels, beneath, and to the south of the dam, by the rapid currents over it, and through its openings. On the breaking up of the stratum of rock which formed the junction, the loose sand on which the rock rested, and by which it was protected, would on being uncovered, be swept away by storms, and by the rapid currents flowing through the openings and interstices among the broken fragments. These currents, after passing the rocky barrier, and reaching the open space to its south, spread, and lose their velocity, and being at the same time met by opposing currents from the east and south-west, the sand washed from among the rocks would be deposited in the place now occupied by the bank, where the water is comparatively still and smooth, being protected to the north by the dam, and on the south side by a chain of small islands.

The stream through the principal opening is extremely rapid at times, and as soon as it escapes from the rocks, and reaches the soft sandy ground, it will be seen, scooped out for itself a deep and extensive channel to the distance of upwards of a mile and a half. The sand from this channel being thrown up and deposited at its sides, and also to the southward, where the stream, by spreading, and meeting with opposing currents, loses its rapidity, has no doubt contributed to the formation of the bank. It does not appear that the bank is now subject to any material alterations or changes; the Pilots state that the depth of water has not altered within their memory as far as they can judge, and the irregularity of the soundings, which often vary from $1\frac{1}{2}$ to 2 feet in a very short distance, together with the quality of the

bottom, show that the sand is not frequently shifting as at Adam's Bridge. Nor does there seem to be any reason for considerable changes. The bottom of the sea to the north is either rock or clay, and the currents from that direction appear to bring very little sand with them; for the water during the north-east monsoon is usually clear, and free from mud or sand. Storms may produce material changes, and probably do, but whether these are permanent or not, there are no means at present of ascertaining.

A careful and attentive examination of the whole of the channel between Paumban and point Ramen, suggested the three following plans for its improvement.

1st. The present principal opening through the dam may be cleared of the rocks which obstruct it, and straightened, without increasing its depth.

2nd. The same opening may be deepened to $8\frac{1}{2}$, or 9 feet, at high water ordinary tides, or another channel may be opened of the same depth in some other part of the dam, if considered more expedient, and

3dly. A channel, 12 or 14 feet deep, at high water, may be formed either through the dam, or through the projecting point of land in the Ramnad coast, at the distance of about 2 miles west of point Ramen.

From the description that has already been given of the channel through which Dhonies now pass, it will be evident that much difficulty and delay must have arisen from the crooked and winding shape of the channel. There were several turns in it, and one in particular, where the current is the strongest, which increased the difficulty very much, and frequently, when the weather was rough, interrupted the passage entirely for several days at a time. It will be satisfactory to Government to know, that these obstructions have been all removed by the small working party which was authorized to be employed for the purpose of assisting in the examination and survey of the passage, and the channel rendered quite straight, and also a little deeper than it was formerly. Dhonies now pass through it quickly, using only one warp, instead of three or four, as they were obliged to do before the rocks were removed, and one or two keeled vessels, drawing about 6 feet of water, have sailed through. This alone is a very considerable improvement, for it will prevent much of the detention to the north of the dam, which has hitherto been unavoidable, and which was always attended with danger, and will at the same time admit of vessels passing through, drawing a little more water than formerly, by enabling them to pass when the tide is quite full. The party continues at work in the channel, and may be expected still farther to improve it, before the work is stopped by the monsoon.

The second plan, namely, opening a channel, 8 or $8\frac{1}{2}$ feet deep through the rocks, may be accomplished I think, with most ease and least expense, at about 1300 feet from the west end of the dam, where it will be observed from the Chart, there is $7\frac{1}{2}$ and 8 feet of water,

near the main dam on the north side, and within 100 yards of it on the south side. The quantity of rock therefore to be removed, to obtain a channel of that depth, would not be very great, while in its removal much comparative facility would be experienced, in consequence of there being very little current or swell to interrupt or retard the work. For the main dam at that place is tolerably compact and entire, and there is consequently very little current in its vicinity. By allowing a part of the main dam to remain till the last, to obstruct the current and swell, and by completing the channel on both sides before its removal, the greater portion of the work would be performed in comparatively smooth water, which is of very great consequence in blasting and weighing rock. The narrow part of the channel would also then be very short, not exceeding 150 or 200 yards in length, which would be a great advantage to vessels.

The objections to it are, that the anchorage and channel would be more exposed to the strength of the wind and swell during the north-east monsoon, than the present channel, which is sheltered in some degree by the west end of Ramisseram; and being farther removed from the eastern shore, the Pilots would have more difficulty in communicating with vessels, and affording them assistance in stormy weather.

On the south side of the dam, there is a projecting point of the sand bank, between the proposed place, and the deep channel opposite to the principal opening, on which there is not more than from $5\frac{1}{2}$ to $6\frac{1}{2}$ feet of water at low tide; if this were to remain in its present state, vessels, after getting through the channel, during the north-east monsoon, would be obliged to pass round the head of it in a direction across the current, which would evidently be attended with considerable difficulty to Dhonies and country craft. But, as this point of the bank is nearly in the direction which the stream through the new channel would take, it would, I have not the slightest doubt, be entirely swept away on the opening of the channel, for it seems to owe its existence to the absence of any strong current or stream in that part, in consequence of the compact quality of the dam there. The only real objection which I can perceive is its greater distance from the shore, and consequently greater exposure to the wind and swell during the north-east monsoon.

To deepen the present channel to the same extent would be a much more tedious and difficult undertaking. There, it will be seen, the shallow water extends to a much greater distance to the northward, for at 600 yards from the dam, the depth is only $6\frac{1}{2}$ feet at low water. To obtain a channel of the desired depth, it will be necessary, therefore, to excavate and deepen not less than 7 or 800 yards in length, while at the former place the distance does not exceed 200 or 250 yards. The difficulty of the operation also would be increased in a very great degree, by the distance from the dam; the heavy swell which often prevails, and the rapidity of the currents. These causes would retard the progress of

the work very greatly, and raise the expense proportionally, for when there is a heavy swell or rapid current, it is impossible either to blast or weigh the rock.

A large proportion of the space to be deepened, it is true, does not appear to consist of solid rock, but of fragments of rock and stones, firmly fixed in sand or gravel, and covered with weeds. It is probable, from the appearance of the adjoining beach and land, as has been already observed, that no large masses of rock would be found at a greater distance than 150 or 200 yards to the north of the dam, and that beyond that line the bottom consists of small pieces and fragments of rock, carried there originally by the current, and now firmly fixed in hard gravel and sand. These, generally, it would not be necessary to blast, as it is presumed they are not too large to be weighed entire; but still, much difficulty and inconvenience would be experienced in loosening and removing them, in an exposed situation, with a heavy swell, and in 5 or 6 feet of water. The bottom appears to be too compact and rough to be cleared and deepened by dredging, or by any similar means procurable in this country. A diving bell, sufficiently large to admit of two or three men working within it with short iron crowes and pickaxes, might be employed with great advantage, and would be highly useful. Divers, of whom there are great numbers in the vicinity, might also be used to assist, in loosening the fragments with the same instruments, and afterwards in raising them into boats or catamarans, either with the hand or with windlasses, as circumstances might require. An operation of this kind, subject too as it would be, to frequent interruptions from rough weather, it is evident, must be very tedious and expensive, and could not be completed probably in less than two or three years. But, of its success, I think, there is no reason to entertain any doubt, and it certainly would be a vast improvement. It would be more convenient and useful than a channel of the same depth at any other place, and there would be this advantage attending the plan, that to whatever extent the improvement might be prosecuted, whether continued to its full accomplishment, or stopped at any intermediate stage, no part of the work, if judiciously conducted, would be thrown away or prove useless, but all that might be performed, would in some respect or other be beneficial.

The only objection is the expense, which would be at least three times as great as the cost of a similar channel at the place already mentioned.

The advantages to be derived from an $8\frac{1}{2}$ or 9 feet channel through any part of the dam would be very important. Many of the smaller Dhonies would be able to pass through at once without any detention, and the inconveniences and delays now experienced by the larger vessels would be very greatly reduced. They would have to unship a comparatively small portion of their cargo, and when sufficiently lightened, would be able to pass through in almost any weather, and reach a perfectly safe anchorage, instead of being detained in a very exposed and dangerous situation.

What effect the improvement of the present channel, to the extent here contemplated, or the opening of a new one, might have on the sand bank to the south of the dam, it is impossible to foretell, but that a considerable change would be produced, appears to me very probable; and if the increased stream and currents were taken advantage of, and judiciously directed, it is not unlikely that the passage across the bank might be considerably deepened. But this forms no necessary part of the plan now under consideration, though, in the event of its being adopted, this branch of the subject ought to be carefully attended to, for without a very material change in the sand bank, the navigation of the straits, if the channel is made through any part of the dam, must remain very imperfect, and be confined chiefly, as it is now, to country vessels.

The third plan is to open a channel, 12 or 14 feet deep, either through the Paumban dam, or if it should be thought more advisable, through the promontory on the Ramnad coast. To form a channel of that depth through the dam, would be a very expensive and exceedingly laborious undertaking. The length of the cut would be upwards of 1200 yards, with an average depth of 4 feet to be excavated. The labour of blasting and weighing rock, when the depth of water exceeds 8 feet, is very great indeed, and almost impracticable, except in very smooth water. At the distance of 800 yards from the dam, the swell, during a great part of the year, is very considerable, and would add very greatly to the expense and labour of the work, for it could only proceed there during very moderate weather, and would be liable to constant and tedious interruptions.

Of the whole extent, perhaps not more than half would be found to consist of rock requiring to be blasted, and the remainder of fragments of various sizes mixed with gravel and sand, a considerable portion of which, it might be expected, would be swept away by the currents, on the removal of the rocky ledges or beds which now protect them—still the labour would be very great, and extremely tedious, and the undertaking would require several years, probably not less than five or six, for its accomplishment.

But even if the channel were completed to the proposed extent, I think it very doubtful whether the northern part of it would not be liable to fill up again. For, on the north side, at the distance of 800 or 900 yards from the dam, the current is not, I think, sufficiently strong, to keep such a channel clear, and the influence of the stream, through the enlarged opening of the dam, would scarcely extend to so great a distance.

The plan would also be incomplete without the removal of part of the sand bank to the south of the dam, or a considerable improvement at least in the passage across it. This, it has already been stated, is uncertain, under any circumstances, though I think the increased quantity of water and force of the stream which so extensive an enlargement in the opening through the rocks would produce, would contribute very materially to any measures that might be undertaken with that view.

Though at first sight the bank appears to resemble very much the bars which are formed opposite to the channels through Adam's bridge, still I think it is essentially different from them; as far as can be judged, it is permanent, and not liable to shift, and the principal causes which formed it, have it seems probable from the reasons assigned in a preceding part of this report, long ago ceased to exist, or at least now act in a very inferior degree. The bars opposite to the channels through Adam's bridge are most extensive on the south side, and are thrown up by the very high surf and heavy swell produced by the south-west monsoon, which acts with great force on the south side of the bank. But at Paumban, the space immediately to the south of the dam, where the bank is situated, is protected from the violence of the south-west monsoon by the range of islands to the south of it, which form a complete barrier, and comparatively little swell or surf are ever experienced there. Any alteration produced in the bank, would, in consequence, be the more likely to prove permanent, and I think that the current and stream might be so directed by means of stone bulwarks or jetties, as to produce a very great improvement.

But this plan, on the whole, appears to me much too laborious and expensive, and at the same time attended in several respects with too much uncertainty to be advisable, and if a 12 or 14 feet channel be considered absolutely necessary, I would recommend, in preference, that it be opened through the promontory of the main land.

In 1814, there was a very severe storm or hurricane at Ramisseram, during which the sea broke over the land in many places, and at about 2 miles from point Ramen, cut a channel completely across it. A ledge of rock on the south side of the land was destroyed and swept away, and a pit excavated 7 or 8 feet below the level of the sea, for a distance of 200 yards, from the end of which, to the north shore, the bed of the channel is 3 or 4 feet above the level of the sea. The gale from the northward lasted only about 4 hours, had it continued a few hours longer from that direction, it is probable that there would have been a deep channel formed entirely through the land, though most likely it would not have continued open for any length of time, for the surf which breaks on both shores, but particularly on the south side with considerable force, not being counteracted by a sufficient rise and fall in the tide, would probably, in a short time, have filled its ends with sand.

The breadth of the land here is 728 yards. It consists chiefly of loose sand, with a little soft decayed rock mixed with it in some parts, which is easily broken with the hammer and pickaxe. On the north side, there is a reef of coral, not solid or connected, but in detached masses, and of no great breadth, for at 400 yards from the shore, the water is 14 feet deep. On the south side, the water deepens very rapidly, the depth at 100 yards from the shore being $2\frac{1}{2}$ fathoms. A channel, 12 or 14 feet deep, might therefore be cut here, with comparatively little difficulty and at a moderate expense, and being

to the south, and entirely clear of the bank beneath the Paumban dam, the removal of that bank or a passage across it, would form no part of the undertaking. It is probable, however, that the channel would not remain open, without some contrivance at its ends to prevent the surf from filling them up with sand, and this would, it is to be apprehended, be the most expensive and uncertain part of the project.

The easiest and most likely way to effect the object, would, I think, be to carry a double bulwark of large stones from both shores in a continuation nearly with the sides of the channel, into deep water, beyond the influence of the surf. The ends of the channel thus terminating in deep water, it does not appear, that any cause would exist there to fill them with sand, for they would be beyond the reach of the surf, and there are no currents likely to produce that effect. It is probable that very little sand would enter the channel, and that whatever did enter would be swept away by the current through it, which, at all seasons of the year, would be considerable. The principal danger to be apprehended is, the formation of a sand bank to the south of the channel, or bars opposite to its ends, as occur before the natural openings in Adam's bridge. This apprehension is perhaps not entirely without grounds, but if, on the completion of the channel, any symptoms of either a bank or bar should appear, I think the formation might be entirely prevented by constructing a second bulwark of stones in front, and perpendicular to the ends of the first bulwark, at 100 or 200 feet from them. This narrow opening between the two bulwarks would be swept by the south-west monsoon and currents produced by it, which would most likely keep it always deep and free from sand. On the north side there is much less danger of any banks forming, for there are none opposite to the Paumban channels, and the sea beyond the rocky ground is clear and free from obstructions of every kind.

After fully weighing all the advantages and risks attending the opening of a channel, 12 or 14 feet deep at this place, I think there are good grounds for considering the undertaking to be practicable, but in deciding on the expediency of adopting or rejecting it, it is necessary to take into consideration, the possibility of a partial or complete failure, for the projects is so entirely new, and so unlike any thing that has hitherto been undertaken in India, that no comparison can be made with the result of other works of the same kind, and no information therefore drawn from experience, while at the same time the nature of the currents, their strength and direction at different seasons of the year, and the manner in which they are affected by the opposite monsoons are all in a great degree still to be learnt.

Respecting the expense of the different projects, from what has already been said, it will be evident, that much uncertainty must necessarily exist, and that it is impossible to form any thing like even an approximation to a correct estimate. The expense will depend greatly on the season being favorable, or otherwise, the exact qua-

lity and nature of the ground beneath the surface at the place where the channel may be opened, on the currents, and the effect they may have in accelerating the operations, by sweeping away the sand and loose soil when the solid rock is removed, or retarding it, by producing in some cases a contrary effect, and on a thousand other circumstances, which it is impossible to foresee, and which can only be discovered as the work advances. In the present state of our information, a general plan, or course of proceeding only can be laid down, which will be liable to constant changes and modifications, and whichever of the projects that have been suggested, may be preferred, it will be necessary to leave a great deal to the discretion and judgment of the Officer who may be intrusted with its execution, not only as to the manner of proceeding with the work, but also the means to be used, the expense to be incurred, and the extent to which the undertaking may be carried with advantage. The following sums must therefore be considered as very rough guesses only, which may exceed, or fall short of, the actual cost to a very considerable extent.

The plan of opening a channel, 8 or 9 feet deep, and 50 feet wide, through the dam, at about 1300 feet from its west end, may be calculated at 70,000 Rupees, and two seasons would probably be required for its completion.

Deepening the present channel to the same extent cannot be estimated at less than 1,500,000 rupees, and probably three years would be required to complete it.

The practicability of opening a channel, 12 or 14 feet through the dam, and of keeping it open, appears to me so uncertain, with our present knowledge, that it cannot with propriety be recommended, and it is unnecessary therefore to consider its expense.

Cutting a channel through the main land, where the sea made a breach in 1814, would cost probably from $\frac{1}{2}$ to 3 or 4 lacs of rupees, according to the nature and extent of the works that might be required at its ends, to prevent them from filling up with sand, and an equal uncertainty of course exists with respect to the time required for the performance of that project.

From a review of the several plans that have been proposed, it will appear, I think, that, if a channel of 8 or 9 feet through the rocks be required, without reference to the removal of the sand bank to the south, or the improvement of the passage across it, the most advisable place for such a channel, is, at about 1300 feet from the west end of the dam.

If it should be considered expedient to confine the operations in the first instance to an 8 or 9 feet channel, but to keep in view the chance of extending the depth afterwards to 10 or 12 feet, if circumstances and experience should justify the measure, it is probable that deepening the present channel would be the most desirable and safe way of prosecuting the undertaking. Though much more expensive, it is the more certain, and the channel would be in the most convenient situation.

The removal of the works which obstructed this channel, have altered it considerably since it was inspected in last March, and in some places the layer or crust of rock which covered its bottom has been entirely removed. It is extremely desirable that the effect of one north-east monsoon should be seen on the channel in its altered state, before any final conclusion is come to, respecting its comparative merits and defects with those of the proposed new channel near the west end of the dam. If there is only a covering or crust of rock, as there seems every reason to believe, the rapid current through the channel during the north-east monsoon, may, as that is now removed in several places, produce considerable alterations, not only on the channel itself, but on the ground to the north and south of it, and this, it is highly desirable to ascertain, before the expediency of improving or abandoning the channel is decided.

If a channel of 12 or 14 feet is considered an object of sufficient importance to warrant the attempt, under the uncertainty which now exists, with respect both to success and expense, and the imperfect state of our knowledge on the subject, I think the plan of opening a channel across the main land, where the sea broke over in 1814, ought to be adopted.

The best seasons for working, whatever plan is preferred, as far as can be judged from the experience of the present year, are, from the beginning of March to the middle of May, and from the end of August to the commencement of the north-east monsoon. There are occasional intervals of fine weather in the months of February and August, which might also be taken advantage of, but more than four or five months in the year cannot be calculated on for carrying on the work with advantage. The sea appears to be smoothest and least affected by currents from the beginning of September to the middle of October, and during that period, the improvement to the north of the dam, or promontory, ought to be executed; for in the north-east monsoon, the water there is generally too rough to admit of the work being prosecuted with much success. In the months of March, April, and May, the rocks to the south of the main dam might be removed.

The process of boring and blasting rock under water, was readily learnt by the small party of Pioneers employed on the survey, and after a little practice, was conducted with much success. In blasting the rock previously to removal, jumpers 6 inches in diameter were generally used, and found most efficient. They were worked by three men at a time, on a low raft, formed of two large canoes lashed together, and covered with loose planks. After a great number of experiments with different quantities of gun powder, charges of from 4 to 6 lbs. were thought to produce most effect and were usually employed. The rock was bored quite through, the object being to separate and displace the fragments completely, and the charge covered with gravel and small pieces of rock and coral. The gunpowder was fired in the usual manner by means of tin tubes. The large fragments were weighed by means of a common country boat furnished with a windlass, derrick and tackle. Slings,

made of strong rope, were placed round the fragments by divers, to which the tackle was made fast, and in this way pieces of rock, 3 tons in weight, were occasionally raised into the boat. The apparatus was very imperfect, the flat boat, and the small supply of timber sent from Madras for this part of the operations, having been lost on the way down to Ramisseram, and the only substitutes procurable on the spot, were a clumsy country boat and some drift timber. The small pieces of rock were brought up with the hand, by divers.

The most convenient and expeditious apparatus for weighing and removing the fragments of rock, in future, would perhaps be a large flat boat, partly decked, furnished with a double set of derricks, windlasses and tackles, so arranged, as to be used at the same time on opposite sides or ends of the boat. To save the necessity of raising the fragments into the boat, which was found very difficult, and attended with much delay, there ought to be three or four double canoes with decks, to receive the rock, and convey it to the places where it is to be deposited. There would then be no necessity for changing the situation of the weighing boat, when once placed, till all the broken rock within its reach was removed, which is a point of much importance, for it was found a very troublesome and dilatory operation to fix the boat in the right spot, when there was much current.

The canoes of the boring rafts ought to be decked, to prevent them from filling with water and sinking, which they are apt to do, when there is any considerable swell.

A diving bell, which might be made at Madras, would be of great use, for examining the bottom, and fixing the most convenient places for blasting. The divers, it was soon found, could not be safely entrusted with this; they usually directed the jumper to the first rock they happened to meet with, and frequently caused the same rock to be bored several times, which occasioned the loss of much time and labour, and left the rock imperfectly broken, and in a very unfit state for farther blasting. Much depends on the selection of the points for boring and blasting, and a diving bell would enable the Officer in charge of the work, to regulate this part of the operation himself.

When the water was tolerably smooth, and the current not strong, very little difficulty was experienced in blasting and weighing rock at the depth even of 8 feet, but when there was any considerable swell, or a rapid current, it was impossible to proceed with the work; hence the great advantage in respect both to time and expense, in selecting such a situation for the channel, as will afford smooth water for the longest periods.

In conclusion, I beg to observe, that it would afford me much satisfaction, if Government, previously to adopting any of the preceding plans, or coming to any final resolution on the subject, would be pleased to forward to the Honorable the Court of Directors, for the purpose of being submitted to experienced Civil Engineers in England, copies of the charts of the straits, and of all the information which has been collected during the late survey. The improvement of the navigation through the Manar straits is an object of so great value

and importance to Indian commerce, and so much depends on the choice of place, and on the means to be used, that every precaution ought to be taken to obtain the best possible information and advice on the subject, and a delay of a year or two is of little consequence, when compared with the advantages which might possibly be derived from the opinions and advice of Engineers in Europe, who have been employed on similar undertakings.

If this suggestion should meet with the approval of the Right Honorable the Governor in Council, I would further beg to propose, that the papers should be intrusted to the care of Captain A. T. Cotton, who it is likely, will be obliged to proceed to England in January, for the benefit of his health, and who having been employed at Paumban during the whole of the survey, and having had the immediate charge and direction of the experiments, will be able to afford information on many points, which cannot be sufficiently explained by either charts or reports.

Pending thereference to England, I would recommend that the observations on the passage should be continued, and that the present party of Pioneers, increased to 50 men, with some ship Lascars and divers, should be employed under the direction of an Engineer Officer, in the improvement of the present opening, and in making some experiments on the bank to the south of it. Whatever the final decision may be respecting the more extensive improvements, the labour of such a party cannot fail to be very beneficial, while the expense would be inconsiderable, and much valuable information would be obtained, which would be highly useful in the event of the prosecution of the work afterwards on an extended scale.

It is due to Captain A. T. Cotton, and Lieutenant F. Cotton, to make known to the Right Honorable the Governor in Council, the valuable and zealous assistance afforded by both Officers in the performance of the duty at Paumban. The survey and experiments were, with the permission of Government, placed under the direction of the former Officer, and have been conducted by him to my entire satisfaction, and with great skill and judgment.

(Signed) D. SIM,
Inspector General.

26th Nov. 1829.

REPORT BY LIEUTENANT G. C. COLLYER, JULY 1845.

The Paumban passage, is a channel through the barrier or reef of rocks, connecting the island of Ramisseram with a peninsula of the continent of India in the Madura district, at a place called point Ramen, or Thonitory.

The reef of rocks forming the barrier through which the channel has been cut, consists of three separate ridges, two running parallel to, and at about 100 yards from each other. Of these, the northern one alone slightly protrudes from the water, the middle one is visible at low water—the southern one is 300 yards from the

middle, and is not so; and does not, as the others do, run across the channel, but terminates a little to the east of it. The rock is sand stone, sand-stone, grit and a conglomerate of sand and shells, of different degrees of induration, but generally easily perforated by an iron jumper, is Lamellar, dips at an angle of from 12° to 15° in a south easterly-direction, (having fissures filled with sand, pieces of coral &c.) and extends down to a maximum depth of 12' 4". This reef is most certainly not a work of art, but part of a natural formation, which extends both ways, across the island of Ramisseram, and into the continent for miles, easily to be traced, (there are quarries in the island of Ramisseram, where the stone is compact and of a fine grain, and good quality, and not perforated with cavities, as on the opposite shore, whence stones for building the odas &c., have been excavated.)

The improvement of this reef, so as to make it navigable, has at various times been agitated; reports have been framed by Captains Fullerton, and Arthur Cotton, of the Engineers, and some, though not extensive operations carried on by the latter; principally confined however to try and open a channel or canal through a part of the peninsula 1½ miles to the west of point Ramen—(where a cut had been made by the sea in 1814) so far back as 1822—but it appears finally to have been determined, that the present cut was upon the whole, the one which promised the most certain result at the least expense.

In the year 1829, during Mr. Lushington's government, when but little was known of the passage, Lieut. Col. Sim was deputed to examine it, and report upon its capabilities, and reported that, "at the date of his examination, the principal channel through the rocky reef connecting the main land and the island of Ramisseram, was scarcely four feet deep at low water, very tedious and obstructed with rock, all vessels making use of the channel were in consequence obliged, before attempting to pass through it, to anchor at some distance, unload the greater part of their cargoes, and then warp through; this was always a tedious and a troublesome process, and during the N. E. monsoon was occasionally attended with both danger and loss."

Called the "sand bank" and the channel the "sand bank channel."

"About 1½ miles to the south of the reef, there is a bank of sand and mud to cross, with about 5 feet of water at low tide, the existence of which was not generally known previously to the survey of 1829, and the only obstacle to the navigation of the straits, it was supposed, was the reef of rocks."

Several of the obstructions were removed subsequently to Captain Sim's examination in 1829, by Officers of Engineers, under the orders of Major General Monteith, K. L. s., and in 1838, Lieutenant Jenkins assumed charge of the work under Major General Monteith's orders. He reports, "that he found a channel with 5½ feet water in it, had been made the previous year, but it being narrow

Vide a letter from Lieut. Jenkins dated Paumban August 11th 1844.

and winding, and in some places at an angle with the set of the current, its navigation was difficult; as in case of a vessel grounding, the current forced her on her bilge up the bank, and on many of the banks there was only 3 or 4 feet of water."

"In the course of the season 1838—the channel was by order of the Chief Engineer, made nearly straight, and widened to 70 feet, the banks were cleared away, but the depth of water was not much increased. A cut

The Horse shoe channel is to the north of the channel at its entrance.

was also made in 1838 through the channel in the Horse shoe bank, increasing the depth of water in it about 1 foot. I have lately examined the bank, and find it after two monsoons, in precisely the same state as it was when the works upon it ceased."

"North of the channel, and between it and the anchoring ground, there is a coral reef about 500 yards broad, with only 6½ and 7 feet water on most part of it."

"The present channel is 600 yards long and 70 feet wide."

Vide letter from Lt. Jenkins to Maj. Gen. Montelth K. L. S. dated 21st Oct. 1839.

"In Oct. 1839, the breadth had been increased in nearly every part to 100 feet, except between the reefs, where it is about 75 feet broad."

"The least water now in the channel for vessels is 6½ feet at low water spring tides, which allows of a vessel drawing about 7 feet of water, to pass through on any day, and those drawing 8 feet, can pass through with ease on spring tides, (the water rises 2'2") allowing half a foot to spare. Many of the coasting vessels now sail through with a full cargo, and some of a good size, (as the Lutchmee of 60 tons) have done so, without even taking a pilot."

* Vide letter from Lieut. Jenkins to Major General Montelth K. L. S. Chief Engineer 1st November 1841.

In November 1841, the channel is reported to be 8 feet deep at low water, that is, about 50 feet* wide, the centre of the channel is cut to that depth, with a slope to between 5 and 6 at 30 feet. In the extreme ends of the channel there will be a little blasting required, should the works be prosecuted after next season, as also in a few places in other parts, but generally it may be said that the crust of the rock has been cut through. A good steam dredge, would I think in three years clear out the channel to 10 or 11 feet at low water; the Horse shoe bank is so shallow, however, that the full benefit of this increased depth, cannot be derived.

Vide a letter to Colonel Sim dated May 1842.

In May 1842, the depth of water over the Horse shoe bank had been considerably increased, but the exact depth is not stated, however it had not attained a depth of 8 feet.

Vide letter to the Adjutant of Engineers, dated Pamban 16th May 1843.

On the 2nd April 1843, it appears by a report from Lieutenant Robertson, who assumed charge of the works in July 1842, "that a depth of 8 feet had been obtained throughout the Horse shoe channel, and that on the 16th May, a great part of it had been cleared out to 9 feet at

neap tides. On the 11th September the sand bank channel had been cleared out to a depth of 9 feet at neap tides."

Vide letter from Lieutenant Robertson to Chief Engineer of that date.

On the 14th November 1844, the Officer in charge, reports the channel, as will be seen by a plan forwarded to the Chief Engineer, is not quite so straight as has been represented, and notwithstanding all the work, there are spots where it is not quite so deep; the soundings through the centre of the passage, which have been placed as close as possible, cover an extent of 80 feet. The remarks placed along the course of the channel apply to the sides, not the centre passage, where, with the exception of the places, where a less depth of water than eight feet occurs, the whole of the rock has been removed as far down a the south post.

From the above extracts of the reports of various Officers employed on this work, from 1829 to November 1844, it appears, that tho' a very gradual, still a very great improvement has taken place; that a tedious, dangerous, and expensive navigation, and that only for the smallest craft, has been rendered safe and commodious for all descriptions of vessels drawing 8½ feet of water, and that by taking advantage of extraordinary spring tides, vessels drawing even 9½ feet, may, without being unloaded, get through safely.

Vide letter 24 May 1843 to the Chief Engineer.

The Honorable Company's steam vessels Nemesis and Pluto have also made use of this channel, and Captains Fells and Airy, commanding these vessels, gave it as their opinion, that by making use of this channel instead of rounding Ceylon, they had gained three days in time, and saved upon the two vessels, fuel to the amount of 1100 rupees. A very sufficient proof, moreover, of the utility of this passage is, that during 1843: 98,238 tons of shipping, and in 1844 115,939 tons of shipping passed through the channel, shewing an increase of 17,701 tons upon the year, and a total for two years of 214,177 tons.

The money expended hitherto upon this great and important improvement, (exclusive of Jail establishment and Sappers and miners), amounts to 77,301 10 7. The profits on vessels deducting the expense of the Pilot establishment, amounting to Rs. 14,368 2 8.

The particulars of these expenditures and receipts are in the appendixes.

Appendix A. shipping.

Appendix B. receipts and disbursements.

Appendix C. particulars of material removed from the channel, from January 1841 till October 1844.

There is a difference between Captain Jenkins' and Lieutenant Robertson's reports, as to the depth of channel at low water; and now, notwithstanding the vast quantity of material removed by Lieutenant Robertson, since Captain Jenkins' departure, there is still a considerable deal of rock to be blasted, before it can be said to be cut through.

STATE OF CHANNEL IN 1845.

The plan accompanying this report, shews the state of the channel (from soundings taken across it at every 10 feet) as taken on the 19th and 20th June 1845, from this it appears, that there are still places, and those in the "channel," where there is but 8 feet of water at neap tides, and from the section, which contains a series of borings made also in June 1845, under my instructions, it appears that there are still in places, upon an average, from two to two feet 4 inches of sand stone, coral &c., to blast and remove, before the rock will be cut through; this rock is as hard and compact as that which has already been blasted, and I judge so from the fact, that it takes as long to bore through this remaining two feet, as through any other two feet; the borings are sand stone of grey and yellowish white colour, after the jumper has penetrated as far as marked in the section it goes down easily, and the clearings of the holes or borings raised are blue mud and sand.

The part of the channel called the Horse shoe channel is 8 feet deep; the bottom of this composed partly of what is here called dead coral, (brain coral) it occurs in boulders imbedded in the sand, and is easily, from its lightness, removed by a weighing Dhoney, when the sand has been removed from around it. In this channel there are also one or two places where it is but 7½ feet deep. These are now being blasted.

The sand bank channel is generally 10 feet deep at neap tides, and is, I am informed, by Corporal Elder of the Sappers, (who has been here 16 months, and appears an observant and intelligent person) continually, though gradually, being deepened by the action of the current, which is in accordance with the opinion expressed by Maj. Gen. Monteith K.L.S.

This channel has been cut through, at the part indicated as having been deepened by the current, in that report, and the result proves the judiciousness of having done so; its direction is moreover favorable for shipping going to Columbo, which is the great bulk of the trade, and it is after all not out of the way for vessels going to Malabar (not above 1 mile.) It has, I believe, been proposed to open a direct cut through the bank, instead of the present one, or in addition to it, as more convenient for the the shipping to Malabar. I think it would be very objectionable to do so, as it would not only be liable, by the current being divided and weakened, to silt up from the inside, and but by breaking the force of the current on the other, perhaps cause it to fill up also, and would be liable to be choked by silt from the low islands to the south. Its present state is good, and quite sufficient for all the wants of the trade.

I am of opinion, that 10 feet at neap tides, is amply sufficient depth for the channel between the reefs; this will allow vessels of 11' 6" draught of water to go through at high water, without unloading. Very few of the Dhonies, and indeed a very few vessels of any build, very likely to be employed in the coasting trade, draw more than ten feet water, those which do, are exceptions, which it is

not worth while going to a very great additional expense to accommodate.

2ndly.—All the vessels in the coasting trade, (either from inability to beat against the monsoon, or want of skill on the part of the commanders) going to Malabar, use what is called the "inner passage," (a passage in which there is only 12 feet water) between Killeecary and the range of small islands opposite, and so coast along.

3dly.—Because, from General Monteith's report, it appears, that there is not more depth of water on the Ceylon coast, for the coasting trade; and lastly, because it was the opinion of Admiral Owen, that large vessels would not find it to their advantage, to run all the risk of a confined and dangerous navigation, for a questionable saving in time.

I trust I have satisfactorily shewn that an uniform depth of 10 feet at neap tides, which will allow of vessels drawing 11½ feet of water to pass through at the proper time of the tide—(and which would be, as pointed out above, enough for all ordinary wants) is amply sufficient.

The width indicated between the posts, as they are at present placed, is 200 feet, this I think unnecessarily wide; the channel however now is not more than 80 or 90 in some parts. Mr. Ebell, the head pilot here, concurs with me in opinion, that a channel of 100 feet in width, will answer every purpose that can ordinarily be, or is ever likely to be required, that if this channel is as nearly straight as can be, and the indicating posts removed into the sides of it, there need be no excuse for running vessels aground.

From the above circumstances, I have confined myself in the estimate to a channel of 10 feet deep at neap tides, and 100 feet in clear width.

I have been induced to send in these reports and estimates, without waiting for the steam dredge. Had the steam dredge been here in 1841, much benefit in point of time, would have been reaped from it; the sand bank channel, for instance, which it took nearly a year to cut through, might have been done in probably ½ or less of that time; but in the actual cost, I do not think it would have been less, there being an expensive establishment belonging to it; and though it is true, that prisoners cut the fuel, still they would otherwise be elsewhere employed.

Between the reefs the steam dredge, will not, I anticipate, be of any use, but in the Horse shoe channel, notwithstanding the coral (which has sometimes yielded even to the hand dredge) it will I hope be found useful.

I shall not lengthen this report with a detailed statement, either of the different nature of the soils at the bottom of the channels, or method of carrying on the works, (which I have put into appendixes D and E) but it is due to Lieutenant Robertson, to point out, how much by his attention and management, he has reduced the expenditure on almost every item of the work, since he has been in charge of the operations, and that consequently future operations, as well as those now proceeding under Lieutenant Gib, will be economically carried on.

PAUMBAN,) (Signed) G. C. Collyer Lieutenant.
July 1845.) Asst Civil Engineer 8th Division.

APPENDIX A.

General Summary of Vessels of different descriptions that passed the Paumban Channel during the years 1843 and 1844.

1843.									1844.									Total number of ves- sels for two years.	Total amount of Tonnage for two years.
Steamers.	Barques.	Brigs.	Schooners.	Sloops.	Cutters.	Dhories.	Total.	Total Tonnage.	Steamers.	Barques.	Brigs.	Schooners.	Sloops.	Cutters.	Dhories.	Total.	Total Tonnage.		
2	1	185	201	13	17	1,220	1,639	98,238	2	0	230	263	13	6	1,645	2,159	115,939	3,798	214,177

A correct Statement of export and import duties connected with the Sea Customs at Paumban, during the years 1843 and 1844.

1843.			1844.			1843 and 1844.		
	Rs.	A. P.		Rs.	A. P.		Rs.	A. P.
Export.....	908	2 1	Export.....	1072	6 10	Export for 2 years.....	1980	8 11
Import.....	612	6 2	Import.....	382	3 7	Import.....	994	9 9
Stamp.....	184	4 0	Stamp.....	464	8 0	Stamp.....	684	12 0
Anchorage.....	2405	0 0	Anchorage.....	2824	8 0	Anchorage.....	5229	8 0
Pilotage.....	5677	4 0	Pilotage.....	6402	8 0	Pilotage.....	12,079	12 0
Total Company's Rupees..	9787	0 3	Total Company's Rupees..	11,146	2 5	Total Company's Rupees..	20,933	2 8

Pilot Establishment Per Mensem.

Head Pilot &c. &c. Rupees per month.....	100	0 0
1 Native Head Pilot.....	15	0 0
4 Native Assistant Pilots at 12 each.....	48	0 0
4 Do. do. do. at 10 ..	40	0 0
1 Gomastah @ 7 Rupees per month.....	7	0 0
6 Custom House Peons @ 3½ Rupees per month each.....	21	0 0
For oil, paper, ink &c. &c.....	0	14 0
Total Company's Rupees..	231	14 0

APPENDIX B.

The following are the dates of the sanction received from Government for the charges incurred from the year 1837.

Vide Chief Engrs. letter to Govt. dated 24th December 1840 Page 137.	} Expenses incurred during the year 1837.....	Rs.	5,527	15	2			
4th & 6th Jan. 1841. p. 1-10.		Do. do. 1838.....	6,919	5	2	23,308	1	2
Vide letter to Government 2d April 1842		Do. do. 1839.....	10,860	12	10			
Do. do 18th June 1842.		Do. do. 1840.....	14,098	8	0	14,098	8	0
Do. do 10th Jan. 1844.		Do. from December 1840 to October 1841	12,097	3	0	12,097	3	0
Do. do 27th Aug. 1844.		Do. from November 1841 to April 1842.....	4,233	11	5	4,233	11	5
		Do. from July 1842 to February 1843.....	3,987	12	9	3,987	12	9
		Do. for May and June 1842.....	1,153	3	0	1,153	3	0
		Do. from March 1843 to January 1844.....	5,794	3	10	5,794	3	10
		Do. from February 1844 to June 1844.....	3,158	0	8	3,158	0	8
		Total....			Rs	67,830	11	10
<i>The following are the amounts disbursed but not sanctioned.</i>								
	Expenses incurred for July 1844 by the Superintendent.....		878	14	1			
	Do. do. August.....		1,186	2	4			
	Do. do. September.....		525	7	9			
	Do. do. October.....		510	13	2			
	Do. do. November		100	5	0			
	Do. do. December.....		108	10	0			
	Do. do. January 1845.....		119	11	0			
	Do. do. February.....		667	12	10			
	Do. do. March.....		608	3	7			
	Do. do. April.....		415	7	8			
						5,121	7	5
May 9th.	Cash remaining in the hands of Superintendent.....					349	7	3
" 6th	Do. Authorized by Government.....					1,000	0	0
" 27th.	Do. Remaining still to be drawn.....					3,000	0	0
		Total....				77,301	10	7

APPENDIX C.

Commencing January 1841.	Sand and Mud.	Stones.	Coral.	Sand and Shingle.	Cubic feet	REMARKS.
January. - - - - -	27,920	"	"	"	"	
February. - - - - -	20,440	611	"	"	"	
March. - - - - -	5,630	19,939	9,450	4170½	"	
April. - - - - -	"	21,968	14,239	8,983	"	
May. - - - - -	"	5,963	7,829	10,644	"	
June. - - - - -	"	5,355	2,751	12,730	"	
July. - - - - -	"	3,834	12,306	11,983	"	
August. - - - - -	"	9,915	24,819	18,214	"	
September. - - - - -	"	1,988	10,020	28,033	"	
October. - - - - -	"	4,485	7,772	27,394	"	
November. - - - - -	35,988	"	"	"	"	
December. - - - - -	66,423	"	"	"	"	
Total for 1841. -	156,401	74,058	89,186	122,151½	"	
January 1842. - - - - -	48,073	"	"	"	"	
February. - - - - -	62,484	"	"	"	"	
March. - - - - -	105,070	"	"	"	"	
April. - - - - -	68,622	"	"	"	"	
May. - - - - -	28,352	"	"	"	"	
June. - - - - -	46,456	"	"	"	"	
July. - - - - -	44,052	"	"	"	"	
August. - - - - -	29,088	"	"	61,488	"	
September. - - - - -	78,412	"	"	"	"	
October. - - - - -	88,051	"	"	"	"	
November. - - - - -	81,963	"	"	"	"	
December. - - - - -	93,234	"	"	"	"	
Total for 1842. -	773,857	"	"	61,488	"	
January 1843. - - - - -	99,534	"	"	"	"	
February. - - - - -	"	"	"	"	"	
March. - - - - -	"	"	"	"	"	
April. - - - - -	"	"	"	"	"	
May. - - - - -	"	"	14,811	"	"	
June. - - - - -	"	"	"	25,584	"	
July. - - - - -	"	"	"	37,410	"	
August. - - - - -	"	3,043	55,917	"	"	
September. - - - - -	"	3,680	51,040	"	"	
October. - - - - -	72,315	2,440	9,891	"	"	
November. - - - - -	94,475	"	"	"	"	
December. - - - - -	52,920	"	"	"	"	
Total for 1843. -	319,244	9,163	131,659	62,944	"	
January 1844. - - - - -	65,340	"	"	"	"	
February. - - - - -	75,198	"	"	"	"	
March. - - - - -	89,410	"	4,199	"	"	
April. - - - - -	41,392	3,630	5,382	"	"	
May. - - - - -	42,261	2,007	19,951	"	"	
June. - - - - -	43,001	2,984	17,271	"	"	
July. - - - - -	22,842	7,035	18,088	"	"	
August. - - - - -	38,442	7,960	23,512	"	"	
September. - - - - -	36,281	5,569	13,299	"	"	
October. - - - - -	17,650	9,789	"	"	"	
Total for 1844. -	471,818	44,974	107,712	"	"	
	1,721,319	128,195	328,557	246,633½	2424704½	{ Total in cubic feet of mud, sand, stone, coral sand and shingle excavated in the Paumban channel during the years 1841, 42, 43, and 44.

APPENDIX D.

Nature of soil in channel, commencing at the Buoy,—Marked A.

From A. to B, a distance of 300 yards, the bottom is a coarse sand having detached masses of dead coral (brain coral) in it.

From B. to C. a distance of 100 yards has also coarse sand and masses of dead coral, together with a very hard conglomerate of sand and shells, occurring in masses of from 10 to 20 yards long and broad, and about 3 feet thick, under which there is again coarse red sand.

From C. to D. the bottom is similar to that from B. to C. but in this part some exceedingly hard masses of Madrepore were found, (they are now removed.)

From D. to E. red sand stone grit, 11 to 12½ feet thick—(from 2½ to 4 feet remaining to be cut through.)

From E. to F. Do. Do. Do. Do. Do. Do.

F. to G. fine grained (compact) sand stone, very hard—11 to 12½ feet thick (from 2½ to 4 feet remaining to be removed.)

From G. to H. the same, but having a good deal of shingle over lying it (this has been removed.)

From H. to the end, soft sand stone, lying in layers of about 8 to 10 inches thick, much broken up, and full of fissures filled with sand, pieces of coral, shingle &c.

APPENDIX E.

Method of carrying on the works.

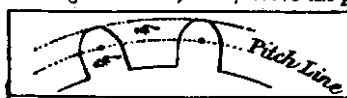
The work in the channel consists of removing sand and mud ; and sand and masses of dead coral, and between the reefs, of blasting and removing sand stone.

A hand dredge of rather a rude construction* worked by prisoners, has been used hitherto for removing the sand and mud, and notwithstanding its many imperfections, it has done a great deal of work ; it cannot be exactly stated what quantity of work is done by it a day, but it may be said on an average to bring up about 1800 cubic feet in a day of 12 hours, worked by two gangs of prisoners, at an expense including 3 boats for removing the soil, (exclusive of prisoners) of Rs. 111 : 9 : 0 per mensem.

There were also two spoon dredges used for removing shingle, but they are now dismantled.

The boulders of coral are first cleared from the circumjacent sand, by working round them with the dredge, when a rope is attached to them by a diver, and from their lightness, they are then easily raised by a common derrick placed in a boat of about 15 tons, called a weighing Dhony—these boats are hired at 6 annas per diem, they generally make one trip a day, the expense of raising the coral is 3 pie a foot for divers (the boat and boatmen are excluded.) When these weighing Dhonies are used for raising the stone blasted out of the reefs, they have a large thick rope net, kept open at top by a hoop attached to the derrick tackle, (the expense of one of these nets is one anna a day), they are filled by the divers who receive 3 pie a foot for filling. For blasting the rock, the holes are bored by jumpers, about 1 inch in diameter, having chissel shaped ends, of about 6 inches broad, tempered with steel—two canoes are lashed together, (forming a jungar) with cross pieces, and the holes are bored by four men, and a diver who guides the end. Sometimes a fifth man is required, it takes from 1½ to 2¼ hours to bore a hole of from 2' 10" to 3' deep, the diver clears out the sand from the hole, and when prepared, inserts the charge of powder for blasting it, he then tamps it by filling up the hole to the top with sand, which he takes down with him in a leather bucket. The charges formerly used were of from 5 to 10 lbs. of powder, inserted in tin cases, with long tin tubes, this was found expensive, and not to answer so well as those now used, which are composed of leather, with bamboo tubes, the leather is formed into a bag, of the diameter of the hole, and sufficiently large to hold from 1 to 2 lbs. of powder, which has been found the best size of charge, (the line of least resistance in feet cubed for the number of ounces of powder), they are made wet, and then filled with sand, when dry the sand is poured out, and the charge filled, a long reed of the bamboo kind, called (Coorukke) is then inserted, which is filled for the priming with coarse powder ground and mixed with conjee water, and rubbed into cotton thread, after this it is carefully bound at the junction of the reed and leather with twine, and served over with country cloth, and dammered, each costs thus prepared, exclusive of powder 6 annas and 1 pice—as follows, skins (sheep) cotton, bees wax, 1 anna and 6 pie, coorukke 2 annas 9 pie, dammer and oil 1 anna 4 pie, country cloth and chatties 1 anna. It has been suggested that a diving bell might be used with advantage. I think perhaps a diving dress might, which would enable the Superintendent to do all that he could with a diving bell, at less trouble and expense, for the currents are so strong, that it could not often be used, moreover the method now used viz. by tying a quantity of boats together, and sounding all across at short distances, and wherever there is a stone or projection, putting down a small buoy, is more speedy, less trouble, and as efficacious a way of ascertaining the nature of the bottom.

* The teeth of the wheels are not properly constructed, the proper way to make the teeth of wheels, is to set off ¼ of the pitch below the pitch line, for the length of tooth, and ¾ above the pitch line thus.



The ladder should be made with three, instead of two longitudinal timbers, and the friction rollers, of much larger diameter, and of cast iron,—the barrel also over which the buckets turn, should be 4 sided, instead of 6 sided, as they are in this, by making them 4 sided the buckets are less likely to slip, and clear themselves better, and the barrel being less, there is more leverage—the wheels and rollers in this are brass, which is a great waste—by selling these, and getting cast iron ones from Porto Novo, a saving would be effected, and a better machine obtained.

DESCRIPTION OF AN ASSORTER'S SCALE, AND WEIGHING MACHINE OF A NEW KIND, CONSTRUCTED FOR THE USE OF THE MADRAS MINT.

BY CAPTAIN J. T. SMITH, F. R. S. F. R. S. N. A. &c. &c. &c.

1. In the peculiar system of adjusting coins to the correct standard weight, which has been practised in the Madras Mint for the last four years, and which will be fully described hereafter, it is necessary that all the pieces on first being cut should be accurately weighed, and separated into classes of equal weight, varying from one another by differences which are suited to the particular description of coin under execution, being for instance, with rupee pieces $\frac{1}{4}$ a grain, and for 2 anna pieces the $\frac{1}{8}$ th of a grain. This operation is required to be done with considerable accuracy, but at the same time with as much expedition as possible, and it has been therefore a matter of great interest to investigate the form of apparatus best adapted to the fulfilment of the necessary conditions; and a number of experiments having been made with that object, the result has been the adoption of the contrivances, which it is the object of the following paper to describe.

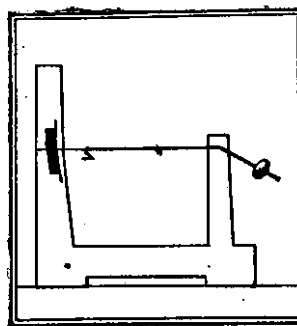
2. On first commencing business, we had no alternative but to use the common hand scales with moveable weights, and the rupee pieces which we were then engaged in fabricating, had to be separated into 12 distinct classes. This as will be readily imagined, was a work requiring no little time and attention, and I was apprehensive at first that mistakes and impediments to business would have ensued, upon the endeavour to separate numerous successive batches of coins into so many classes, by ordinary means; but after a little practice, the steady and experienced sorters soon got into the way of shortening the process, and with very tolerable accuracy avoided the confusion which such a system is liable to; so that in time an expert hand was able in a day of 9 or 10 hours work, to complete the sorting of 1500 pieces; those who were less skilful, smaller numbers, varying from that to 1000.

3. The plan they adopted was, to weigh the whole of a lot approximately first, in a rough and quick manner, and with the use of a single standard weight, separating the pieces into their supposed classes by a guess, founded upon the rapidity and extent of the vibrations with that weight. After this, all the classes were separately gone through, beginning with the "standard" one, and on taking up each class successively adding the fraction necessary to make up the coun-

terpoise to the proper weight, setting aside each piece which was found unsuited to the class it was temporarily placed in, for a fresh examination in whatever other class appeared to suit it.

4. In this manner, whatever skill and judgment the sorter might possess, he could not avoid the necessity of weighing all the pieces twice, and many of them four or five times; and it thus happened, that the same men who, in examining finished coins, against a fixed weight and remedy, could complete 6000 a day, failed to do more than one fourth that number, under the conditions particularised above.

5. The advantages which accompanied the system with which this method of weighing the pieces was connected, were sufficient to overbalance the inconvenience of this peculiarity in the sorting, but we were from the first desirous to diminish it as much as possible. It soon occurred to me to try the bent lever balance, as a means of obviating the repetition of weighings above spoken of, and after one or two experiments we succeeded in contriving a beam of this description which was admirably adapted to our purpose. Our first attempts were however made with a beam of the shape

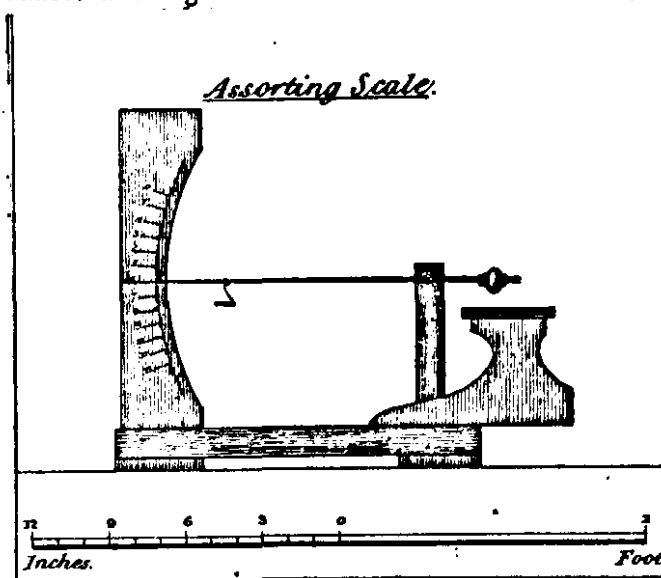


given in the annexed figure, and we were led to abandon the scheme as hopeless, after trial of an instrument of this form, in consequence of finding that for the very minute differences which we had to discriminate, the indications were too small to admit of being practically distinguished with accuracy.

6. It was not till some time after the failure of our first attempt, that I was led to try the influence of the bend of the beam upon the sensibility of the scale, for given differences of weight; or in other words, upon the dimensions of the scale which would indicate given additions to, and subtractions from the standard. This enquiry removed all the difficulties we had previously

experienced, for we immediately discovered, what indeed might have been anticipated from the theory of this instrument, that we had nothing to do but to regulate the scale to suit our convenience, by the easy method of altering the inclination of the two arms, a small angle between the two parts of the beam giving a larger, or very sensible scale, and a larger angle the contrary.

7. The instruments now in use, therefore, for this discriminate sorting are represented by the annexed figure, in which it will be observed that the beam is almost a straight line. The amount of flexure, or



the distance of the centre of suspension above a line $10\frac{1}{2}$ inches long, joining the centre of the counterpoise weight and the suspension point of the pan, being only $\frac{1}{16}$ ths, or about $\frac{1}{16}$ th of an inch. One very great recommendation of them is the great ease with which they are constructed, and the diagram represents one of a number made up in a hurry. The beam is merely a piece of steel forged and filed to the proper shape, and the end tapped to receive the weight, with a couple of adjusting nuts, one in front and one behind it. The stand and scale are made altogether of deal wood, the planks of a rejected packing case, and the centre of suspension is a fine sewing needle.

8. In respect to the suspension just spoken of, it is remarkable that the simplest and easiest of execution proved also to be the best. As it was an important object to make these instruments as accurate as possible, a trial was made of a knife edge suspension, similar to what is used for the most delicate scales, but we were at once met by the difficulty which is inseparable from all accurate weighing of this kind, *viz.* the tendency of the beam to vibrate, and the very great delay occasioned thereby. In the common hand scales which are used for examining finished pieces, and in the use of which the system of weighing is different, this peculiarity forms no objection, because the question required to

be solved by them in regard to each piece, is merely whether it corresponds with the "standard," or not, and the weighing-men or sorters who perform this office, acquire by habit the power of instantaneously judging, by the first movement of the index of the beam, whether the piece is sufficiently true, or otherwise; and if the latter, it is set aside for re-examination against a fresh standard of greater or less weight, corresponding with the utmost deviation, either way, which can be allowed. But in the peculiar method of assortment required by us, wherein not only a knowledge of the truth or error of the blank, but the exact amount of its deviation is sought for, it is evidently necessary to wait till the beam is brought to rest in equilibrio, and this with ordinary instruments, if of delicate construction, would be altogether unsuited to the despatch of business. On this account I found that some retarding agent, such as friction, was indispensable, and after experimenting upon a variety of different means of effecting this, we at last found that a simple needle, passing through a circular hole drilled in the beam, was the most practically useful. With it, the beam was sufficiently sensible to answer all the purposes we required, and it vibrated very little, if at all. In the course of work, in order to bring the index to its point more quickly, and to obviate any error arising from the friction of the pivot, the sorter taps the foot of the stand with the piece next to be tried, and in this way gets through his business with considerable expedition.

9. The extreme simplicity of these instruments has constituted their greatest value for our purposes, for the construction of them is so very easy, that a dozen of them may be made by a carpenter and a blacksmith in two or three days. When finished, the scales are marked off, and the beams adjusted to them by the Superintendent of the sorting department, and before beginning each day's work it is proper to examine each beam by testing it with pieces of the highest and lowest denominations comprised by the scale, to guard against any accidental injury or alteration of the beam.

10. By the adoption of this form of instrument we were enabled very much to simplify our system, and in consequence of this a twofold economy ensued. As the index points at once to the true weight of the piece, it was easy also to make it designate the class to which it belonged; and thus marking off the scale into divisions of classes, instead of weights, we at once freed the operation from a part of its difficulties and chances of error. Accordingly, the divisions were merely distinguished numerically, and all that the sorter has to do in separating pieces (or *disks* as we call them) is to note the number the index points to, and remove the disk to the corresponding division of a series of compartments chalked on the floor close beneath the low table on which the weighing instrument stands, whence they are removed for use by other parties.

11. The operation thus carried on is so intelligible and easy, that the number of disks assorted has been increased from 1500, the greatest number above stated to have been accomplished previously, to 4000, per working day of $8\frac{1}{2}$ hours; and what is of more importance, we have been enabled to employ upon it young apprentice boys, whose salaries are only one half of what it was necessary to pay to experienced weighing men. On our first beginning work the expence of assorting every lac of pieces was upwards of 20 rupees, the pay of each sorter being $7\frac{7}{8}$ rupees per month; but by the introduction of the beam above described, this charge has been reduced to 4 rupees, boys upon that salary being quite competent to do the business, and easily completing a lac of pieces within the month.

12. It will be seen by the description which will be presently given of a mechanism for doing the work of the sorters, that this charge is capable of being further reduced, but before closing the account of these comparatively humble, but most useful little instruments, I must observe, that in the absence of the more elaborate apparatus just alluded to, the Mint has derived the greatest benefit from the use of the bent lever balances, and the whole of the work of the department since September 1842, has been performed by them, with the exception of that of rupee pieces, which, since the construction of the larger machine have been assorted by it.

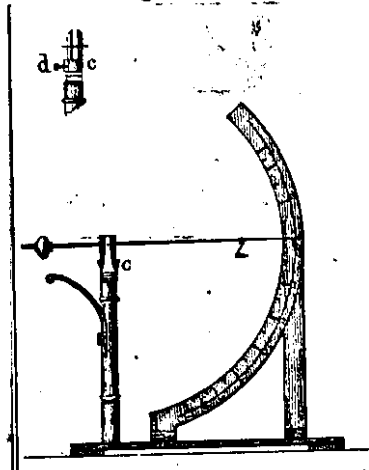
13. As the operation of these instruments is peculiar, they may perhaps be of less interest where the system of manufacture is different from what it is in this Mint.* They are however available for one species of work which is common to all Mints, and may probably be found to be of great advantage in it. I refer to the examination of finished coins previous to issue. I am not quite certain that this duty is always performed elsewhere, but in Madras, not a single piece is issued without examination after stamping, and as the remedies are very small in some coins ($\frac{1}{8}$ ths of a grain in 2 anna pieces), and are rigidly adhered to, it would be impossible to carry on business without it.

14. We have lately made some experiments as to their adaptation to this duty, but have not brought them to a final issue. It was found that a boy could examine 6000 pieces daily with one of these beams, when the object was merely to ascertain whether they were within certain limits or not, but although this result affords a very satisfactory prospect of future success, we have not had sufficient time since the experiment was made to obtain data whereon to speak with certainty. Should the result just mentioned be confirmed on the large scale, the expence would be reduced nearly 50 per cent; the same duty being performed by boys as would be otherwise executed by men on double their

pay. The only doubt which suggests itself as to the general introduction of the plan is, whether in making the alteration, it would not be best at once to proceed to the construction of the larger instrument about to be described, by which the expence would be reduced to the minimum.

15. There is another use for which the bent lever beams are peculiarly suited, and for which they have been exclusively employed in this Mint ever since they were first successfully tried, and this purpose is one in respect to which they will be found equally valuable in all Mints. This is in the examination of the test pieces cut from the straps after the last rolling in the finishing mill, which, as will be readily understood, it is a very great convenience to weigh by an instrument which at once indicates the exact amount of deviation, either way, without the troublesome addition or subtraction of fractional weights.

16. We have found it most conducive to accuracy in rolling, not merely to test the straps by single pieces, but to judge of their average condition by the average weight of three pieces cut out of different parts; and the finishing mill is furnished with a couple of instru-



ments of the accompanying form, finished in brass, one of them supplied with a counterpoise suited to the weight of three pieces, and the other suited to the weight of one. The beam is swung between two cheeks, one of which is moveable round the pillar, which supports the beam, by means of the collar *c* which is fixed by the thumb screw *d*. The needle

is passed through holes drilled through the two cheeks and secured in one by a deal wedge, and in consequence of one of the cheeks being moveable, the needle is easily adjusted to a position exactly at right angles with the plane of the face of the instrument, and the beam can be made to travel at a greater or less distance from the surface of the scale.

17. The same scale suits any description of coin, but a different beam and counterpoise is required for each. It is necessary therefore to have a beam suited to each different description of coins, and to make use of them as required. It is also advisable, upon every occasion of mounting a new beam, to test the accuracy of the scale at its medium and extreme points, to make sure that no change or injury of its shape has occurred, which has affected its accuracy.

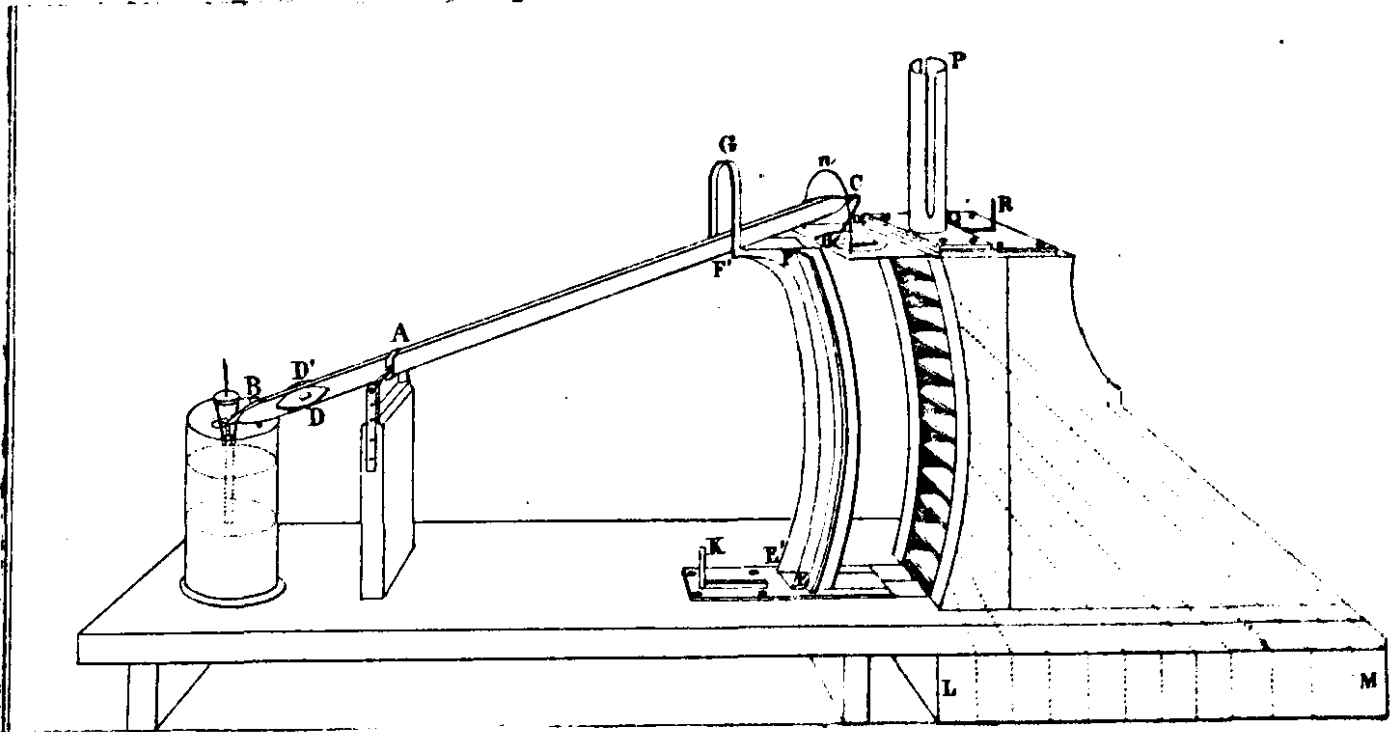
* Even where the file is used for adjustment, I should think these instruments would be very valuable, for an expeditious classification in a rough way, of the pieces to be operated on.

18. When this preliminary has been settled, the pieces as they are handed from the blank cutting machine are successively weighed in one or both of the instruments. If the average deviation of three pieces be required, then the three blanks are placed in the larger scale, and the index will point to the average difference at once; If the discrepancy of only one is to be tested, the smaller instrument is used, which shows the same result as applied to it.

19. *Sorting Machine.* This instrument was made up in order to test the possibility of performing the weighing and sorting of coins by machinery, and the result has been completely successful; nearly the whole of the rupee disks being now assorted by it. The principle is that of arranging a number of beams side by side, and attaching to them an apparatus by which the pieces are mechanically placed upon the pan swung from the end of each, and after equilibrium has been attained, removing each piece to its proper compartment in a series of cells, which are appropriated to the different classes into which the pieces are to be assorted. The

idea naturally suggested itself in connection with the use of the simple bent lever beams, before described, in considering the possibility of obviating any chance of the pieces, after their true classes had been pointed out by the index, being misplaced by the sorter. It occurred to me, that as the pan is raised by the end of the beam to a different height for each class, and it was in our power to regulate the distances between the different marks on the scale to any dimension most convenient, by altering the length and flexure of the beam, it might be possible to arrange a series of shelves at the exact heights marked by the divisions; and then, by merely giving the pieces a sudden horizontal movement, they would be at once carried to their proper places, and might be conveyed by means of partitions, down to any receptacles most convenient for the accommodation of large numbers.

20. Before proceeding to make any experiments upon a large scale, it was first thought advisable to test the main principles of the scheme, and this having been done by a rude model, with a satisfactory result, the



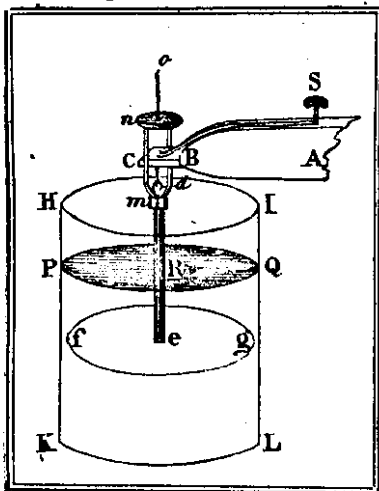
model of a single beam of the full size was accurately made, and the following description of this will be the best introduction to the study of the compound machine.

21. In the above figure the letters *A. B. C.* show the beam, which was made of a piece of seasoned fir, which had been baked to thorough dryness, and varnished. It was altogether 30 inches long, the arm *A C* being 24, and *A B*, 6 inches. This was poised upon the ordinary knife edge suspension pivots, in the usual way, the only difference being, that they were placed rather widely apart, in order to ensure steadiness in the direction of the beam, and to obviate any lateral vibration.

The points *C* and *B* are also provided with pivots, in the manner represented in the figure, the former a knife edge for the support of the pan for the reception of the pieces, the latter a silken loop passing through two holes in a steel plate holding the weight, which will be presently described. Great pains were taken in making the edges of the three suspension pivots in exact line, in order that the equilibrium of the beam might not be in any way affected by the amount of the weights opposed to one another; and equal care was bestowed in adjusting the centre of gravity of the beam itself, to the point marking the position of the edge of the central pivot, to effect which it was found necessary to attach counter-

poise weights *D. D.* on opposite sides of the short arm *A B*, to balance the weight of the larger arm *A C*. These counterpoises were made of lead, and fixed in the manner represented.

22. These conditions having been attained, the test of accuracy was, that the beam rested in any position in which it might be placed; or to speak more correctly, it had no tendency to assume any particular position, for although it was in perfect equilibrium at every angle, the fineness of the pivots, and the length of the arm *A C* totally prevented its assuming a state of rest; the mere motion of the atmosphere being quite sufficient to keep it in constant oscillation. This circumstance was one of the reasons which induced me to make an alteration, which will already have attracted notice *viz.* the adoption of a new kind of weight. It has already been mentioned, that in the small bent lever scales it was found absolutely necessary to sacrifice in a small degree their sensibility, to get over the difficulty of their constant motion, and that this had been done by making use of a pivot which was not without a very trifling degree of friction. In constructing the model now under description, the idea suggested itself of introducing a retarding agency, which might be effective in preventing motion, but incapable of exerting any influence when the beam was at rest. This condition naturally points to the use of a fluid, and it being at the same time very desirable to devise a plan by which the spaces between the different shelves intended for the classes of "disks" might be made equal to one another, those of the bent lever balance being rather smaller at the limits of the scale above and below the zero point, it was determined to attempt the combination of a retarding plate with a fixed wire, on the principle of the hydrometer, the whole weight of the plate and wire being so adjusted in the first instance, as to exactly balance a disk of the medium weight, when the beam was horizontal, and the pan opposite to the middle opening *O P*.

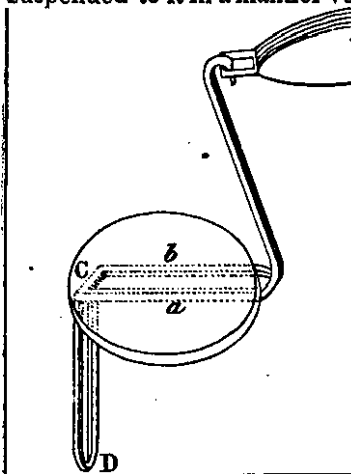


23 The annexed figure represents this part of the apparatus, as it was constructed on that occasion. *A B* is the end of the short arm of the beam, to which the plate *B C* was attached. In this plate a couple of very small holes were drilled, through which passed the two ends of a silken thread, which form a loop at *d*, in which the circular stem *d e* is suspended by means of the hook *d*. The ends of

this thread are secured by means of the pin *s* round which they are wrapped, and by screwing or unscrew-

ing which, an adjustment of the distance of the plate below the point *B* may, to a small extent, be made. The bottom of the stem is fixed to the circular brass plate *e f g*, and by the motion of the beam the plate rises and falls in the cylindrical vessel *H I K L* in which it is placed. The diameter of the cylinder was 3.2 inches, and of the plate 2.9, thus leaving an interval of about 1/4 tenths of an inch all round, between the edge of the plate and the inner surface of the cylinder; that is, when the former is in the middle of its track as regards height; for as the motion of the end *B* of the beam is circular, it follows that at the highest and lowest points of its rise and fall, the edge *g* of the plate is drawn nearer to the side *I L* of the cylinder, and the edge *f* further from the side *H K*. The level of the surface of the water is shown by the letters *P R Q* the wire passing through it at the point *R*. *m n o* is a light cup of thin brass, supported by a couple of thin wires bent into the form of the letter *Y*, and attached to the upper part of the stem *d e*, the object of the cup being to contain the fractional grain weights which might be required in finally adjusting the weight of the stem and retarding plate &c. to perfect equilibrium with the standard disk, in relation to which all the remainder of a series were to be assorted.

24 The other end of the beam merely carries a pan suspended to it in a manner very similar to that of a letter balance, the width *a b*



of the frame upon which the disk is supported being much less than the width of the piece, to allow the two cheeks which are employed to remove the piece, to pass freely without carrying the pan with them. The same object is intended by the skeleton plate *C D*, which is a continuation of the pan frame *a, b*, at right angles to its face, and serves as a stop to prevent the latter being carried into the inside of the shelves, within which the piece is to be projected.

25 It has already been stated that the whole beam is poised upon knife edge suspension pivots in the ordinary manner, the only thing at all unusual in the arrangement, being, that the pivots are sharpened to a point outwards, the point being on a line with the knife edge, and a plate being attached outside beyond the circular cups in which the knife edges work, and touching these points on each side, so that any lateral motion of the pivots is prevented, and they are thus kept in their proper places.

26 If we now consider the action of the beam, we shall

see that the principle of its operation is different from that of balances in general. It has been remarked above, that great pains having been taken to bring the three points of suspension into exact line, and also to cause the centre of gravity to coincide with the centre of suspension, the result was, that previous to the introduction of the fluid in the cylinder, the beam would rest equally in any position in which it was placed, whether bearing weights or not, excepting as regards the motion produced in it by the currents of the air. As the suspension pivots were delicate, a very trifling weight would disturb the equilibrium, and thus the sensibility of the instrument and its capability of marking slight differences was secured, irrespective of any difference in its action brought about by the use of water.

27 When one of the weights consists of a plate suspended in water by a wire or stem of any given thickness, two changes take place. The first of these is the resistance of the water to the surface of the plate, and the difficulty of its motion, in consequence of the inability of the water to pass quickly from the lower to the upper side of it, and *vice versa*, owing to the plate nearly filling the area of the cylinder, and also the friction of the fluid, these being the retarding effects which were aimed at by the use of the plate; The second, that even supposing these resistances to be overcome, the beam once being in equilibrium, can not change its position without destroying that equilibrium. Indeed, it will be evident on a little reflection, that if the piece at the other end of the beam were exactly balanced against any solid body, part only of which was immersed in water, any movement which caused a further portion of the body to rise out of the water, would add to the effective weight of the whole mass, by a difference equal to the weight of the mass of water which was previously displaced by the part now raised out of it. In other words, the increase of weight which would be required to lift it out of the fluid, and by which it would act against the disk in the opposite scale, would be equal to the buoyancy of the part lifted out of the water, supposing it to be itself intrinsically of no weight. And this last supposition is true in regard to the parts of the stem and retarding plate now under consideration, because, as their actual weight is counterbalanced, and neutralised by the equilibrium previously existing, it ceases to have any power of interference in respect to the differences in that equilibrium effected by alterations of the position of the beam.

28 If we could possibly conceive that the stem attached to the retarding plate were, like the mathematicians definition of a line, absolutely devoid of the dimensions of breadth and thickness, then the above conditions would not arise, till the retarding plate itself came to be lifted out of the fluid. If the wire stem could be supposed to displace *no fluid at all*, the equilibrium would not be disturbed by any change which did not effect the uncovering of the plate. As had been ascer-

tained with respect to the action of the beam in air, so in the water, the equilibrium would be perfect; and, owing to the resistance to the plate, more stable, in every position in which it might be placed; and the plate would act simply by preventing the vibrations, which have been above spoken of as occasioning so much delay in delicate weighing.

29. In the above case, we should require a series of weights, to counterbalance the differences in the various disks to be assorted; and then, as before, the beam would rest equally in any point in which it might be placed (the plate not being exposed) but the required conditions would not have been attained, one of these being, that each position should be one of equilibrium for a different weight, which should rest stable at that point and no other. It thus appears that apart from the influence of a sensible dimension in the wire stem carrying the retarding plate, the necessary conditions are not fulfilled; but the moment we take into consideration the consequences of a certain thickness of it, we perceive that its motion into and out of the fluid has precisely the effect which is desired, by its requiring a different weight at every point to bring about equilibrium.

30. One of the first ideas which suggested itself in connection with the attempt to weigh mechanically, was that of attaching to the pan containing the counterpoise weight, a silken thread, having fixed to it, at regular distances, weights corresponding to the differences which should exist between the different classes of disks; so that, as a heavy disk descended on the one side, it might, one by one, raise the successive weights on the other, until equilibrium was established. After the use of water was resolved upon, this idea was superseded, because it will be perceived that a balanced stem rising and falling in the way the retarding plate stem does, has the very same effect, though in an infinitely more regular and perfect manner, as the gradual addition or subtraction of weights; its operation being indeed precisely similar to that of the hydrometer, with this exception, that the latter is sustained by its own buoyancy, and the former by the counterbalancing effect of the disk upholding the stem.

31. The most important advantage, however, which was gained by the use of the water and the stem was, that it enabled me to fix upon any size most convenient for the openings between the shelves or partitions for the reception of the coins, without any reference to the length of the beam, and without diminishing its accuracy, by merely regulating the dimensions at my own convenience. Like the hydrometer, the sensibility of the instrument, that is, as affected by the immersion of the stem, is obviously dependent altogether upon its sectional area. If the immersion to any given depth, say an inch, of a wire of 2 tenths of an inch diameter, caused an effective diminution of the weight at the short end of the beam of 8 grains, corresponding with

a difference in the weight of the disk of 2 grains, any other wire of greater or less sectional area would produce a greater or less difference with the same degree of immersion, or an equal effect with a greater or less immersion, and consequent rise of the longer arm through a larger or smaller space.

32 Hence it followed, that after the adoption of any given height as that most convenient for a series of shelves, it was merely necessary to regulate the thickness of the stem of the retarding plate, to suit the difference of weight which it might be desired should exist between the different classes of disks to be assorted into the distinct compartments. In the model, we determined upon having a set of 12 shelves, each one inch above the next below it, and it was determined also, that the difference of weight between the disks belonging to each shelf or compartment should be half a grain. To fulfil these conditions, a wire of the above mentioned diameter, viz. 1/16ths of an inch, was found to be necessary, and the beam thus fitted up answered every expectation. After the weight of the whole counterpoise, stem, plate, &c. had been adjusted to the weight of one of the disks in any position, for instance at the top of the series of shelves, the addition of any number of half grain weights, successively, would carry the piece down with great regularity, from partition to partition, in exact accordance with the weight applied to the piece, which on their removal would with equal regularity rise to the proper height, bringing the disk opposite to the compartment suited to the weight which belonged to it. Thus, so much of the contrivance had been fully realized, and the only remaining steps were to adapt to the beam instruments for the laying on and removing the disks, as they were successively weighed.

33. The removal of the pieces was effected by means of the apparatus shown in the figure given at para 20 *E F* and *E' F'* and *G* represent a sliding frame composed of two upright brass cheeks *E, F* and *E', F'* curved to suit the form of the face of the shelves, (which is necessarily circular to adapt it to the motion of the pan *H*), standing on, and firmly fixed to a bed plate sliding in groves cut in a plate of brass, secured to the floor of the stand, and moved backwards and forwards by the pin *K*. When the disengaging frame is moved forward to the utmost, the face of the two cheeks coincides with the front face of the shelves, and the disk is separated from the pan, and projected to within the interior of the shelves, whence it is carried, by the partitions represented in the figure, down to its appropriate compartment in a drawer *L M*. The beam on being released, rises quickly, (but not too suddenly, on account of the retarding plate) till it is arrested by the stop *o, n*, which is so adjusted, that when the beam is held in that position, the pan *H* is exactly suited to receive a fresh disk, which is carried forward and lodged upon it by means of a tongue, or feeder, working beneath the hopper *P, Q*, which is kept filled with a supply of the disks to be assorted.

34 It will be observed, that at the point *F F'*, the upper part of the upright cheeks of the disengaging frame is filed flat and horizontal; and after a disk has been projected into its partition, the frame remains in the forward position close to the face of the shelves, the horizontal surfaces at *F* lying immediately under, and in the middle of, the circular opening where the disk is delivered; and they support it until, after the delivery has been effected, the disengaging frame is withdrawn, and the disk is left upon the pan *H*, and descends by the force of gravity till it finds a suitable position of equilibrium corresponding with its weight; and thus having been brought to rest, it is in its turn removed by the frame, and the feeder is made to supply another, and so on.

35 The working of this model is carried on as follows. First the disengaging frame is advanced close to the shelves, the feeder is next made to deposit a piece, the frame is withdrawn, and in a short time, when the beam has become quite steady, the frame is quickly brought forward again, by the pin *K*; after this a new piece is delivered, and so the operation continues. The time taken for the beam to come to rest, is found, with an instrument constructed of the above stated dimensions, to be about 20 seconds; so that three pieces could be weighed per minute, in a single machine. In working a number together, a longer time is allowed, in order to make sure that the slowest shall have quite settled. It is worthy of notice in connection with this point, that a curious fact was observed in the use of this model, which seems to depend upon the friction of the fluid, as distinguished from its resistance to the retarding plate; and this was, that there was found to be a trifling difference between the position of equilibrium at which the beam settled, when it descended from a high elevation, or when it ascended from a lower point, (although in each case it vibrated backward and forward past the settling point) being in the former case always a trifle higher than the latter. This difference is small, and it has no effect whatever upon the accuracy of the indications of the beam, as the pieces all descend from the same level.

36. In assorting a series of disks by this model apparatus, the middle cell of the series was appropriated to the medium or "standard" weight, in reference to which all the pieces were to be classified. A disk of that weight having been selected and placed in the scale, the weight of the counterpoise was adjusted until the disk hung opposite the middle of this cell, and the whole were then worked off. In case a second series of disks should be brought for assortment, and another standard, slightly varying from the first; then an adjustment required to be made in the first instance, by adding fractional weights to the counterpoise at *B*, till it balanced the standard disk opposite to the middle compartment, as before.

37 When a new species of disks or coins, not only varying in weight, but requiring to be classed in a series

varying by a new set of differences from one another, require to be assorted, it is necessary to apply a new stem, of a thickness corresponding with the difference of weight required between each class; and in some cases a new pan at the other extremity of the beam, and in almost all a new hopper are necessary. This will be remarked upon more at length, in speaking of the construction of a compound machine on the principle of this model, for as this was found to have completely answered its intended object, in proving the correctness of the principle upon which coins or other pieces might be mechanically assorted, it was not considered necessary to do more than apply it to those it was first prepared for, and the next step was the construction of the compound machine itself.

38. It will have been observed on reading the description of the mode of using this model, that after it has been once adjusted to any given series of pieces, which are intended for classification, all the remaining work to be performed is merely mechanical. Nothing whatever is to be done, but at certain regular intervals, to move backwards and forwards the two pins *R*, and *K*, as follows; first, *R* forward and back again, 2d *K* backwards; then, after an interval of 20 seconds, *K* forwards, then *R* forwards and back again, then *K* back, and so on. In all these movements no discretion, or intelligent operation of the mind is necessary, and if a little longer allowance of time be made, to avoid the necessity of observing when the beam comes to rest, the whole of the motions could as efficiently and well be performed by a steam engine as a man's hand.

39. Upon the encouragement afforded by the satisfactory performance of the model above described, I resolved upon attempting the construction of a compound apparatus consisting of a number of them, to be worked by one man. To avoid the length of time which a large set would consume in construction, and in consequence of the uncertainty which existed as to the amount of mechanical force which would be called for, it was resolved to restrict the first attempt to a set of 20 beams, and after some time, this was accomplished. A general idea of the apparatus will be obtained by consulting plates 18 and 19, and if it be borne in mind that the whole apparatus consists simply of a set of 20 of the instruments which have been above described, arranged side by side, with some few additional parts necessary for working and adjusting them together, the drawings will be found, I trust, not unintelligible.

40. It was the fear of some derangement happening to any one of the beams, the repair of which might be an impediment in the use of the whole, on actual duty, which led to the plan of their being constructed quite independently of one another, and afterwards placed together upon a frame suited to accommodate the whole; but the lengthened experience we have now had of it has proved that there was no necessity whatever for this precaution, and that in the construction of others,

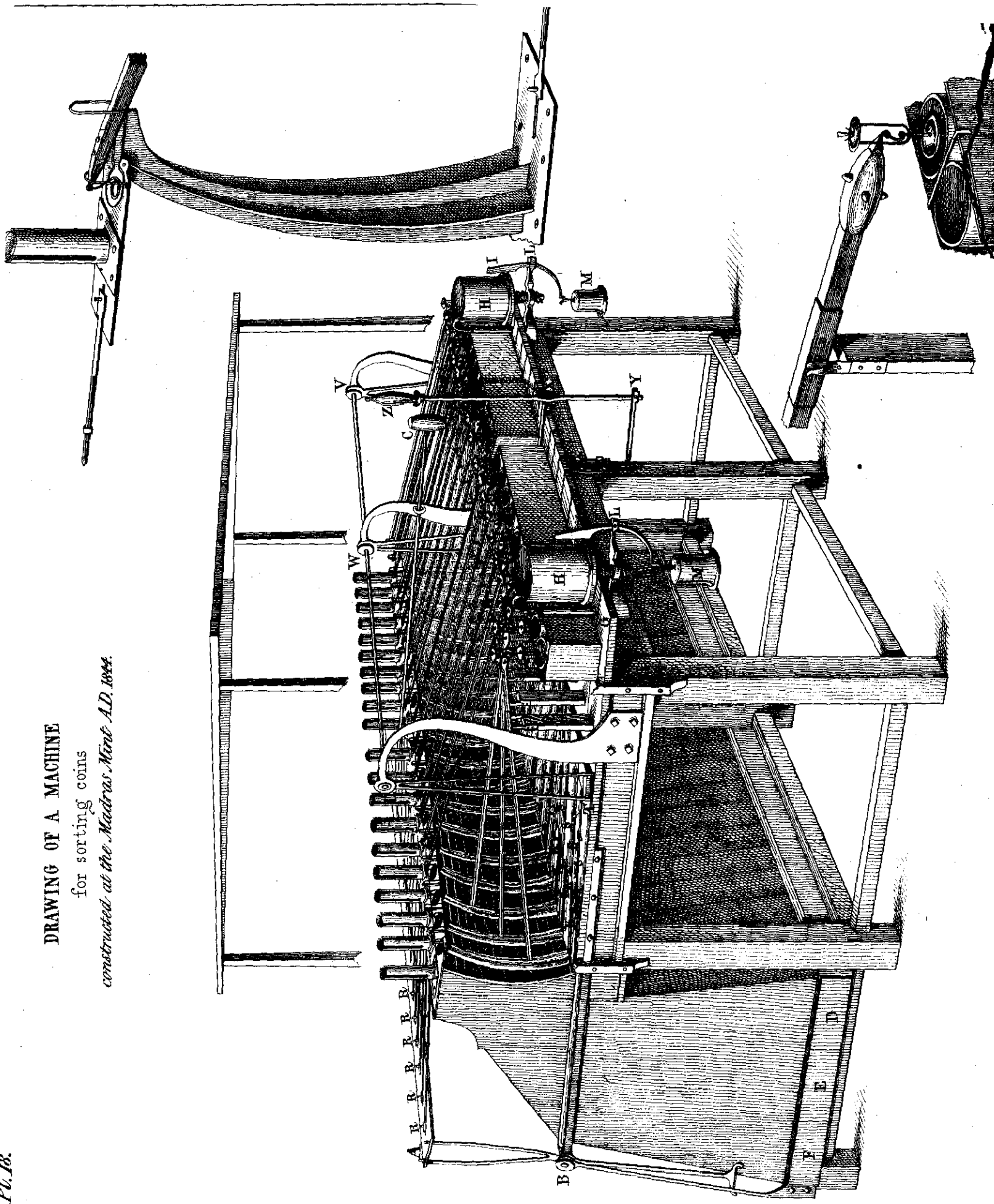
it will be quite safe, as it will also be much more convenient and economical, to frame the whole of the largest series in one system; as the beams are not liable to any derangement, after once being properly made and adjusted.

41. For greater convenience of reference, the two plates above referred to have the same letters attached to the same parts in each. The only parts which it will be necessary now to describe particularly, are those which are added to enable a number of the motions which were stated to be necessary to work the simple machine, to be united in the compound one, so as to be effected by one effort. Those motions it will be recollected were merely of the two pins *K* and *R*. It will be observed, then, that in order to unite the series of motions of all the pins *K* into one, they are all joined by means of connecting rods *s, s, s*, to a wooden bar, of which only one end, marked *T*, is visible, in either plate; which bar is suspended by means of three stirrups of iron *T, U, W*, and *V*, to a long arbor which turns in sockets at the points *U, V*, and *W*. These stirrup frames are firmly rivetted to the arbor, and cannot be moved without carrying it round with them. The consequence is, that any small motion given to any one of them is communicated to the others by means of the arbor, and all the three frames, being thus made to move simultaneously, the bar *T* is carried forward in a direction always parallel with itself, and by means of the connecting rods, or couples *s, s, s*, the whole of the pins *K, K, K* &c. are moved uniformly together.

42. As it would not be convenient to move the bar *T* by the hand applied to it, a rod passes from it to an upright lever *Z Y* which turns upon a pivot *Y*, attached to an arm projecting from the body of the frame. This rod is seen in plate 18 joining the lever at the point *X* where the handle *Z* by which it is worked is also clearly shown. Before quitting the notice of this part of the apparatus, it may be useful to explain what is the use of the connecting couples *s, s, s*, and why it would not answer to have simplified the machine by applying the moving power directly to a bar fixed upon the tops of the pins *K, K, K*, themselves. The reason is, that in all machinery of this kind, it is indispensably necessary to provide against the risk of any obstruction accidentally occurring to prevent the movement of one of the series of parts, which in default of such provision might be injured. In these beams, for instance, it occasionally happens that the piece is carried by the disengaging machine precisely upon the *edge* of the partition, and though this accident very rarely produces a stoppage, owing to a contrivance which was made use of for the purpose of preventing it, still it even now does occur, and but for the use of the connecting rods would most probably occasion the fracture of some parts, an accident which by their intervention is entirely prevented.

43. This is done by making the rods of two parts

DRAWING OF A MACHINE
for sorting coins
constructed at the Madras Mint A.D. 1844.



joined together longitudinally, like a split cane, and connecting them together by a sliding ferule, moving along the rod with sufficient friction to prevent its becoming accidentally displaced, when once fixed. The two parts of the rod are made of steel, with a slight temper, and they are joined at the end *T* and fitted, by means of a hole drilled through it, upon the pin which rises out of the bar *T*. The loop which fits upon the pin *K* is of course drilled through the junction of the two halves of the connecting couple, and as these are not united together at this end, they are free to separate and release the pin, on the occasion of any jirk or violent movement, or in the event of any obstruction, such as the striking of a piece against the partition, in which case the pin remains unmoved, and the two halves of the couple open out from one another and pass on without it. The use of the ferule is to adjust the degree of force which shall be required to detach the couple from the pin, which is of course easily effected by passing it closer to, or removing it further from the point *K*. By this means the adhesion of the two jaws is increased till it is just sufficient to move the pin backwards and forwards and perform its work with certainty, and a little more.

44. The other row of pins *R, R, R,* &c. is moved in a manner very similar to what has just been described, with the exception only, that the bar *A* to which all their connecting couples are linked, instead of being suspended by three stirrup frames, in this case stands upon them; but exactly as in the former case, the motions of all the three frames are connected together by an arbor *B*, to which they are firmly joined. The bar *A* is moved backwards and forwards by a plain rod passing from the back of the machine to the front, where the assorter stands who works the machine, and it is there provided with a handle *C* in a convenient position for use in reference to the other one *Z* before described. It is almost needless to mention, that the connecting rods, are precisely similar in this set to those just described, and the necessity for it is much greater in this part of the apparatus; as it not unfrequently happens that amongst the feeders pushed forwards by the motion of the bar *A* one may be prevented from doing its duty by the pieces contained in the hopper sticking fast, and being immovable for the moment.

45. The mere handle which is shown in the plates as attached to this movement is sufficient for the limited number of 20 assorting beams, working with rupee disks, but as it performs the work at no mechanical advantage, the force required in the way of a direct pull would be too great were that number much increased; for although there is generally no actual obstruction whatever, and it therefore ought, theoretically, to take little or no power, to move the feeders, still practically it is found that the friction of even twenty, when all the hoppers are loaded with 100 disks each, becomes something considerable; and when the workman has to apply this force a thousand or twelve hundred times a day, is quite as much as he can manage. It would be therefore necessary in constructing a machine

combining a larger number, to make this handle differently, and to give it a mechanical aid by means of a lever, in a manner somewhat similar to the arrangement of the handle *Y Z*, which would be very easily done; for the space through which the handle *C* now moves is only about 2 inches, and this, if necessary, might with ease be increased to 10 or 12, thus diminishing the force necessary to be applied in the ratio of 5 or 6 to one.

46. I before mentioned that a contrivance had been applied to obviate the risk of the pieces under assortment, on being disengaged by the frame, striking against the edge of the partition adjoining the cell into which they were to be thrown. This was effected by merely arming the edge of each partition with a roller, and thereby presenting to the piece about to be projected a circular and moveable, instead of a fixed obstacle to strike against. These rollers are about a quarter of an inch diameter, and accurately fixed upon steel pivots; and the slightest force is sufficient to turn them, so that nothing but the circumstance of the piece striking it with the utmost truth in the direction of its centre, can prevent its turning round and giving it admission into one or other of the compartments above and below. It comparatively seldom happens that the piece strikes it with so much truth as to fix it, but when this does occur, it is rectified by the workman drawing back his hand and repeating the stroke, by causing the disengaging frames to recede partially and advance again. This liberates the piece, which by the vibration of the beam assumes a new position, whence it is sure to be carried into its proper place by the forward movement.

47. The section given in plate 19 will show very distinctly the partitions, by means of which the pieces, after being thrown into the proper cells, are carried down to the drawers where they are kept separate from one another, and removed from time to time as they are required. Each single beam is, as before stated, mounted separately, and standing on the horizontal platform *B G* may (with the exception of its water cylinder) be removed and separated from the rest. Thus the upper half of the series of partitions is distinct from the lower, the junction being at the horizontal line, where they meet at a considerable angle. This is no doubt a defect, which will be remedied on the occasion of constructing a second machine of this kind, as it would be obviously so much better that the partition guides should be formed in continuous curve lines instead of meeting at an acute angle, which is apt to occasion a lodgement of the pieces, if they should be very large in comparison with the breadth of the spaces. We have not, however, been troubled with this accident since the first construction of the machine, although we at first met with it from another cause, namely owing to the upper and lower partitions not being fitted exactly to one another, and a projection being left which caught the pieces as they fell.

48. As the large machine, was merely experimental, it was constructed as economically as possible, and

owing to that, the upper partitions were made of tin plate from old packing cases, the lower partitions were of wood. The pieces fall into drawers, of which there is a double set of three, opening on each side of the bottom of the frame, each set of drawers thus answering to ten beams. Each drawer is divided into four partitions, so that the three drawers which belong to ten beams, afford 12 spaces for the accommodation of the 12 classes into which all the disks assorted by them are separated.

49. The only parts which now appear to require description, are the cisterns containing the water, and the apparatus for regulating the height at which it stands in them. In regard to the former, it was found advisable to alter the system of using a separate cylinder for each beam, partly on account of the greater neatness and substantiality of larger reservoirs, and partly also for the purpose of regulating them with greater facility, according to the plan which will be presently described; but it was necessary still to retain the cylinder, for after a variety of changes and experiments upon different forms of retarding plates and cisterns, no plan was upon the whole found to be so good as the simple vertical cylinder and circular plate. In order to retain the advantage of this form, therefore, and still to unite the cisterns together, troughs were made of sufficient size to hold five cylinders, and the latter were fixed in their proper places in them, but were not provided with bottoms; there was therefore a free communication between the fluid belonging to all the five cylinders contained in each trough, and the two troughs on each side of the centre *Z X* were also made to communicate freely with each other by means of a syphon, so that the water should always stand at the same level in each. By this arrangement, the height of the fluid in all the ten cylinders belonging to the beams on one side could be regulated at once; a point of some importance.

50. The circumstance which made it desirable to effect with facility a uniform change in the level of fluid in the whole series of cylinders, was the frequent necessity for very slight changes in the weight of the "standard" disk, in comparison with which the whole of a large number were to be classified. In the course of business, the disks are usually brought in bags containing about 1000 or 1200, and each bag is provided with its own standard piece, which forms the middle or zero point of the scale, above and below which, all the rest are regulated. I have before stated, that on first construction of the beams, the counterpoise at the end of them is adjusted by the addition of fractional weights, till the standard piece is made to rest opposite to the centre of the middle shelf, or zero point in the system, and this must of course be done for each beam individually. But if, in the course of business, this had to be done for every new bag of pieces, and all the ten beams had to be accurately adjusted individually, it would not only occupy a great deal of time, but would introduce great risk of error, in consequence of the probability that delicate adjustments so frequently and hastily made would have but little accuracy, a difficulty which is completely surmounted by adjusting by means of the fluid.

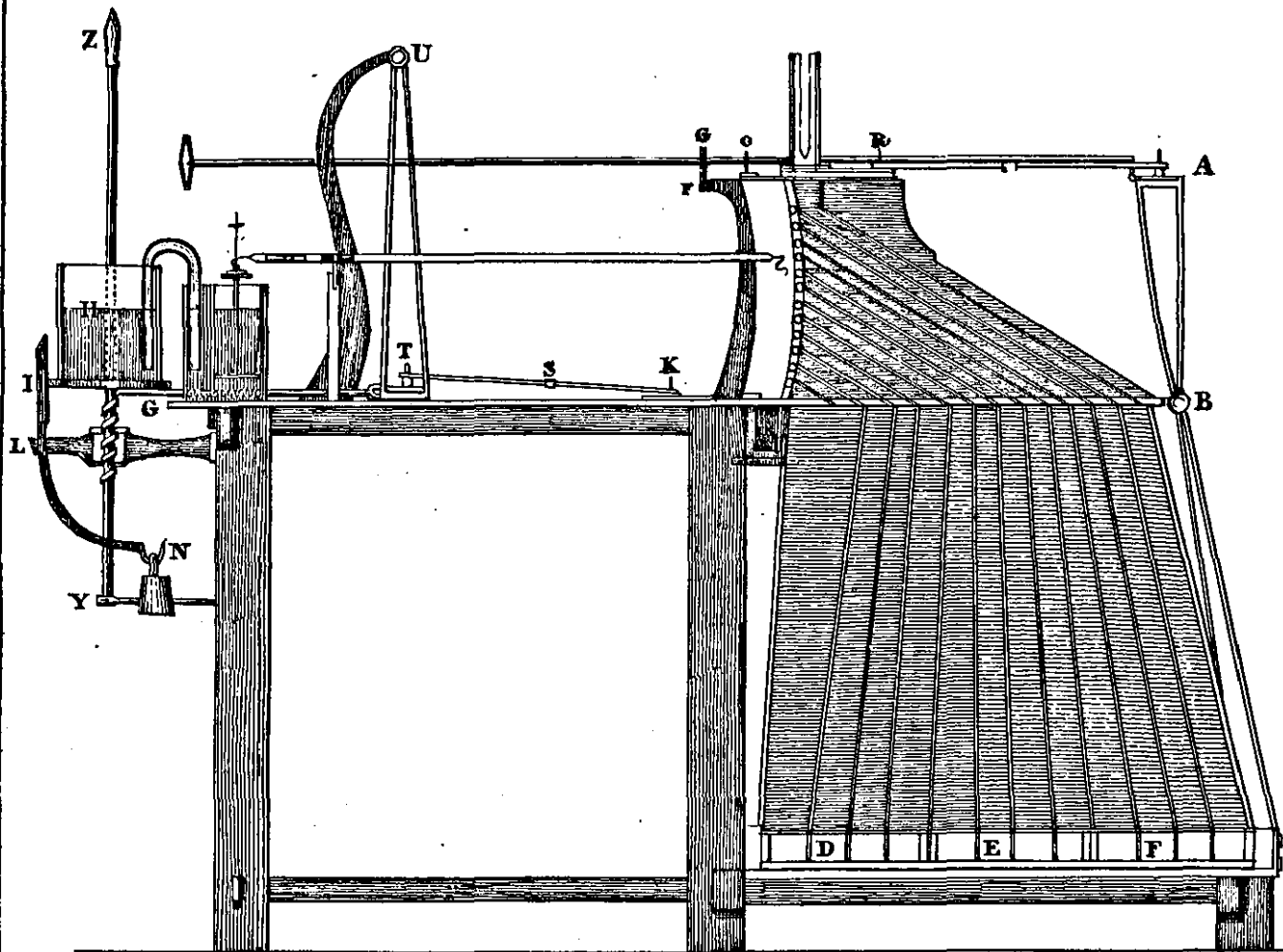
51. How this is done will be easily understood. It has been before explained, that the weights on both sides of the beam having been settled, the piece will cause its end of the beam to sink till so much of the wire stem attached to the retarding plate has been drawn up out of the water, as by its additional weight to balance it. If we suppose equilibrium to have been obtained, at the time that one inch of the stem is uncovered and 5 inches are immersed, it is proved by that circumstance, that the weight of the counterpoise minus the buoyancy of the immersed part is exactly sufficient. And the same would be the case, with the same degree of immersion, at every inclination of the beam, which it will be remembered was tested and proved to show the same results in every position. If therefore a standard piece on coming to equilibrium should be higher or lower than the zero point, nothing more would be necessary to rectify this, than to raise or lower the cistern containing the water, which would immediately produce the desired effect.

52. The same end would be attained also, of course, by allowing the cylinder to remain fixed, and altering the height of the water in it; and as this, within certain limits, can be so much more easily done to the whole series at once, this plan of regulating the zero point for different weights was the one decided on, and it was carried into effect by establishing a communication between one of the troughs and a rather large reservoir marked *H* in the drawings, by means of a syphon, and fixing the reservoir in such a manner that it could be easily elevated and lowered at pleasure. It will be observed that in plates 18 and 19, the two reservoirs belonging to the troughs of the two sets of beams, are represented as standing upon circular wooden trays, which are supported by a central stem which is tapped to enable it to fit into a female screw held by an arm projecting from the body of the frame of the machine. Near the position of each of these reservoirs there is a projection in the side of the trough next to it, a circular well of about an inch diameter, and of a depth equal to the depth of the trough, having been made and attached to it in free communication with its contents. This well is for the purpose of holding one arm of a syphon, the other being inserted in the reservoir; and as the latter is cylindrical, and moves round a centre coinciding with its axis, whenever the reservoir has to be raised or depressed by means of the screw, no change takes place in the position of the syphon, which continues to act uninterruptedly whatever height the reservoir may be set to.

53. By this means, on every occasion when it is found that the standard piece belonging to a new set of disks does not exactly correspond in weight with that which preceded it, the necessary alteration to bring the whole of the beams on one side to point to zero is made in a moment, by raising or lowering the reservoir *H* to such a height as to make a compensation; which it does by the immediate alteration in the level of the fluid in the troughs attached to it, by the agency of the syphon. The reservoirs are kept steady in their places, and immovably fixed in the positions assigned to them, by the

PL. 19.

A SECTION
of the
DISK ASSORTING MACHINE.



Inches 12 9 6 3 0 1 2 3 Feet

pressure of an arm *I* which turns upon the pivot *L*, and is kept in constant contact with the circular tray by the action of a weight *M* attached to it. It is usual to assort two sets of disks at once, by allowing each half of the machine to be occupied with work distinct from the other, so that the adjustments in the two halves are made separately, and have no connection with one another, though all the beams are worked at once.

54. The only thing which now remains to be mentioned is, that during the hot weather, to avoid the disturbance which might be caused by flies settling upon the beams, the whole apparatus is enclosed by a light frame with mosquito curtain gauze stretched upon it, the upper part of which is exhibited in plate 18, the lower parts having been broken off to prevent their interruption of the view of other parts. In this form, the machine has now been in use for many months in this Mint, and during that time has performed nearly all the sorting work in regard to rupees which has been executed. Had it not been constructed in parts, for the reason above stated, so that each beam is separate, carrying its own hopper and feeding apparatus, it would have been easy to have made it do more duty, by applying it to sort other coins. As it was however, as this would have required the removal of the twenty feeders, and addition of new ones, it was determined that it would be best instead of undertaking that work, to reserve this machine for large coins only, and hereafter make a new one capable of being used for every description of coins.

55. The quantity of work which may be executed in a day by the use of even this machine has of course been much augmented. It has been found that as a general average of all the work done, the proper days duty is 20,000 pieces. This is a large increase upon the best performance which had ever been attained previously, but far short, it may be presumed, of the utmost that may be done. It has been before remarked, that in consequence of the doubt which attached to the whole scheme, and the uncertainty as to the number which could be conveniently managed by one man, only twenty were at first arranged together: but from the experience we have had of the very easy and satisfactory working of this, I have little doubt but that with the improvements which may be made, it will be possible to combine from 50 to 80 or perhaps even 100 so as to be within the power of a single assorter.

56. Until the above experiment has been tried, it is not possible to form a certain judgment as to the economy which is attainable by the use of the instrument, because what has already been done is quite an insufficient criterion. We find it best to employ a man and boy together, the former to work the machine, and the latter to feed the tubes or hoppers containing the pieces. The first of these receives the pay of an experienced assorter viz. 7 Rs. 14 As. per month. The boys who are entertained in this department receive from 2 to 4 rupees per month each. I therefore think that if an allowance of 11 rupees be made for both it is

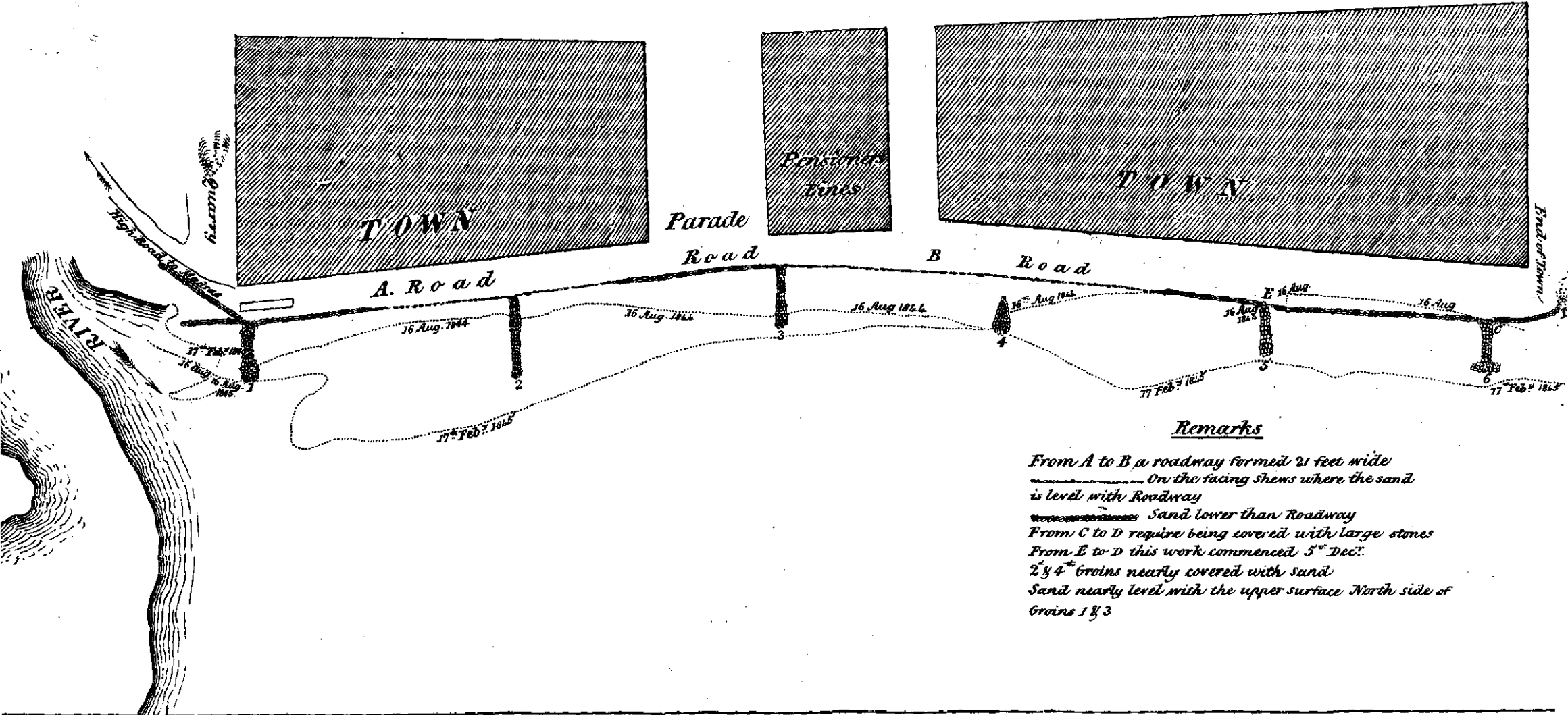
amply sufficient. Reckoning 25 working days in the month, the number of pieces which would be assorted during that time would be five lacs, or at the rate of 2 Rs. 3 as. 2 pice per lac, with an instrument of 20 beams; and if the same calculation be made for sets of 50, 80, and 100 beams, the results would be the rates of 0,, 14,, 1 in the first 0,, 8,, 9 for the second, and for the third the trifling sum of Annas 7,, 0½ per lac as the cost of the work. We cannot of course speak with certainty as to this last reduction until the practicability of working so many as 100 beams together shall have been tested, but with the improvements which I am aware may be made, both as to diminution of friction and economy of space, I think there is reasonable ground to think it quite feasible, and almost certain in regard to small coins.

57. It may be useful that I should mention one alteration which would be necessary were any large number of beams worked together, as it seems to me the easiest method of overcoming what would be the chief difficulty in the undertaking, viz. the difficulty of close approximation. In the case of an instrument of 40 or 50 beams being made, for example, it would be desirable that some of the parts should be made for sets of ten, instead of for single beams, as in the one I have described. This might with advantage be applied to the feeding apparatus, the troughs, and the shelves. There would be no difficulty, then, in bringing the beams close together, so much so that I think they need not to occupy more than 1½ inches in breadth for the largest coins, but in this case there would be a remaining difficulty, namely that of providing for the accommodation of the cylinders and retarding plates, which could not perhaps be conveniently reduced very much below their present size.

58. It will be recollected that the size of the cylinders has above been stated to be 3.2 inches, and this dimension applies to the interior. But we might safely calculate upon such a reduction as would make the whole space occupied by each cylinder equal to 3 inches; but even this would be twice too large. If however we pay attention to the circumstance that it is only at the surface of the fluid that the hydrometric part of the apparatus comes into operation, and that in so far as this is concerned, it is immaterial what the length of the stem, or depth of immersion of the retarding plate is, we shall arrive at a solution of the difficulty.

59. In such a case as the above, where it is very desirable to economise space as much as possible, the breadth of room occupied by the cylinders might be reduced one half, by placing a double series, one over the other. There would be a double series of cylinders but only a single trough, and all the cylinders immersed in the same body of fluid, the upper series of cylinders being so placed on the tops of the lower series, that the points of junction of the former should stand over the centres of the latter. A small opening would require to be left between the upper cylinders, so that they

Viragapatam Beach
Low Water Mark of the 17th Feb^y 1845
as compared with that of the
16th Aug^y 1844.



Remarks

From A to B a roadway formed 21 feet wide
On the facing shews where the sand
is level with Roadway
Sand lower than Roadway
From C to D require being covered with large stones
From E to D this work commenced 5th Dec^r.
2 & 4th Groins nearly covered with sand
Sand nearly level with the upper surface North side of
Groins 1 & 3

EXTRACTS FROM LETTERS AND REPORTS BY MAJOR ARTHUR T. COTTON ON
THE SUBJECT OF THE BULWARK CONSTRUCTED FOR THE DEFENCE OF
THE TOWN OF VIZAGAPATAM.

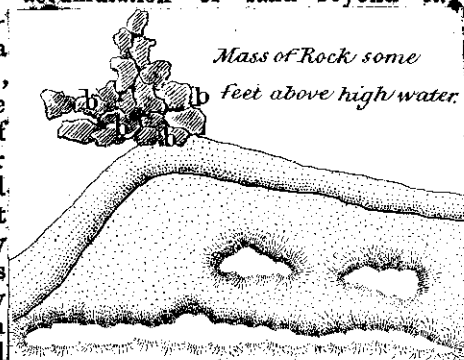
Extract from a letter to the Secretary to the Military Board.

SIR,

I have the honor to transmit a rough plan, showing the state of the Beach of Vizagapatam, which I have prepared in reference to the orders of the Board, contained in their letter No. 1238, dated 12th May last, to consider the mode of constructing the proposed Bulwark.

The point therein especially referred to me was the substitution of detached masses of bulwark for the continuous line proposed by Captain DeButts. As this plan shows the position and effect of a remarkable natural bulwark of this kind, situated about 2000 yards from the fort, it might be expected that if duly examined and considered, a very sound judgment may be formed by that means of the effect of the artificial works suggested.

Nothing can be more distinct and marked than the effect of this mass of rock on the line of coast, the outermost point of it is about 500 feet from the general line of the high permanent sand drifts, which are covered with mud. But about 80 feet from the outer point, the rocks are disconnected, so as to allow a passage for the water, marked in the plan *b b b*, which seems to prevent the accumulation of sand beyond it. Within it however, there is a solid bank of sand, level with the wash of the surf at high water spring tides, and extending about 1100 yards. By this the sea seems to be effectually prevented from encroaching all along that part of the beach. About 1200 yards from these rocks, the town commences, and the sea is washing quite up to the houses along its whole length, having carried away the front line for a considerable distance near the fort.



This accumulation of sand is found only on the south

side of the rocks. On the north side, immediately beyond them, the sea washes up to the high sand drifts. I should account for this by supposing that the principal current is from the southward. * * * * *

From these considerations I conclude.

1st. That projecting stone groins would certainly cause the sand to accumulate to the southward of them.

2nd. That they would affect a great length of beach; the rocks at *A* extending about 420 feet from the line of sand hills, seem evidently to collect the sand from a distance of 1100 yards. I should rather say the rocks are situated about 420 feet from the sand drifts, for it is not certain that they extend to them, as there are no rocks visible above the sand. A groin extending 50 yards would, according to this proportion, affect the bank for 400 yards, in which case *B* would protect the whole town.

3rd. That a very slight line connecting the outer point of the groin with the shore would be sufficient, as it would immediately collect the sand, the outer end alone being exposed to the force of the sea. * * * * *

It is evident that those works, though intended only to protect this town, will be of very considerable general importance, as an experiment which, if successful, may greatly facilitate the protection of any other part of this extensive line of coast, and on this account it is well worthy of much consideration.

24th June 1843.

Extract from a letter to the Secretary to the Military Board.

* * * * *

The first groin now contains about 3000 cubic yards of stone, and as it has been repeatedly exposed to very severe surfs while in progress, I do not think it would sink much more. We have on the spot and in the quarries, about 800 or 1000 cubic yards of the largest stones, which I think will be sufficient to complete the groin. The outer stones will be from 8 to 15 cwt., but by continuing the rails to the sea, we could easily convey stones of two tons.

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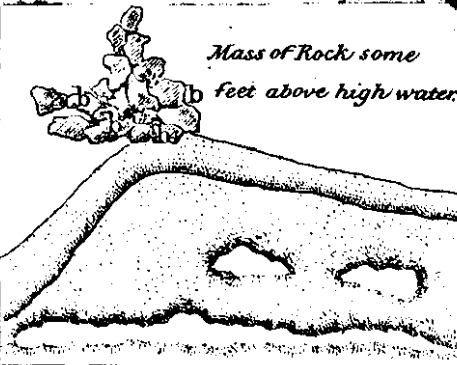
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The second groin is commenced at the western

end of the Pensioners lines, 270 yards north of the first, so that, if necessary, a third may be interposed between them. This work may be carried on more rapidly than the first, as there is now a great number of persons ready to contract for any quantities of stones.

The cost of the first groin of 70 yards will have been almost 3500 rupees, if completed to 80 yards, including all the preparations, viz. making roads, purchase of stones, tools, rail-waggons, iron for rails &c. The second will cost almost 1800 rupees if made of the same length, which I conclude would certainly be advisable. The second point which I beg respectfully to bring before the Board is the effects of the first groin; I am happy to be able to state that they are already highly satisfactory. The last three or four spring tides have been very high, and accompanied with very stormy weather, producing a severe surf. The consequence has been a great encroachment of the sea along almost the whole line of the town (protected by the groin) by which a great number of houses have been washed down, both north and south of the groins, and at the southern end of the town a very solid mass of prickly pears forming the last barrier to the sea, has been almost totally swept away. But so complete has been the effect of the groin in accumulating sand to the southward of it, that the sea has not touched the shore for full 150 yards, that is, from the groin to something beyond the southern end of the parade, and its influence was so extending, that in the last two springs the sea did not encroach on the shore nearer the groin than about 200 yards. The residents have all expressed their assurance that the groin has effectually stopped the encroachment on the parade, and that but for its construction a considerable breadth of ground there would have been cut away by the spring tides of the last two months. I thus felt satisfied that the first object, the preservation of the parade, is already attained. I transmit a section of the beach on the north side of the groin, and also that on the south side, both taken on the 13th September, from which it will be seen that near the inner end of the work, the sand is $6\frac{1}{2}$ feet higher on the latter side than on the former. The plan contains also, a section taken before the work was commenced, showing that while all along the outer point of the town great encroachments have been made, there has here been a considerable accumulation. The full effect of the groin can scarcely be seen yet, having been so short a time under construction; but as its influence already extends upwards of 150 yards, I should judge that it would ultimately protect full 3 times its length; and hence it may be hoped, that if the groin just begun is extended to 80 or 85 yards, it would not be necessary to construct one between the two now constructing, which are 270 yards apart. But at present I do not feel inclined to lengthen them beyond 70 yards, as I shall not be able to observe their further effects for some time to come, in consequence of the change of the monsoon, which will at all events prevent any accumulations on the south side of these works. I am informed that the currents in the north

east monsoons are so weak, that the accumulations are never removed from the south sides of the rocks on the coast, nor any considerable accumulations formed on the northern sides * * * * I beg to call the attention of the Board to the great excavation of sand immediately beyond the end of the groin, as shown by the section, the water there being 6 feet deeper than it is a few yards farther. The reflow of the surf causes a strong current along the sides of the groin, which is continued beyond it, so that a man cannot swim from seaward to the end of the work. I think this particularly worthy of notice, because it would seem at first to show that a communication across the surf might be effected by a simple groin or jetty, for if there is so strong a current at the point of such a work, it seems probable that by carrying the jetty beyond the break of the surf, and sinking a short break water at right angles with it, and little detached from it, there would be always both deep and smooth water between the end of the groin and the break water, where boats could lie safely. This subject seems to be worth examining, with reference to the improvement of the port of Madras. Should it be thought worth while to make any experiment on this point, I would observe that no place on the coast would be more suitable than this, where it could be done so cheaply, both on account of the low cost of labour, ($1\frac{1}{2}$ anna for the highest rate of cooly) and also the facilities of carrying, and the short distance from the rocks to the beach, for the southward groin will be only 300 yards from the quarry. The cost of stone per cubic yard at that point will not exceed $2\frac{1}{2}$ annas, so that per 1000 rupees 6400 cubic yards might be added to that groin, making 11400 cubic yards, sufficient to extend it to 150 yards, and make a small break water opposite to the end of it. I only give this calculation to show at how small expence some experiment could be made here, if the subject is considered worth prosecuting.

1st October 1843.

Extract from a letter to the Secretary to the Military Board.

I stated in a former letter that the backwater rose to a level of from $1\frac{1}{2}$ to 2 feet above the highest spring tides, but I had mistaken the water mark, and I have since found that it rose exactly 5 feet above the level of the highest springs; and as the greatest height was at 2 A. M. on the 25th, the hour of low water, and the tide rises nearly 5 feet at springs, it is evident that the backwater was at that time nearly 10 feet above the level of the sea, from which a judgment may be formed of the vast body of water that came from the interior. The point of sand on the north side of the river was entirely swept away, making its mouth much wider than it was before.

With respect to the effects of the hurricane on the beach, it should be observed, that just at the previous spring tides, there had been a severe and continued storm, which had washed away most of the sand that

accumulated near the groins, and this gave the hurricane a great advantage, and caused the encroachment where otherwise there would have been none. On the other hand, most providentially, the strength of the storm was from half ebb to half flood, had it blown in its force at the time of high water, when the sea would have been two or three feet higher, the destruction in the town must have been far greater. As it was, an encroachment of from 6 to 10 yards in breadth, took place throughout the whole length of the town, (taking away a complete row of houses) excepting near the groins, that is from 100 yards south of the first groin, to 100 yards north of the second, where the encroachment was less, that is from 1 to 4 yards in breadth. Since that time, there has been a very great deposit of sand, both north and south of the groins, but especially between them, so that at low water, a person can walk straight from the outer end of one to that of the other on the dry sand, that is at 70 yards from the shore. I am therefore of opinion, that had the two groins been completed long enough for the sand to have collected between them, the hurricane would not have cut away the beach there. I have not yet however sure grounds for judging of this, I feel confident that no great deposit of sand can take place during the stormy part of the south-west monsoon, that is, nothing like that which occurs during the fine weather. From constant observation of the changes in the beach at this place, I have satisfied myself of these points respecting the sands.

1st. They are always carried away as the strength of the surf increases during stormy weather, and deposited as the sea subsides.

2d. They are always carried away as the spring tides advance, and deposited as they go off.

3rd. They are always carried away during flood tide, and deposited during the ebb.

4th. The effect of the current upon them is very small, probably quite insignificant in comparison of that of the wind. In whatever direction the surf strikes the beach, (which will almost always have some slight degree of obliquity), in the same direction the sand will be carried forward, even though the current may be the opposite way; thus if the wind is from east by north, on a coast lying north and south, the sand will be carried to the southward even though the current may be running to the northward. If at any time the surf should strike quite directly on the beach, perhaps the sand might be carried forward in the direction of the current, but I think it would scarcely move either up or down the coast, because the current close in shore is extremely slight. Just within the mouth of this river the progress of the sand inwards by the action of the surf is plainly seen, while there is a strong ebb tide, until there is a large body of water coming down from the country, producing a current of several miles an hour.

I have now commenced a facing of stones along the beach, in addition to the groins, for the following reasons.

1st. The storms of the last monsoon, and especially the hurricane, have now cut so far into the town, that to obtain a road for conveying the stone to the groins, a vast number of houses must be removed, and the expense would be so great, that it seems out of the question to carry the stones that way; to convey them along the sands would be a most laborious and expensive work, and there therefore seems no alternative, but to make a road outside of the town, on a level a few feet above high water mark, and securing it by a slight facing of stones. It will not require much stone, because the whole fine season is before us, and the force of the surf now is nothing compared with what it was in the south west monsoon; and also before the strength of the next monsoon, we may expect that a much greater deposit of sand will have formed.

2nd. There is now no communication along the beach at high water, and this was before one of the principal roads from north to south of the town; this communication will therefore not merely answer for conveying the stone, but it will be of great use afterwards.

3rd. I am not yet certain respecting the distance between the groins, and should they be too far apart, I think it will be as effectual and easy to make a slight bulwark, as to interpose additional groins. It should be observed, that I consider the groins at their present distance, will at all events effectually resist the main force of the sea, so that the facing of stone I am now forming, need not be of more than an eighth of the section that a regular bulwark would be, and I hope that it will always have a large deposit of sand outside of it.

Part of the wooden railroad has now been worked with waggons on wooden wheels, bearing loads of 2½ tons and under, for more than two months, and it has thus far answered admirably, but it takes a long time here to collect any quantity of materials, and to construct the waggons &c.

A third groin has been begun 250 yards south of the first, and a railroad is under construction from the end of the hill south of the town to it, a distance of only 300 yards. On this line, the waggon works with perfect ease on a curve having a radius of only 19 yards. When the works now in hand are completed, there will therefore be three groins 70 yards in length, including between them 480 yards, and protecting, I should hope, 800 yards of beach, along which also there will be a road with a facing of stone. They will require about 9000 cubic yards of stones, of which 1000 are ready.

The actual expenditure about the beginning of this

month was 5500 rupees, of which about 1700 rupees had been expended on stores, railroads, waggons, the removal of huts at the quarries &c. The quantity of stone deposited, or ready for deposition, was about 9000 cubic yards, which gives an average of 10 annas per cubic yard, including every thing, and deducting the cost of preparatory work, about 7 annas per cubic yard, including native superintendence.

* * * *

The length of railway already laid is 1100 yards, the cost about 10 annas per yard of road, including laying; the material is dammerwood, the waggons cost about 50 rupees each, and it requires about 2 men per ton of load to work them on a level. From their cheapness, I think they would often be useful in public works. We have no difficulty in working a curve of 19 yards radius, and one with radius of 12 yards is now constructing, which upon trial appears to answer. To cover the rails with an iron plate of $1\frac{1}{4}$ inch by $\frac{1}{4}$, would cost $\frac{1}{2}$ rupee per yard of road. It costs here about 2 pice to convey a cubic yard of loose stones 200 yards on the railroad, and about 1 anna for the same if conveyed by coolies.

13th November 1843.

To the Secretary to the Military Board.

* * * *

Since my last report I have continued to cover the north groin with large stones and it is now nearly completed. The 3d or south groin is also carried on, extending 32 yards. An embankment of sand faced with rough stone now extends along the beach from the new quarry on the Mosque Hill at the south end of the town to the north groin, but it requires yet to be raised and much additional stone to be thrown against its face, which work is in progress; the smaller stones being thrown on this line, while the larger ones are taken to the groins along this embankment, the rails are laid from the new quarry to the south groin, and they will be continued along it to the first groin.

* * * *

The deposition of stone at the south groin, has been considerably retarded by a sudden and strong set of the surf upon the southern point of the town, which has obliged me to throw a large quantity of stone down there for the protection of the railroad, and also of the common road beyond the end of the former. This encroachment of the sea is very remarkable, as there is now little surf, and also the main level of the sea is near a foot lower than in the south-west monsoon, on which account the sea usually makes no encroachment. All along the remainder of the town, there has been a continual deposit of sand since the stormy part of the monsoon terminated; and of late, the accumulations have been very great between the groins, where we had made a raised embankment 3 or 4 feet high only a month ago, the sands are now nearly level with the

top of the bank, and there is a prodigious deposit of sand against the groins. Yet the set of the sea upon the southern part of the town was so decided, that there is no doubt it would have washed away all the ground up to the Mosque Hill, and have cut off the communication from the town to the river, had it not been for the stones thrown down for the protection of the railroad; and beyond the end of those stones it cut away the ground with such rapidity, that I could not prevent it from destroying part of the common road, though I threw down all the stone I could obtain. As this is a very important point, being the only line of communication from the town to the river, and the great road to Madras, it seems absolutely necessary to protect it by the construction of a groin of 30 or 40 yards in length. As the distance for the conveyance of stone would be only a few yards, the cost of this would be very small, about 3000 cubic yards at 5 cubic yards per rupee, would probably be sufficient.

* * * *

There has been no encroachment at all at any part of the beach, excepting the southern point, since the hurricane. But there are several reasons for this; 1st, at this season of the year there is no surf of any consequence, 2nd; from the continuance of fine weather and lightness of the surf for a long time, the sand has gradually accumulated; so that instead of a steep beach, as there is towards the middle and end of the south-west monsoon, there is now a broad flat of sand extending to upwards of 50 yards in breadth, and opposite the groins it is upwards of 100 yards in breadth, 3d; the mean level of the sea is nearly a foot below that in the south-west monsoon. There is thus always a cessation of encroachments during the fine part of the north-east monsoon, and the effect of the sea upon the southern point of the town lately seems to be quite unusual, it may be in a great measure owing to the retention of the sands by the groins, but it seems not to be entirely attributable to that, because there has been no such encroachment immediately south of the first groin, from which part the sand coming from the north is as much cut off as it is cut off from the south point.

But while there is this general accumulation of sand along the face of the town, the effect of the groins is most distinctly seen, both in the height and breadth of the sand in their neighbourhood.

* * * *

27th December 1843.

To

W. U. ARBUTHNOT Esq.

Collector of Vizagapatam.

SIR,

In reply to your letter of the 27th instant, desiring me to prepare an estimate for the extension of the works now under execution, for the defence of the town from the encroachments of the sea, I have the honor to state that, from the experience of the progress

of the sea of late years, and especially during the season that I have been here, there seems no ground to expect that it will not continue to advance and destroy any part of the town that is left unprotected by stone work. The original estimate was intended to provide for the protection of 350 yards in length only, viz. the parade and the pensioners lines, but I have reason to hope that it will be found quite sufficient to protect the beach from the river as far as the present northern groin, and I have therefore prepared an estimate for the remaining 500 yards of the town lying north of that point. This additional work can be executed at a lower rate than was before estimated, on account of the apparatus, viz. rails, waggons, and cranes already provided, the rails are sufficient to reach from the quarry lately opened to the north extremity of the town, but two or three additional waggons would be desirable, that the work might be hastened. The estimate now forwarded provides for the construction of two additional groins, and a raised road with a slight facing of stone between them, which would complete a good line of communication along the whole sea face of the town; this is very much needed, especially on account of the encroachments having compelled the people to build in the most crowded manner along that line. It is of course most desirable that this work should be done now; besides the cost of apparatus, it has of course cost much time and money to get the present arrangements organized, to get the people accustomed to the quarrying work, the rail-waggons, cranes &c. and if the works are not completed, it will cause much additional expense to begin entirely anew at some future time. It is also of great importance to press on the work as much as possible during the present season of the year, for two reasons; first, because that there is now no interruption from storms, which caused much additional expense in the south-west monsoon; and secondly, if the groins are constructed before the stormy part of the year, the sand now accumulated along the beach will be retained, whereas, if they are not constructed till after May, the sand will be carried away, and considerable encroachments will again be made in the stormy months.

With respect to the necessity for the completion of these defences, I should mention that about 15 yards in breadth of the whole surface of the town, excepting about the parade, has been washed away since I came here, the whole of this entirely covered with houses; and as the sea advances the buildings that will be destroyed by it are increasingly valuable. At the southern end of the town the sea has cut away part of the high road to the landing place and to Madras, and but for the stones lately deposited there this communication would have been entirely cut off, considerable work will be required to secure this point.

* * * *

28th December 1843.

Estimate of the Expense of extending the Bulwark now constructing at Vizagapatam, for the protection of the Town.

2 Groins 70 yards in length containing 10,000 cubic yards.

5000	}	Facing 500 yards length of beach north of the present northern groin at 10 square yards of section.	
Cubic yards 15,000		Rough stone, at 3 cubic yards per rupee....	5000
Additional apparatus.....			500
			Total C. Rs. 5500

Vizagapatam, 28th December 1843.

Extract from a letter to the Secretary to the Military Board, under date 6th May 1844.

* * * *

The bulwark has been completed to the northern end of the pensioners lines, that is, so far as it can be, till the effect of the south-west monsoon upon it can be seen. The southern groin, at the southern part of the town is 30 yards in length; the other three 70 yards each, and the facing between them is in all 800 yards long and 7½ feet above the level of the highest spring tides. There remains of the estimate about 750 rupees, which would be sufficient to cover the expense of depositing about 4000 cubic yards of stone, and this would be available for raising the points of the groins or any part of the facing which might sink during the monsoon. We have already had some considerable surfs, and a great part of the sand deposited during the north-east monsoon along the whole face of the town has been carried away, but much more at the northern end than between the groins. Though the points of the groins have been exposed to the surfs now for several weeks, they have not yet sunk at all perceptibly. The total quantity of stone deposited is about 24,500 cubic yards, besides some ready in the quarry, and the cost 12,560 rupees, being at the rate of just 8 annas per cubic yard, including railways, cranes, purchase of houses, forming roads, and every other item.

We are now proceeding with the railway, and facing, north of the northern groin, upon the estimate sanctioned in the Civil Department, and have completed nearly half of it, but the beach is there now so steep, and the sand still washing away so fast, that we shall scarcely be able to make good our line of communication the whole length, and secure it before the moonsoon.

* * * *

6th May 1844.

Extract from a letter to the Secretary of the Revenue Board, Department of Public Works, under date 25th May 1844.

* * * *

The bulwark however will certainly require the Superintendence of an officer during the monsoon without

intermission, to observe its effects, and be ready to press on the work in case of any point being endangered; the extension of the bulwark to the northern end of the town especially, is in a very exposed state, there being only a weak facing, and the first of the new groins being but just begun. During these months I suppose a Civil Engineer cannot do much in this Division, the rains being so constant, and the country so impassable from want of roads, yet it is extremely desirable that he should be at liberty to do whatever circumstances will allow. I have not yet been able to see much of the division, but from what I saw in my late tour to Gangam and Kimedy, and all that I have learnt of Rajahmundry, it is quite evident that three active Officers are most urgently required in it, the expenditure in it hitherto has been so utterly inadequate &c. &c.

Extract from a letter to the Secretary to the Military Board.

I have continued the roadway and facing to the northward as fast as we could obtain stone for it, but it proceeded very slowly on account of the great quantity of sand which had been swept away by the first surfs we had in the beginning of the month, which yet were comparatively light, the southerly winds evidently still blowing along the coast only. We had continued it 400 yards from the northern groin, when on the 24th instant, the heavy bay swell indicating that the southwest monsoon had commenced in the bay, set in with considerable force, and in two days swept away all the remaining sand from the foot of the facing, leaving the work exposed to the full force of the sea. It was evident now that there was no hope of continuing the extension of the roadway, as every stone that could be obtained would be required to secure what had been already constructed. Since that date therefore, we have been adding to the stone facing, and the sea every day causing the stones to sink as fast as we could bring them, we have now employed coolies in addition to all the rail bandies to convey stones to this part of the work, by which means we are now throwing in about 200 cubic yards a day, we are now rather gaining ground, and the surf having a little diminished in the last two days, the sand has again risen there. No time however must be lost in strengthening this facing as there will be in future no complete intermission of the heavy swell, and in the course of next month we must expect severe surfs.

Had the work been one month in advance of what it is, the groin would have been carried out some distance before the sand was washed away, and much of it would have been retained. At present we cannot spare any stone to carry on the groin which had been just begun.

It will be evident, that in this state of things, we shall be compelled so to strengthen the facing that much smaller groins will be required.

I had before come to the determination in this new part of the work to make the groins shorter, and at smaller intervals, for the following reasons; first, so far as I can at present judge from what I have seen of these works, I am inclined to think less favourably of the very long groins than I did at first, that is, I think it probable that short groins at shorter intervals would protect the beach with less stone; chiefly because it does not appear that nearly so much stone would be required at their points as I had thought; secondly, it seemed very desirable to obtain as much information from this work, as possible, and that therefore it would be better to make a trial of short groins as well as long ones, if it could be done without the probability of a waste of stone. I had consequently commenced the two first groins of the new work at intervals of 150 yards, purposing to make them 30 or 40 yards long. As matters however now stand, I must be guided entirely by the effects of the surf upon the work, purposing however, that, if we get the facing well secured, I would proceed with the groins as begun.

With respect to the effects of the groins already constructed at present, they are very striking, as will be seen on inspecting the accompanying plan and section of the beach; throughout the whole length of that part of the work, there is a high and broad bank of sand outside the road-way, while north of the groins, the sand is 14 feet below the top of the road-way, and the surf breaks with its full force on the facing. This, so far as it goes, is highly satisfactory, but we must wait for the heavy and continued surfs of July and August, before we can properly judge of the effects of the groins. There is not yet the least appearance of any sinking of the ends of the groins, though for the last week the surf has broken on them very heavily.

There is every proof that the surfs would have already made a further cut into the town, and destroyed many houses, but for the new work, so that it was of great importance to extend that work as far as possible. There is however still about 100 yards of the town exposed, beyond the end of the work, and I am afraid it will be impossible to save it from encroachment this season.

30th May 1843.

Extract from a letter to the Secretary to the Military Board.

After my last report dated the 30th May, I continued for some time to struggle against the heavy surfs, which broke upon the new work towards the northern part of the town, but I was unable to supply stone fast enough to maintain the whole extent of facing; (400 yards) I was obliged therefore to abandon 100 yards of it, and as soon as I had sufficiently strengthened the remainder, for the time, I ran out a new groin at the end of it, 300 yards from the next southern groin. This

5th groin is only 55 yards in length measured from the bank, that is 15 yards shorter than the other; I left it thus short in order to see whether it might not be sufficient, as the other groins appear now to be longer in proportion to their intervals than is necessary. I also covered this groin and the new facing with large stones. During these 3 months the sea has broken frequently with great violence upon this new facing, as it was quite unprotected by sand, and I have had constantly to raise it in consequence of its sinking. The surf has repeatedly broken over it, and thrown up volumes of spray 7 or 8 feet above it, though it is 8 feet above high water spring tides, especially during the late springs when we had the heaviest surfs this year; we had then again to take up the rails in consequence of the stones having sunk so much. During the monsoon no sand of any consequence accumulated here, some collected at times and again washed away, excepting in the angle formed by the next groin, where the sand soon formed sufficiently to protect the facing; and its effect in this way was remarkably seen in the last heavy surfs; where the sand had risen to within 4 feet of the top of the facing, not the least injury was done to the railway, while further on, where the sand was 4 or 5 feet lower, the stone work was so deranged that it was necessary to take up the rails.

Since the turn of the springs the sand has deposited with extraordinary rapidity, and where it was $14\frac{1}{2}$ feet below the top of the facing about 6 weeks ago, it is now only $4\frac{1}{2}$ feet. This last new moon is generally the end of the stormy part of the south-west monsoon, so that it is not probable that any severe surfs will break on this work till the setting in of the north-east monsoon, when there may be expected one or two gales, but in the interval probably a large quantity of sand will be deposited.

On the 14th of this month, there remaining nothing of any consequence to do to the work already done, and it being impossible to extend the bulwark to the northward from want of space to convey the stones, I reduced the establishment to the lowest that I safely could, keeping only one or two bandies at work, in case of stones being required at any point. There will not probably be sand enough to the northward till November, to enable us to proceed and complete the line to the north end of the town.

I will now remark upon the state and effects of the old work beginning at the south end. The short groin marked No. 1 in the sketch, sunk a little on the south side during the monsoon, but not so as to lower the work, some of the stones on that side only having slid down a little; it has not been necessary, nor is it now, to add any stones to it. The surf washed away the sand south of it, and the facing there sunk a little. Between Nos. 1 and 2, the sand was washed away gradually during the last two months, principally, of course, in stormy weather and at spring tides, till a part

of the facing was laid bare, to 6 or 8 feet below the rails; during the last springs this part sunk a little, the surf breaking very heavily on it, and flying over the roadway, and it has been necessary to add a small quantity of stone to the facing. The difference between the quantity of sand in this part of the work, and that further to the northward is very remarkable, it is also to be observed that the quantity is greater between the groins Nos. 3 and 4, than between Nos. 2 and 3. There appear to me to be two reasons combined for the sand being so washed away between Nos. 1 and 2 viz. first, that the surf leading round the Dolphin's nose strikes here nearly directly on the beach, in consequence of which it does not carry the sand along and lodge it against the south side of the groin No. 2, but draws it back into the sea; 2nd, in consequence of the failure of the monsoon, there has not been a single fresh in the river to sweep away the bar, and all the sand that has been brought round the Dolphin's nose has collected in front of the mouth of the river, leaving, instead of a narrow bar 5 or 6 feet deep at low water spring tides, an extensive flat of sand covered with only 1 foot of water at that time, and forming a most serious obstruction to the trade, so much so that I believe the large donies will hardly be able to leave the port this year, unless there is a fresh in the north-east monsoon. The usual supply of sand for the beach north of the river has thus been almost entirely cut off. Had the usual freshes taken place, they would have swept the sand away from the mouth of the river, and it would have been carried on shore by the surf. If there should be a fresh at the setting in of the north-east monsoon, it is probable that a very large quantity of sand will be deposited along this part of the work. It seems probable, however, that it will be necessary to strengthen this part of the facing a little more.

The groin No. 2 has also sunk a little at the end, but far less than I had expected, and it has required no additional stone. Between Nos. 2 and 3, there is even now, at the end of the monsoon a large mass of sand, and instead of the facing having been laid bare, it has been covered with sand to within a few perches of the roadway. The sand here continued to diminish in breadth, though it was thrown up higher, till lately; but it has now begun again to accumulate.

The groin No. 3 has not undergone the slightest change. At the end of it, where at this time last year there was 11 feet of water, at low water, the sand is now bare, as it is also at the ends of the other groins, excepting the north one; shewing I think, that there is a permanent change in the line of the beach. Between No. 3 and 4 the quantity of sand is enormous, extending nearly to the end of No. 4, on a level with, and in some places higher than the groin, and even than the roadway; no where are more than a few inches of the facing uncovered. As this is the time of the year when the sand is usually most swept away, or nearly so, it seems a very satisfactory state of things. North of No. 4, and

immediately adjoining it where there was time for sand to accumulate between the construction of the facing and the setting in of the monsoon, it has never been swept away, being protected from the force of the surf, in a great measure, in consequence of its striking obliquely on the south side of the groin. At this time last year the surf washed up on the north side of No. 4 to within the line of the battery. If we were now to have a heavy gale, it would doubtless wash away a great deal of the sand all along the work, but I doubt whether it would remove any part of the facing from the groin No. 2 to No. 4, there would be some sinking of the facing south of No. 2, but a little additional stone would probably repair the damage. Excepting a short interval of bad weather at the setting in of the north-east monsoon, we have now a prospect of 8 months of smooth water, during which time the sand will accumulate all along the town.

The following points seem worthy of being remarked, in addition to what has been said.

1st. It has not been nearly so stormy a season as the last, nor have we had any decided gale, so that the work has not had so severe a trial as it might; but on the other hand, as most part of the work was executed during the fine weather, it had not had time to accumulate any thing like so much sand about it, as there will be another year; and also the part that was then finished stood the storm and hurricane of October without injury.

2nd. The ends of the groins have scarcely sunk at all, even No. 2 and 4 which were thrown out in fine weather, and consequently did not sink to any considerable depth at the time, though they have been exposed to heavy surfs almost all the monsoon. Even No. 5 which was constructed only 6 weeks ago, has not sunk perceptibly. Thus, No. 3 the first constructed, which was carried out 70 yards in the height of the monsoon, has a foundation of probably about 6 yards at the end, while Nos. 1, 2 and 4 can scarcely have more than 2 yards, showing how much stone would be saved by carrying out the groins immediately after the monsoon, or as soon as the sand is thrown up.

3rd. The surf has not the slightest effect on the stones themselves; not a stone has been moved at the ends of the groin, though the slopes are not near so great as I at first proposed. And even on the facing, where the water was about 7 feet deep at high water, and the surf broke so violently as to fly 7 or 8 feet over the top of the roadway, though the slope was quite steep, and many of the stones were not large, the largest being under $\frac{1}{2}$ a ton, the slope was scarcely altered, standing probably at about $1\frac{1}{2}$ to 1.

4th. A slight facing seems to be useful, at least at first, in case of the sand being washed away, but I am almost inclined to think that with groins extending as

these do, or 55 yards beyond the line of facing, when once the sand is accumulated, the facing stones might be taken away.

5th. From an inspection of the plan, it seems as if with this length of groins much larger intervals might be allowed, especially on a straight line of coast, where the surf breaks obliquely. Even at No. 4, the direction of the surf is, in consequence of the Dolphin's nose, more perpendicular to the beach than it would be at Madras, for instance. It appears as if it would not make any difference if the groin No. 3 were removed. There is no doubt that where the evil had gone so far as it had done here, and no time was to be lost, so many groins were useful, as they formed a better protection to the beach at first, but from what yet appears, I rather think that one groin at each end of the town, and one in the centre, would have been sufficient.

6th. It seems evident that a small number of long groins, are preferable to a greater number of short ones, in this respect, that they inclose a greater breadth of sand, and in case of a succession of storms, it would take so much longer to sweep it away. And if they are constructed in the fine season, the quantity of stone in them would not be very greatly disproportioned to their length.

7th. I have made the groin No. 5 only 40 yards long beyond the facing, that is 15 yards shorter than the others, and at 300 yards from No. 4, in order to see whether a shorter groin will not be sufficient for the intervals.

There has not been the least danger to any part of the town behind the bulwark, but I regret to state that to the northward of it, many houses have been washed down, which I could not find any means of preventing. The quantity of stones in the northermost part of the facing near No. 5, is very great indeed, we have had to add to it almost throughout the monsoon; in consequence of this, the cost of this part of the work has been greater than its due proportion of the last estimate, on the other hand I hope that from past experience we shall be able to do the remaining portion of it below the estimated cost, by postponing it till the sand is accumulated there.

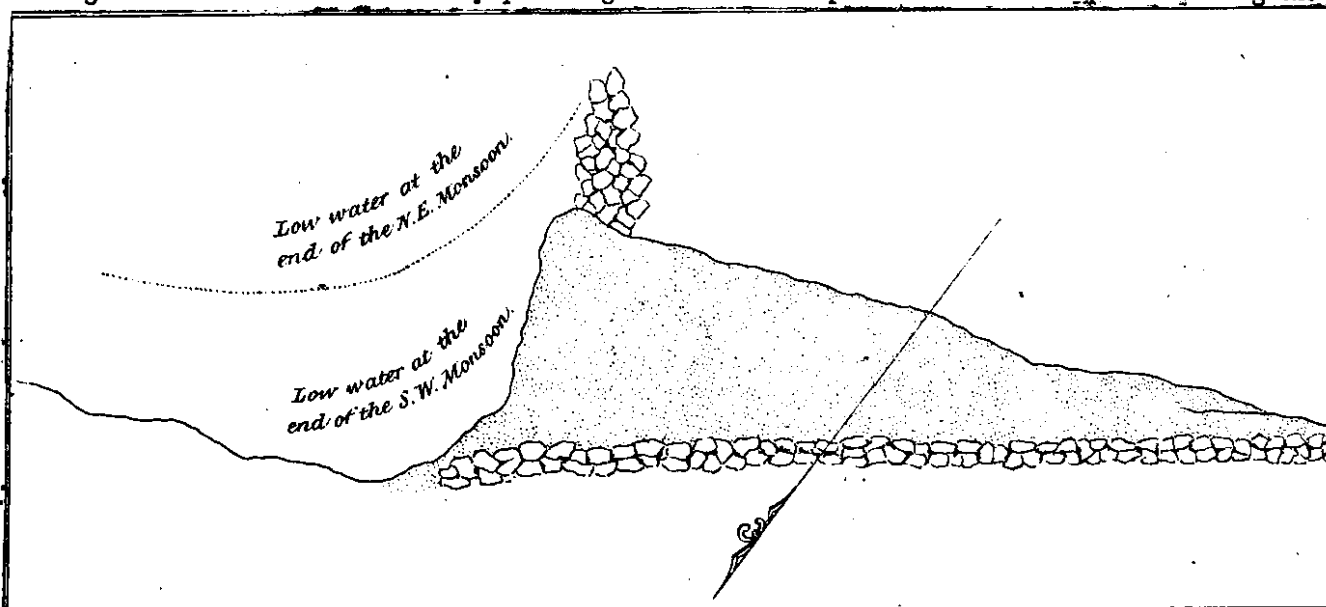
* * *

In the sketch, the low water mark of the 16th August shows its state at spring tides, the low water marks of the 17th and 19th are added, to show the rapid increase of sand as the springs subsided, a greater breadth of sand being exposed though the water on the last day did not fall so low as the 16th. The high water mark of the 21st is inserted, to show how far the high part of the sands extends towards the end of the groins, this was an ordinary tide between the springs and the neaps. At spring tides, with a heavy surf, the water washes up to the facing almost throughout.

Upon the whole, the quantity of sand along the work is far greater than I at all expected; I thought that by the end of the monsoon, the whole line of facing would have been more or less exposed.

I think I omitted to mention at the time of the setting in of the south-west monsoon, what had been the effect of the north-east monsoon upon the sands, generally, along the coast. Its effect upon the sand in moving it to the southward was evidently quite insigni-

ficant, in comparison of that of the south-west monsoon in the opposite direction. At the ledge of rocks forming a natural groin between the town and Waltair, which was particularly mentioned in my first report to the Board, there was then a hollow in the beach on the north side. This was not filled up in the north-east monsoon, that is, the line of high water was scarcely at all altered; but it became shallower, so that the line of low water was further-out, in the way here shewn. But this deposit of sand takes place all along the



straight line of the coast, as well as in this hollow, during the fine weather. Hence it appears, that though there is some little time during which there is a heavy surf from the northward, just at the setting in of the north-east monsoon, which must move some sand to the southward, yet that this effect is very slight, and that there is consequently a very great balance in favour of the sand moved by the south-west monsoon, so that upon the whole the sand is continually carried to the northward, and consequently where there is a promontory like the Dolphin's nose, which in a great measure cuts off the supply of sand from the southward, the sea must necessarily encroach on the shore north of it, unless stonework is thrown out to prevent it. I have no doubt that this preponderance in the effect of the south-west monsoon is also found at Madras, (though not to so great an extent) as the surfs produced by the southerly winds continue much longer than those of the north-east monsoon; and I am convinced that the movements of the sand depend solely upon the direction and force of the surf, and are entirely unaffected by the current, simply because the force of the current along the shore is nothing, when compared with that of the surf. As respects Madras, I should draw this inference from what I have seen here, that stone groins would protect the beach for a considerable distance, probably 5 or 6 times their length, and that it will make an enormous difference in the cost of such works if they are executed during the fine season, for the reasons mentioned above.

26th August, 1844.

Extract from a Letter to the Secretary to the Military Board, under date 18th June, 1845.

Since my last report on the progress of the bulwark at Vizagapatam, I have several times expected to have an opportunity of personally inspecting the work, and on that account I have postponed sending any further statement hitherto. I have, however, had such important duties in this district, the works have gone on so well, and Serjeant O'Hara's reports have been so entirely satisfactory to me, that I have not again visited Vizagapatam. What I have now to report, therefore, is merely what I have learned from the reports of Captain Shaw, (late in charge of the division during my absence) who inspected the work, and of Serjeant O'Hara.

The 6th or northernmost groin was completed, and the facing carried about 100 yards to the north of it, that is, to the western extremity of the town, before the change of the monsoon, but not early enough for the sand to collect about that part of the work to the extent that was desirable, though still a large quantity had formed against it. At the first commencement of the strong southerly winds, the sand was rapidly removed from that end, and the extremity of the groin and the adjoining facing sunk a good deal. A good quantity of stone had been deposited near each groin previously, to be ready to apply to any point that might require it, and this was immediately used to repair the facing.

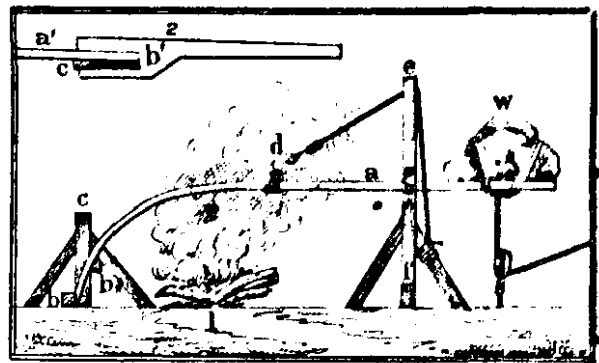
Since then the sand has again rather increased at that part of the works, and the late accounts state that the whole work is well covered with mud. This is exceedingly satisfactory, as the season has been more stormy and the surfs higher than has been known for many years. As a considerable part of the work had not had a whole fine season to collect sand about it, it was to have been expected rather, that the facing would have been laid bare, and have required additional stone from time to time. The mass of mud in front of the older portion of the work is so solid, that in these severe surfs and at the spring tides, the wash of the sea at high water has scarcely reached the stone facings. There are yet two stormy months, the effects of which remain to be seen, but thus far the work has answered completely. Part of the town has now been protected one whole season, and part of another extremely stormy one, without a house having been endangered. There is still a little money in hand, and the old materials are of some value, there being upwards of a mile of wooden

raile, &c., but I purpose keeping the accounts open till towards the end of the year, in case any additional work should appear necessary.

As I propose hereafter, when I have had an opportunity of visiting the place, drawing up a more complete report on this important experiment, I will only here observe, that near a mile of coast has thus been protected, at an expense of about 18,000 Rs. including all items, such as construction of railroads, and cranes, cost of tools, powder, &c., subordinate superintendence, and office establishment, the purchase of many houses, &c. I think if the necessary allowance is made for the difference of distance of transport of stone, and of the cost of this work with that of the Bulwark at Madras, it will put in a very striking light the superiority of loose stone groins with a light stone facing, to a solid continuous bulwark with a wall of masonry behind it.

Extract from a Letter from Captain G. C. Collyer, on the Subject of the Mode of bending Planks.

I suppose you are well acquainted with the method used in this country for bending planks for ship-building purposes. I had never seen it before I went to Cochin, where I was constructing a Steam Dredge. It is a simple, cheap, and very efficient method, and as others may not have seen it, like myself, perhaps a slight description may be of assistance to some one similarly employed. Planks for all sizes of craft from boats to vessels of the largest class are thus bent. The plank *a* to be bent is wetted all over with a solution of cow-dung in water, tolerably thin, and mixed with sand; it is then put in between the two transverse timbers *b*, *b'* (as shewn in the accompanying sketch), attached to the upright *c*, and is bent over *b'* by attaching a weight *w* or any other contrivance, (a rope and pulley purchase) at *d* a chain is attached, thence a rope goes over a pulley at *e* on the upright *f*, by which the plank can have a little more curvature given to it if required. Sometimes a peg is inserted at *o* as the case may be, by which an additional strain upwards can be borne at *a*—all this time a plentiful dose of the above mixture is applied underneath, and at top, to prevent burning from the fire, &c. &c. It is taken down and fitted occasionally to the part of the vessel to see if the curvature is right. It may sometimes happen that the plank is too short for the frame; when this is the case, the end of the plank *a'*, fig. 2, is inserted into another piece *b'*, and confined by a cleat *c'*; this is perhaps a very rude way, but it is a very cheap and efficient one—and I have seen planks bent by its means, without a flaw being produced in them. Perhaps the above not very elegantly worded description, and still worse diagram, may, when put by your master-hand into shape, be of some use in the Transactions—a hint sometimes helps a man who would otherwise be thinking about boilers, steam-boxes, and all the other contrivances European ship-builders require.



ABSTRACT OF SOME EXPERIMENTS ON THE STRENGTH OF WOODS TRIED AT GUNTOOR IN 1840, AND AT SINGAPORE IN 1843—FURNISHED BY CAPTAIN S. BEST.

No.	NAMES.	Length.	Breadth.	Depth.	Cubic Inches.	Weight.	Specific Gravity	Length between supports.	Weight sustained before breaking.	Corresponding deflexion in the middle.	Deflexion corresponding to	Weight sustained.	REMARKS.
		Inches.	Inches.	Inches.		oz.		Inches.	lbs. oz.	Inches.	Inches.	lbs. oz.	
1	{ Mimosa Arabica, Baubool (Hindoostany) } { Toomakurra (Telooogo)	62-625	1-375	2	172	96	964	59-156	539-2	1-8125	{ 0-5 1-094	{ 155-12 346-0	{ The weights were removed and the wood became again perfectly straight.
2	{ Borassus Flabelliformis, Palmyra, } { Tar (Hindoostany)	62-625	1-375	2	172	96	964	59-156	255-14	1-1875	{ 0-5 1-0	{ 104-0 217-4	{ This specimen was cut partly across the fibres.
3	Do. do.	62-625	1-375	2	172	96	964	59-156	474-14	1-71875	{ 0-5 1-0 1-5625	{ 117-2 230-2 423-4	{ Cut parallel to the fibres, but $\frac{1}{2}$ was of the pithy internal wood.
4	{ Bambusa Afundinacea, common hollow bamboo, } { Bāns (Hindoostany) } { Moongil (Tamil)	62-625	D. 1-625 to 1-875	Δ 1	136-5	19	of the solid part 620	59-156	423-4	3-375	{ 0-531 1-0625 1-5 2-0625	{ 88-8 168-10 255-14 320-4	{ D. exterior diameter. Δ inner diameter.
5	Dāboo Dāgoo (Malay)	73	2-	1-469	214-0	130	1050	66	0	0	{ 0-6 1-2	{ 141-8 497-0	{ The weights were removed and the wood became again perfectly straight.
6	Do. do. (do.)	73	1-469	2-	214-0	130	1050	66	953-8	3-40	{ 0-51	{ 240-8	
7	{ Moorubboo } (Malay) { Marbow	73	1-42	2-	207-5	114	949	66	728-8	3-02	{ 0-78 1-52 1-8	{ 228-8 478-8 978-8	
8	Krānĵy (Malay)	73	1-45	1-8	190-5	152	1379	66	1103-8	3-95	{ 1-28 0-6 0-8	{ 803-8 403-8 228-8	
9	Dāmalāut (Malay)	73	1-3	1-9	180-33	124	1188	66	753-8	3-2	{ 1-7 0-4	{ 478-8 103-0	
10	{ Sirīya } (Malay) { Poon	73	1-35	1-95	192-0	84	756	66	503-0	2-67	{ 1-2 2-48	{ 303-0 153-8	
11	Do. (two pieces, one on the other,)	73	1-23	{ 1- 1- 0-277 0-277 0-277 0-277 0-277 0-277	179-5	78	756	66	278-8	6-10	{ 3-40	{ 203-8	
12	Do. (eight pieces, one on the other,)	73	1-5	{ 0-277 0-277 0-277 0-277 0-277 0-277 0-277	243-0	80	568	66	0	0	{ 3-12 5-58 8-16 10-64 12-02	{ 16-13 33-8 50-3 64-1 70-10	
13	Do. one piece,	73	1-45	1-95	206	85-33	709	66	547-0	3-33	{ 1-0 1-5 1-75 1-25 2-0	{ 155-0 322-0 220-0 372-0	{ The deflexion originally 1-5 increased in 24 hours to 1-75. This was borne 4 days without further deflexion.

The four first experiments were tried by J. Goldingham, Esq. and myself. Having no other convenient weights, and the public Treasury being close to the spot where we were trying them, we made use of bags containing each 500 Rupees, and weighing with their contents each 12 lbs. 4 oz. The pieces of wood were laid on the supports not fixed. The deflexions were measured in the middle after each bag was added, but it would not serve any useful purpose to show them all in detail. The remaining experiments were tried at Singapore by Lieut. C. M. Elliot, of the Engineers, and myself, and with great care. We used as weights on this occasion bricks, of which 9 weighed 25 lbs. The 11th and 12th experiments were tried in order to test the formula $W = \frac{b d^3}{l}$

The general results of these experiments are shewn in the subjoined table, in which for the sake of comparison are entered (Nos. 14, 15, 16, 17,) experiments by Professor Barlow, and (Nos. 18 and 19) by Lieut. Brown, U. S. Engineers, quoted in Mahan's Elementary Course of Civil Engineering, pp. 47 and 48.

No.	Names.	l	b	d	W''	f	$\frac{W''^2 D}{4 b d^2 f \text{ or } E}$	W	$\frac{3 l W}{2 b d^2 \text{ or } R}$
1	Toomakurra,	58.15	1.375	2.0	350	1.125	1300312	539	8546
2	Palmyra, No. 1	58.15	1.375	2.0	170	.875	868436	—	—
3	Do. No. 2	58.15	1.375	2.0	0	0	—	474	7517
4	Bamboo,	58.15	D = 1.75	$\Delta = 1$	270	1.625	1030406	423	7706
5	Daboo Dago,	66.0	2.00	1.41	141	0.6	3023361	—	—
6	Do.	66.0	1.41	2.00	378	0.78	3047872	953	16728
7	Marbow,	66.0	1.42	2.00	303	1.0	1917066	728	12888
8	Kranji,	66.0	1.45	1.80	603	1.28	5335333	1103	23243
9	Damalaut,	66.0	1.30	1.90	203	1.12	2180683	753	15885
10	Poon,	66.0	1.35	1.95	228	0.87	1881695	503	9700
11	Do. 2 pieces,	66.0	1.23	1.00	139	6.10	1331535	139	11167
12	Do. 8 pieces,	66.0	1.50	0.277	8	12.02	1641136	—	—
13	Do. 1 piece,	66.0	1.45	1.95	322	1.75	1230034	547	9821
14	English Oak,	84.0	2.0	2.0	200	1.28	1447026	637	10032
15	Pine,	84.0	2.0	2.0	150	0.931	1492099	—	—
16	Cast Iron (soft gray)	78.0	1.5	3.0	410	.075	17185533	—	—
17	Forged Iron (English)	36.0	1.0	1.0	560	.025	261274700	—	—
18	Pine,	85.2	2.75	5.55	0	0	0	5189	7429
19	Cast Iron,	36.0	1.0	1.0	0	0	0	800	4380

In the above table *l* is the length between the supports, *b* the breadth, *d* the depth, *W* the breaking weight, $R = W \frac{3l}{2bd^2}$, *W''* is the weight answering to *f* the deflexion, and $E = W'' \frac{R}{4bd^2f}$. Δ is the interior diameter of the bamboo, and *D* the exterior. For it, $R = W \frac{3lD}{2D^2 - \Delta^2}$ and $E = \left(\frac{W''^2 D}{3.6f \times D^2 - \Delta^2} \right)$.

$\frac{E}{8} = E$ and $\frac{R}{6} = S$ in the table of data, page 150, in the edition of Professor Barlow's work, published in 1837.

The following particulars I obtained from an intelligent Chinese Carpenter at Singapore, named Ah-See-Ah.

Daboo, Dāgoo, or Dāwoo is used for beams in houses, piles, &c. It is a strong durable wood, and grows to a large size.

Marbow is used for furniture, windlasses, handspikes, ship gun-carriages. It is a very fine wood, but does not grow so large as the preceding.

Krānji. The strength of this wood is very remarkable, being more than double that of oak. The Chinese use it for the sternposts of their junks and for anchors, and they export it from Singapore. A log 24 feet long and 1½ foot square is worth ten dollars.

Dāmalāt and Tampeenus are used for beams and posts in houses and for joists. Dāmalāt cracks and shrinks, lasts long except in water, where worms destroy it. It grows to 90 feet in length by 2½ feet square. Piles 24 feet long and 1 foot square, cost at Singapore four dollars each. The Chinese exchange the masts they bring from China for Singapore Dāmalāt. A mast worth one hundred dollars at Singapore will sell for five hundred in China.

Tampeenus is very difficult to saw, but is a good wood, lasting long, not injured by exposure, and not so liable to crack as Dāmalāt.

The Sirāya or Poon is the most abundant wood in Singapore. Small spars are called Bintāngo. The best sort of Poon is grown on the hills and called Bātū Sirāya. It is distinguished by white threads running lengthwise. The Sirāya grows to 100 and 130 feet long squaring 3 feet at the butt. It is easy to saw and work up, used for all building purposes, but not capable of enduring exposure or moisture for a long period. Planks 20 feet by 1 foot by 4 inches are worth a dollar—16 feet by 11 inches by 1½ inch about a quarter of a dollar each at Singapore. Masts 90 feet long and 2½ feet in diameter may be procured for forty dollars.

NOTICE OF SOME FURTHER EXPERIMENTS UPON THE INFLUENCE OF JAGHERY IN CHUNAM, BY CAPTAIN J. T. SMITH, F. R. S. F. R. S. N. A.

In the first volume of our transactions an account is given of some experiments made by me, for the purpose of determining the value of jaghery as an ingredient in the composition of chunam. The result of those experiments was, that there could be no doubt of its beneficial influence on its first setting at least; the strength of a mortar composed of two of sand by measure to one of lime, mixed with pure water, being upon the average of a number of trials about 1½ lb. per square inch, and that of a precisely similar mortar mixed with a solution containing 1 lb. of jaghery to every gallon of water 3.62 lbs. or more than double as much as the first.

These mortars were only a month old, and I had no means at that time of giving any facts relative to the influence this ingredient might have on the final induration of the compounds; that change being a tedious one, which it might take months or years to accomplish. As the inquiry was an interesting one, however, both with respect to the influence of the jaghery after the cements had undergone the hardening effect of combination with carbonic acid, derived from the atmosphere, and the durability of its action throughout a course of years, I took an opportunity some time afterwards to set aside a series for future examination, and have now the pleasure to give a statement of the trial of five specimens of each kind, which have been three years exposed to all the influences of the weather.

The experiments given in volume 1st had been made, as was stated in the notice given of them, with common mortar taken from a heap prepared for a public building, and which having been exposed to the weather, was thereby probably much deteriorated. It was impossible to procure any of exactly similar quality with which to compose a new series which could be strictly compared with them, and a different mixture was therefore prepared, containing a smaller proportion of sand than before; namely, in the ratio of 1¼ to 1 of lime; and with this mortar the experiments about to be described were made, and with the exception of the difference in the quality and proportion of the ingredients, they were in all other respects precisely similar to those described in volume 1st; the compositions prepared for trial being common mortar made up with pure water, on the one hand, and on the other precisely similar mortar worked up with a solution of jaghery containing one pound to one gallon of water.

From the fact of the impossibility of exactly matching the quality of the ingredients first experimented upon, it is evident, that it would have only led to error had a series of experiments of like proportions (¾ to 1) with them been set aside for trial and comparison

with them; but the truth is, that the adoption of a different ratio of the ingredients was accidental, and the mistake was not found out till long afterwards, so that although the original intention could not have been carried out so as to have elicited the truth, and the change of proportions was in that respect harmless, yet on proceeding to make trial of the specimens which had been set aside for three years, it was found that we had no data with which to compare them, and we were afterwards obliged to prepare and set aside a third small series of each kind, precisely similar to the second, as far as could be remembered, which last were operated on after a month's exposure only.

To make the comparison altogether satisfactory, it would have been desirable that the whole of the two series compared together, namely, those exposed for one month, and those exposed for three years should have been prepared at the same time and under the same circumstances, so as to be, as far as possible, precisely identical; but this was prevented by the accident above-mentioned. I have no reason, however, to believe that there was any difference, as the series exposed for the single month, though cemented together at the close of the three years during which the other series had been exposed, was prepared by the same individual, and with every endeavour to make them identical in every respect.

With these observations I shall now proceed to give the tables of results.

TABLE I.

Experiments upon the cohesive force of bricks cemented together with common shell lime mortar, worked up with plain water, after one month's exposure to the weather.

No. of experiments.	Area of surface of the joint.	Total weight* which caused separation.	Average depth of induration by the carbonic acid of the air.	Whether the cohesion or the adhesion failed.
1	36 inches.	124½ lbs.	¾ths inch	Cohesion totally
2	36 do.	152 do.	¾ths inch	Cohesion totally
3	36 do.	128 do.	¾ inch	Cohesion ¾ adhes. ¼
4	37 do.	144 do.	¾ inch	Cohesion ¾ adhes. ¼
5	37 do.	128 do.	¾ inch	Cohesion ¾ adhes. ¼
6	36 do.	117 do.	¾ inch	Cohesion totally
7	36 do.	148 do.	¾ inch	Cohesion totally
8	36 do.	137 do.	¾ inch	Cohesion totally
9	37 do.	138 do.	¾ inch	Cohesion totally
10	37 do.	137 do.	¾ inch	Cohesion totally
Average.	36.4	135.35	.31	Cohesion .9 Adhes. .1

Nearly 4 lbs. per square inch.

* Including scale pan, &c. &c. &c.

TABLE II.

Experiments upon the cohesive force of bricks cemented together with common shell lime mortar, worked up with jaghery lime water, containing one pound of jaghery to each gallon of water, after one month's exposure to the weather.

No. of experiments.	Area of surface of the joint.	Total weight* which caused separation.	Average depth of induration by the carbonic acid of the air.	Whether the cohesion or the adhesion failed.
1	37 inches.	193 lbs.	$\frac{1}{8}$ to $\frac{3}{16}$ in.	cohesion totally very regular.
2	36 do.	189 $\frac{1}{2}$	$\frac{1}{8}$ to $\frac{3}{16}$ do.	do. do. do.
3	36 do.	196 $\frac{1}{2}$	$\frac{1}{8}$ to $\frac{3}{16}$ do.	do. do. do.
4	37 do.	203 $\frac{1}{2}$	av.	do. do. do.
5	36 do.	179	av.	do. do. do.
6	36 do.	204	av.	do. do. do.
7	37 do.	296	$\frac{1}{8}$ to $\frac{3}{16}$ do.	do. do. do.
8	37 do.	226		do. do. do.
9	35 do.	199		do. do. do.
10	35 do.	209 $\frac{1}{2}$		do. do. do.
Average.	36. 3	209. 6		Cohesion totally

Nearly 6 lbs. per square inch.

These two tables present a remarkable contrast to those of similar character in volume I. It is to be observed that the proportions of sand and lime are different, but this seems hardly sufficient to account for the very great superiority in the cohesive power of those lately experimented upon. In the trials formerly given the average cohesion of the plain water mortars per square inch was about 1 $\frac{1}{2}$ lb. and of the sugared ones 3. 62. In these which have been lately made, it has been for the former nearly 4 lbs. and the latter nearly 6 lbs. for the same area.

The comparison also of these later experiments with those upon the mortars exposed for three years presents some remarkable phenomena. I shall therefore proceed to give the tables of the latter, merely repeating, as above explained, that as far as could be remembered they were precisely similar in character and composition, and that the only difference between them was their age.

TABLE III.

Experiments upon the cohesive force of bricks cemented together with common shell lime mortar, worked up with plain water, after three years' exposure to the weather.

No. of experiments.	Area of surface of the joint.	Total weight* which caused separation.	Average depth of induration by the carbonic acid of the air.	Whether the cohesion or the adhesion failed.
1	35 inches.	123 lbs.	Total.	coh. $\frac{1}{2}$ adhesion
2	36 do.	210	do.	coh. $\frac{1}{2}$ adhesion
3	39 do.	163	do.	coh. $\frac{1}{2}$ adhesion
4	38 do.	123	do.	coh. $\frac{1}{2}$ adhesion
5	35 do.	125	do.	coh. $\frac{1}{2}$ adhesion
Average.	37	148 $\frac{1}{2}$		5.3 4.7

4 lbs. per square inch.

* Including scale pan, &c. &c. &c.

TABLE IV.

Experiments upon the cohesive force of bricks cemented together by common shell lime mortar, worked up with jaghery lime water, containing one pound of jaghery to each gallon of water, after three years' exposure to the weather.

No. of experiments.	Area of surface of the joint.	Total weight which caused separation.	Average depth of induration by the carbonic acid of the air.	Whether the cohesion or the adhesion failed.
1	39 inches.	205 lbs.	Total.	coh. $\frac{1}{2}$ adhesion
2	36 do.	218 $\frac{1}{2}$	do.	coh. $\frac{1}{2}$ adhesion
3	39 do.	263	do.	coh. $\frac{1}{2}$ adhesion
4	36 do.	123	do.	Adhesion totally.
5	38 do.	129	do.	coh. $\frac{1}{2}$ adhesion
Average	37 $\frac{3}{4}$	183. 7		5.2 4.8

Nearly 5 lbs. per square inch.

These two tables when studied in connection with the two first seem to show the unexpected result that mortars are not improved in hardness by continued exposure to the air, after the first month. This conclusion is so much opposed to the general opinion derived from experience, that I can only account for it by supposing that there may be other influences which materially affect the cohesion of cemented masses which may have been overlooked. It appears by Colonel Pasley's experiments upon various mortars taken from the best brick walls within the Chatham lines, that the strength of the plain water cements contained in Table I. only a month old is equal to the average of those whose age was 30 years, being about 4 lbs. per square inch; and the close correspondence between the cohesive strength shown by Tables I. and III. seems to corroborate this inference. On comparing Tables II. and IV. still stronger evidence seems to be adduced, for the jaghery cement of three years' standing is even less cohesive than the recent compound. I can therefore only say, while presenting the facts as they have been experienced, and which I greatly regret my inability to confirm or explain by other experiments, that unless there be some other elements of cohesion which have not met with proper attention, it seems to be shown by what we have now before us, either that age does not improve the strength of mortars after they have once been fully set and dried, or that the experiments we have made cannot be taken as accurately showing the results upon the large scale.

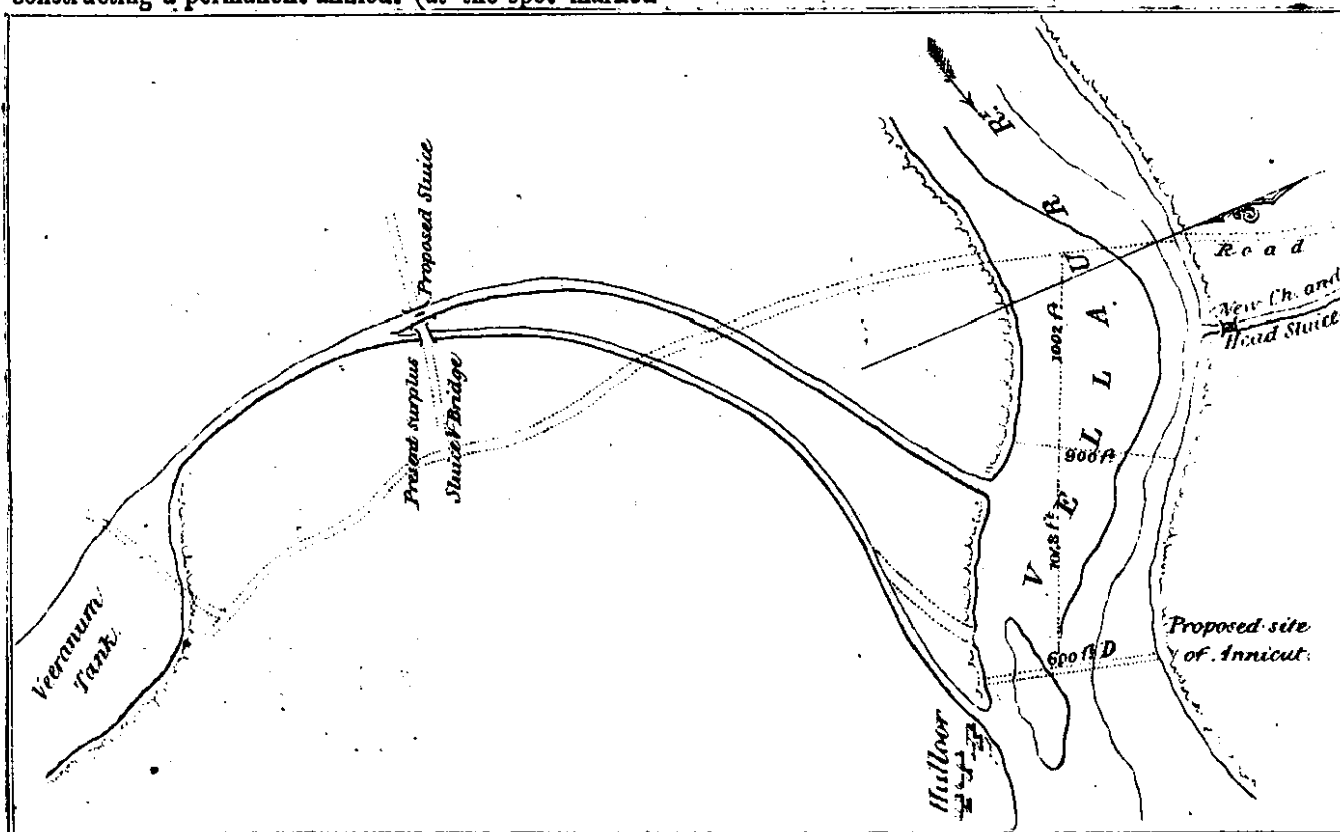
I am inclined to think, that if it be not true that the effect of age upon mortars such as those referred to in the above tables is less than it has been supposed to be, the cause of the results which have been arrived at must be some inaccuracy in the trials which has escaped my observation, as the bricks were not in either instance cemented together under my own eye; but whatever may be the truth on this point, it may be satisfactory to be possessed of a datum in the way of an approximate measure of the tenacity of mortars in this country, which when compounded in the proportions given in the above tables, and applied with care, seem to be capable under favourable circumstances of exhibiting a strength of 3 or 4 lbs. per square inch with plain water, and 5 or 6 lbs. when applied with solution of jaghery of the strength before mentioned.

J. T. S. Nov. 1845.

**REPORT UPON A PROJECT FOR ERECTING AN ANNICUT ACROSS THE VELLAUR, FOR
THE BETTER SUPPLY OF THE LAND UNDER THE WALLAJAH, PERMAUL, AND
MANAMBATTAN TANKS, AND THE KINNANOR AND MEERALOOR
CHANNELS IN THE SOUTH ARCOT DISTRICT.**

The want of a sufficient supply of water for the irrigation of the large tracts of land under the Kinnanoor and Meraloor channels, as well as those under the large tanks of Wallajah, Permaul, Manambattan, and others below them, has long been severely felt, and it was proposed in some measure to remedy this deficiency, by constructing a permanent annicut (at the spot marked

A in the accompanying sketch) across the Mannumootahnuddy at the head of the Kinnanoor channel, for which an estimate was transmitted to the Board of Revenue upwards of 4 years ago, by the Civil Engineer of the former 3d Division, Major (then Captain) H. C. Cotton.



The Board in their letter to Government under date the 4th of May, 1837, stated that there appeared to be ample proof of the necessity of the work, but did not at that time recommend it for sanction, in consequence of their requiring further detailed information regarding the work from the Civil Engineer.

Subsequent to this period, the then Sub Collector, Mr. Pycroft, in a letter to the Principal Collector under date the 28th February, 1839, after remarking on the very great advantages which would accrue from the speedy execution of the work, and regretting the delay which had taken place in its construction, suggested,

as an improvement, that the annicut should be thrown across the Vellaur, instead of the Mannumootahnuddy, as by this means advantage would be taken of early freshes in either river, and a more copious and certain supply obtained.

The site selected for this work is near the village of Audinoor, and 3,200 yards below the junction of the Vellaur and Mannumootahnuddy, and is indicated by the letter **B*, in the accompanying sketch. The report

* The points *B* and *C* could not be inserted in the sketch, and they are of no consequence for the purposes of illustration.

of Assistant Surveyor Oliver upon the relative merits of the two sites proposed has been already laid before the Board, the Assistant Surveyor giving a decided preference to the work across the Vellaur, but the site proposed by him was at the point *C*, which is 1600 yards higher up than *B*, and near the village of Arsocondanuttum.

After Mr. Oliver had completed his survey and report, it was suggested by Major Cotton, that if it were found practicable for the supply of the tanks and channels above enumerated, it would be expedient to place the annicut at the site *D*, which is nearly 4 miles lower down the Vellaur than Audinoor, and a little below where the surplus water of the large Veranum tank enters that river, in order that this water might be made available for the purposes of cultivation: by which plan a much more certain and copious supply might be obtained at a time long anterior to that in which the freshes occur either in the Mannumootahnuddy or Vellaur, and the ryots, by this desirable arrangement, might commence sowing their crops at a much earlier season.

The advantages of this last plan, should it be found practicable, are at once apparent, and are noted in a general manner in the letter of the Acting Civil Engineer of the 5th Division, to the address of the Acting Collector under date the 15th October last.

The only point of importance in the project which was at all doubtful, was, whether the relative height of the works would admit of the free passage of the water, and in order to test which, as well as to consult with Major Cotton on the expediency of the scheme generally, I met that officer in the neighbourhood of the proposed work, as directed in the proceedings of the Board of Revenue, under date the 18th November last.

After a careful examination, in company with the Acting Collector, of the localities, and ascertaining the levels of the ground, we came to the conclusion that the work would be highly expedient, and agreed upon the following plan of operations, viz.

To throw an annicut across the Vellaur, nearly opposite to Shatitape, and about 250 yards below the spot where the surplus of the large Veranum tank discharges itself into that river. This work will throw the water down a new channel, directly into the large Wallajah tank, whence the surplus will pass off by a head sluice to be constructed in the bank of the Wallajah tank to the large Permaul reservoir below it.

About 1½ mile below the head of the main channel, it is proposed to take off a branch for the better supply of the Meeraloor vaikal, where that cut intersects the proposed new line, by which the numerous villages dependent on the Meeraloor channel, as well as those watered by the Manambattan tank, would receive an ample supply; the surplus of the Manambattan again

passing off, as at present, to water the lands belonging to several villages situated lower down.

The proposed position of the annicut is the most favourable one which could be selected, and the banks on both sides are high; wells have been sunk along the proposed line of the work, and although no very stiff soil has been met with, the foundation is as favourable as that on which the Colleroon annicut was built.

It is proposed to make the work 9 feet in height, which will keep up an almost constant supply of water in the Wallajah tank, to a depth over the lowest level of 11 feet, certainly from June till the end of October, and probably even from an earlier period, when freshes sometimes occur in May, and the tank is thus partly filled before the north-east monsoon commences, may be supplied to any extent deemed expedient from the Vellaur freshes, by which means an ample supply considered desirable, may be furnished to the Permaul and Manambattan tanks, and the Me channel.

It will be necessary to regulate the supply of the main channel by means of a head sluice, and to keep the bed of this cut free from accumulations by means of a surplus sluice, a head sluice is required to the Me channel, &c. main channel, for the irrigation of lands at present watered by the Meeraloor vaikal branches from the Vellaur at a point much lower down, and a small under sluice for the Kinnanoor channel, which will then supply the two small tanks of the Me channel and Pinnaloor.

A head sluice will also be required in the Wallajah tank bank, as was mentioned above, for the supply of the Permaul reservoir, and it will be necessary to construct a bridge over the surplus from the Veranum tank to the Permaul reservoir, in addition to the above works, it will be necessary to construct a small earthen embankment along the northern bank of the river, to widen and deepen the Meeraloor channel, to increase the size of the channel leading to the under sluice, and to excavate a small branch cut to supply of the Meeraloor tank.

The several positions of these works are indicated in the sketch, and plans and estimates of them are annexed; the latter amounting in the aggregate to Rupees 44,883 7 10.

The enclosed statement will show the number of names of the villages, as well as the quantity of land under the several works proposed to be benefited, and the amount of the increase which may be anticipated.

From this it will be seen that there are nearly 1000 cawnies of nunjah land under the Wallajah, Permaul and Manambattan tanks, and the Meeraloor and Kinnanoor channels, which should, if properly supplied with water, yield a revenue of no less than Rs. 79,208; but, on an average of the last 20 years, only realized Rupees 35,181, showing an annual

of no less than Rupees 44,027; or, after all deductions for land which is of an inferior quality, of Rupees 39,747.

Considering that the proposed works will bring down the waters of the Coleroon as early as the month of May in some years, and always in June, the tanks and channels, instead of being dependent, as hitherto, wholly on the local rains, which frequently do not commence before the middle of October, will have a certain supply for the greater part of the year, and it is not too much to suppose, with these advantages, that the whole sum exhibited in the column of increase, will in the course of a few years be realized; and that at least half of that amount may be calculated upon as the immediate return the works will yield.

There is more confidence in the present anticipated increase, from the circumstance of the quantity of water thrown off by the lower annicut being much more than can be made use of in the cultivation of the two Talooks of Manargoody and Chellumbrum, and that the main object of the present works is to extend the Coleroon waters, which are so certain, and abundant; so abundant indeed, that the water has been passing over the calingalas of the Veranum, and out by its surplus channel into the Vellaur, with little intermission from the month of July to the present time, in quantities quite equal to that required for the use of the lands belonging to the works under report.

I need not however allude more particularly to the advantages to be derived from the execution of the works proposed, as they have been explained in communications from Messrs. Thomas,* Dent,† Pycroft,‡ Major Cotton§ and Mr. Hallett,|| and recognized by the Board of Revenue.

* In a letter to the Principal Collector of South Arcot under date the 14th September, 1836.
 † To the Board under date the 3d March, 1837.

‡ To the Principal Collector under date the 28th Feb. 1839.
 § To the Acting Collector of South Arcot under date the 15th October, 1841.
 || To the Board of Revenue of the 29th October, 1841.

No difficulty needs be anticipated in procuring the materials for the proposed works, as a sufficiency of cut stone is to be had from the ruined out-houses attached to the Pagoda of Gungracondah, and the Forts of Palamcottah and Por-yoor, distant from the proposed site 20, 7, and 5 miles, respectively; the stones from the first named place can be conveyed for upwards of 18 miles of the distance by water. The other materials can be procured with greater ease, to any extent required.

I must not omit to state that I have availed myself largely of the advice and experience of Major Cotton in projecting and in drawing up the plans of the works under report, and annex transcript of that Officer's diary on the subject. In conclusion, I have only to recommend that sanction may be granted at an early period for the execution of the works, which there is no doubt will be attended with highly beneficial results, viz. a return of no less than 73 per cent. on the outlay, besides preparing the way for vastly extended improvement in cultivation situated still lower down.

(Signed) STAFFORD VARDON,
 Civil Engineer 4th Division.

ABSTRACT OF ESTIMATES.

No. 1	Annicut, - - - - -	29,217	0	10
" 2	Head Sluice to main Channel, - - - - -	1,768	0	4
" 3	Surplus do. - - - - -	1,820	6	1
" 4	Head Sluice to Meraloor Channel, - - - - -	519	13	4
" 5	Under Sluice, - - - - -	466	0	3
" 6	Head Sluice to Permaul Channel, - - - - -	519	13	4
" 7	Bridge, - - - - -	1,498	12	4
"	For Channels, &c. - - - - -	10,620	1	1
	Superintendence, - - - - -	500	0	0
		<hr/>		
		46,929	15	7
		<hr/>		

of Assistant Surveyor Oliver upon the relative merits of the two sites proposed has been already laid before the Board, the Assistant Surveyor giving a decided preference to the work across the Vellaur, but the site proposed by him was at the point *C*, which is 1600 yards higher up than *B*, and near the village of Arsoocondanuttum.

* In a letter from the Acting Collector of South Arcot under date the 29th October, 1841.

After Mr. Oliver had completed his survey and report, it was suggested by Major Cotton, that if it were found practicable for the supply of the tanks and channels above enumerated, it would be expedient to place the annicut at the site *D*, which is nearly 4 miles lower down the Vellaur than Andinoor, and a little below where the surplus water of the large Veranum tank enters that river, in order that this water might be made available for the purposes of cultivation: by which plan a much more certain and copious supply might be obtained at a time long anterior to that in which the freshes occur either in the Mannumootahnuddy or Vellaur, and the ryots, by this desirable arrangement, might commence sowing their crops at a much earlier season.

The advantages of this last plan, should it be found practicable, are at once apparent, and are noted in a general manner in the letter of the Acting Civil Engineer of the 5th Division, to the address of the Acting Collector under date the 15th October last.

The only point of importance in the project which was at all doubtful, was, whether the relative height of the works would admit of the free passage of the water, and in order to test which, as well as to consult with Major Cotton on the expediency of the scheme generally, I met that officer in the neighbourhood of the proposed work, as directed in the proceedings of the Board of Revenue, under date the 18th November last.

After a careful examination, in company with the Acting Collector, of the localities, and ascertaining the levels of the ground, we came to the conclusion that the work would be highly expedient, and agreed upon the following plan of operations, viz.

To throw an annicut across the Vellaur, nearly opposite to Shatitape, and about 250 yards below the spot where the surplus of the large Veranum tank discharges itself into that river. This work will throw the water down a new channel, directly into the large Wallajah tank, whence the surplus will pass off by a head sluice to be constructed in the bank of the Wallajah tank the large Permaul reservoir below it.

About $1\frac{1}{2}$ mile below the head of the main channel, it is proposed to take off a branch for the better supply of the Meeraloor vaikal, where that cut intersects the proposed new line, by which the numerous villages dependent on the Meeraloor channel, as well as those watered by the Manambattan tank, would receive an ample supply; the surplus of the Manambattan again

passing off, as at present, to water the lands belonging to several villages situated lower down.

The proposed position of the annicut is the most favourable one which could be selected, and the banks on both sides are high; wells have been sunk in the proposed line of the work, and although no rock or very stiff soil has been met with, the foundation is as favourable as that on which the Colleroon annicuts are built.

It is proposed to make the work 9 feet in height, which will keep up an almost constant supply of water in the Wallajah tank, to a depth over the lowest sluice, of 11 feet, certainly from June till the end of December, and probably even from an earlier period, as the freshes sometimes occur in May, and the tank by being thus partly filled before the north-east monsoon comes on, may be supplied to any extent deemed expedient from the Vellaur freshes, by which means any quantity considered desirable, may be furnished to the Permaul and Manambattan tanks, and the Meeraloor channel.

It will be necessary to regulate the supply of the main channel by means of a head sluice, and to keep the bed of this cut free from accumulations by means of a surplus sluice, a head sluice is required to the Meeraloor, &c. main channel, for the irrigation of all the lands at present watered by the Meeraloor vaikal, which branches from the Vellaur at a point much lower down, and a small under sluice for the Kinnanoor channel, which will then supply the two small tanks of Meeraloor and Pinnaloor.

A head sluice will also be required in the Wallajah tank bank, as was mentioned above, for the supply of the Permaul reservoir, and it will be necessary to throw a bridge over the surplus from the Veranum tank. In addition to the above works, it will be necessary to raise a small earthen embankment along the northern bank of the river, to widen and deepen the Meeraloor channel, to increase the size of the channel leading to the under sluice, and to excavate a small branch cut for the supply of the Meeraloor tank.

The several positions of these works are indicated in the sketch, and plans and estimates of them are annexed; the latter amounting in the aggregate to Rupees 44,883 7 10.

The enclosed statement will show the number and names of the villages, as well as the quantity of land under the several works proposed to be benefited, and the amount of the increase which may be anticipated.

From this it will be seen that there are nearly 10,000 cawnies of nunjah land under the Wallajah, Permaul, and Manambattan tanks, and the Meeraloor and Kinnanoor channels, which should, if properly supplied with water, yield a revenue of no less than Rupees 79,208; but, on an average of the last 20 years, have only realized Rupees 35,181, showing an annual loss

of no less than Rupees 44,027; or, after all deductions for land which is of an inferior quality, of Rupees 39,747.

Considering that the proposed works will bring down the waters of the Coleroon as early as the month of May in some years, and always in June, the tanks and channels, instead of being dependent, as hitherto, wholly on the local rains, which frequently do not commence before the middle of October, will have a certain supply for the greater part of the year, and it is not too much to suppose, with these advantages, that the whole sum exhibited in the column of increase, will in the course of a few years be realized; and that at least half of that amount may be calculated upon as the immediate return the works will yield.

There is more confidence in the present anticipated increase, from the circumstance of the quantity of water thrown off by the lower annicut being much more than can be made use of in the cultivation of the two Talooks of Manargoody and Chellumbrum, and that the main object of the present works is to extend the Coleroon waters, which are so certain, and abundant; so abundant indeed, that the water has been passing over the calingalas of the Veranum, and out by its surplus channel into the Vellaur, with little intermission from the month of July to the present time, in quantities quite equal to that required for the use of the lands belonging to the works under report.

I need not however allude more particularly to the advantages to be derived from the execution of the works proposed, as they have been explained in communications from Messrs. Thomas,* Dent,† Pycroft,‡ Major Cotton§ and Mr. Hallett,|| and recognized by the Board of Revenue.

* In a letter to the Principal Collector of South Arcot under date the 14th September, 1836.
 † To the Board under date the 3d March, 1837.

‡ To the Principal Collector under date the 28th Feb. 1839.
 § To the Acting Collector of South Arcot under date the 15th October, 1841.
 || To the Board of Revenue of the 29th October, 1841.

No difficulty needs be anticipated in procuring the materials for the proposed works, as a sufficiency of cut stone is to be had from the ruined out-houses attached to the Pagoda of Gungracondah, and the Forts of Palamcottah and Por-yoor, distant from the proposed site 20, 7, and 5 miles, respectively; the stones from the first named place can be conveyed for upwards of 18 miles of the distance by water. The other materials can be procured with greater ease, to any extent required.

I must not omit to state that I have availed myself largely of the advice and experience of Major Cotton in projecting and in drawing up the plans of the works under report, and annex transcript of that Officer's diary on the subject. In conclusion, I have only to recommend that sanction may be granted at an early period for the execution of the works, which there is no doubt will be attended with highly beneficial results, viz. a return of no less than 73 per cent. on the outlay, besides preparing the way for vastly extended improvement in cultivation situated still lower down.

(Signed) STAFFORD VARDON,
 Civil Engineer 4th Division.

ABSTRACT OF ESTIMATES.

No. 1	Annicut, - - - - -	29,217	0	10
" 2	Head Sluice to main Channel, - - -	1,768	0	4
" 3	Surplus do. - - - - -	1,820	6	1
" 4	Head Sluice to Meraloor Channel, - -	519	13	4
" 5	Under Sluice, - - - - -	466	0	3
" 6	Head Sluice to Permaul Channel, - -	519	13	4
" 7	Bridge, - - - - -	1,498	12	4
	For Channels, &c. - - - - -	10,620	1	1
	Superintendence, - - - - -	500	0	0
		<u>46,929</u>	<u>15</u>	<u>7</u>

Vellore Annicut.

Statement of Tanks and Channels, &c. which may be benefited by the construction of an Annicut across the Vellore River, near Shattah-topa, in the Bowengherry Talook, of the Southern Division of Arcot.

Name of Tanks, &c.	NUMBER AND NAMES OF VILLAGES.	Ayacut Revenue.			Highest Revenue ever realized.			Average Revenue realised during the last 20 years.			ANTICIPATED INCREASE OF REVENUE.																								
											From present Ayacut Nunjah land.				From Poonjah into Nunjah.				From Poonjah land at present dependent, on ruin.				Total.												
		Cawnies.	Rupess.	Annas. Pice.	Cawnies.	Rupess.	Annas. Pice.	Rupess.	Annas. Pice.	Cawnies.	Rupess.	Annas. Pice.	Cawnies.	Rupess.	Annas. Pice.	Cawnies.	Rupess.	Annas. Pice.	Cawnies.	Rupess.	Annas. Pice.	Rupess.	Annas. Pice.												
Wallajah.	1 Cottavachang																																		
	2 Vurthumput																																		
	3 Auloor Agaram																																		
	4 Kistnapoaram																																		
	5 Cusbahampaudy																																		
	6 Pinnaloor																																		
	7 Ambaupooram																																		
	8 Prisinaramapooram																																		
	9 Oolootoor																																		
	10 Murdoor	3,991	61	22,003	2	7	2,785	54	21,644	11	0	13,423	3	9	2,075	15	16,913	14	1,377	143	1,666	2	0	15	21	48	9	0	17,996	9	7				
	11 Kolacoody																																		
	12 Jaumcondan																																		
	13 Gomedemolay																																		
	14 Yellacoody																																		
	15 Ollayoor																																		
	16 Boothumpaudy																																		
	17 Thalacolum																																		
17 Total																																			
Permaul.	1 Sevakolinden Pettah																																		
	2 Cooppayacandoo																																		
	3 Thunnoor																																		
	4 Poovaunecoopum																																		
	5 Vullivaday																																		
	6 Agaram																																		
	7 Vengatampooram																																		
	8 Cumbelomodoo																																		
	9 Yadacanduputto																																		
	10 Coondeyamelloor																																		
	11 Muzrahkillavalle	1,758	34	13,830	1	11	1,600	0	11,167	6	3	6,753	9	7	408	124	5,590	13	10	164	31	931	7	6	13	91	22	10	0	4,597	15	0			
	12 Karevappoondy																																		
	13 Seeroopaulayoor																																		
	14 Pareyaput																																		
	15 Theyagavullee																																		
	16 Aundaramullepultom																																		
	17 Theerthanagay																																		
	18 Anookuput																																		
18 Total																																			
Manambattian.	1 Thirkoothla																																		
	2 Sundapettah																																		
	3 Moollepullum																																		
	4 Cooreamungalum	585	94	6,232	15	3	525	1	5,399	7	6	3,324	7	2	246	54	2,877	9	7	115	5	693	0	0	0	0	0	0	0	0	0	0	0		
4 Total																																			
Meeraloor Channel.	1 Chittairy																																		
	2 Thombeckennettamput																																		
	3 Villeanelloor																																		
	4 Keelamanacoody																																		
	5 Vullum																																		
	6 Chuderkellay																																		
	7 Pereaput																																		
	8 Aremoothaven																																		
	9 Pareacoomootty																																		
	10 Munjacoory																																		
11 Audeveraga Nelloor	2,206	104	17,429	15	4	1,253	104	11,321	6	2	7,275	11	5	224	152	7,095	10	2	208	34	1,281	3	6	0	0	0	0	0	0	0	0	0			
12 Tachacandoor																																			
13 Samadim																																			
14 Chumacoomatty																																			
15 Ramavadacoopum																																			
16 Yalungalumput																																			
17 Pauluantoovunnan																																			
18 Manycollay																																			
19 Yayepooram																																			
19 Total																																			

Total Anticipated Increase. 24,190 0 2

Extract from the Official Diary of the Acting Civil Engineer of the 5th Division, for part of the month of December, 1841.

SOUTH ARCOT DISTRICT.

14th to 18th.

Bowengherry Talook.

“Project for extending the benefit of the Coleroon annicut to irrigate lands on the north side of the Vellaur river.

“In company with the Collector of South Arcot, and the Civil Engineer of the 4th Division, I examined the country on both sides of the Vellaur, and got such levels, &c. taken as enabled us to make a complete plan for carrying the surplus waters of the Veranum tank across the Vellaur river by means of an annicut, and carrying it by a new channel to the Wallajah Yairy.

“The whole project proves easily feasible, all the required works will be constructed at a moderate expense, and the effect such as to make it one of the most valuable improvements undertaken since the construction of the Coleroon annicuts. The Civil Engineer of the 4th Division has prepared and will submit the estimates for the works which we have planned, with the statement of expected increase of Revenue, and a general description of the project.”

(Signed) H. COTTON, Major,
Acting Civil Engineer 5th Division.

To

The Secretary to the Board of Revenue
in the Department of Public Works.
Fort St. George.

From the Collector of South Arcot.

Recommending that the project for constructing an annicut across the Vellaur in the Bowengherry Talook, may be taken into consideration at an early date.

SIR,

When the Civil Engineers of the 4th and 5th Divisions lately met on the bank of the Vellaur, with the intention of examining into the merits and practicability of an annicut, which was the subject of my letter of the 29th October, 1841, I made a point of accompanying them in their inspection, during several days, of the spot proposed as suitable for the work, as well as of the whole country which it was considered would derive advantage from the new irrigation.

I have paid great attention to the subject, and have no hesitation in most fully concurring in the views formed by Major Cotton and Captain Vardon, as expressed in the report forwarded by the latter officer to your Board.

The entire cost of the annicut, and the necessary additional works, will be fully covered by the outlay of Rupees 44,883,* which it is calculated will yield a return of 77 per cent.

The Bowengherry Talook will reap the benefit of this work if carried into execution, and its inestimable value is strictly pointed out this very season, for in consequence of a failure in the north-east monsoon, the crops

have not sufficient water, whereas, had this irrigation been in force, much land on the eastern side of the talook would have been receiving the water from the Coleroon, which, as is well known, is certain.

I beg most earnestly to request the Board's favorable view of this project, and strong recommendation to Government. I also have the honor to point out that an early sanction will enable me to do so much of the work this year, as to render its completion in time for the season of 1843 a matter of certainty, which is of course of very great importance.

I have the honor to be, &c.

(Signed) C. HALLETT,
Collector.

Cuddalore,
Collector's Cutchery.
31st January, 1842.

To

G. D. DRURY, Esq.
Chief Secretary to Government.

SIR,

Min. cons. No. 7.
October, 1842.
Do. No. 5.
May, 1841.
Paras. 4 & 5.

1 Estimate.
6 Plans.
1 Report 28.
January 1842.
2 Letter with 2
Enclosures dated
29th Oct., 1841,
with letter and
report from Civil
Engineer 4th Di-
vision, dated 28th
January, 1842.
Cons. 28th Fe-
bruary.

Para. 1. I am directed by the Board of Revenue, with reference to the orders of Government, as per margin, and to the Extract of a letter from the Court of Directors accompanying the first, on the subject of improvement to the irrigation of the Western Talooks of South Arcot, to forward for the purpose of being laid before the Most Noble the Governor in Council, the accompanying Plans and Estimates for the construction of an annicut across the Vellaur river, and of auxiliary works designed to conduct the surplus water of the Veeranum tank across the river to other considerable reservoirs on its north bank, the Estimate amounting to Rupees 56,877 1 6.

2d. The sources of the Vellaur being not affected by the south-west monsoon, its supply of water for irrigation is precarious, and many dams are necessary to retain it in different situations. These are commonly constructed of rough stone, and are found only in situations where there is a natural foundation of rock or hard soil, high up the river, in the lower parts of which the bed is composed uniformly of sand or mud, in which a permanent dam would have been a work of immense cost to the Natives, while the temporary dams or corumboos occasionally used are swept away by every sudden flood, must be as often renewed, and under the most favourable circumstances only partially answer the required purpose.

3d. A permanent dam has been consequently proposed, to collect the waters for distribution to the tanks and lands of numerous villages now supplied partly by channels taken off at different points in the bank of the river, and partly by local rains, and the project has been strongly supported by several gentlemen who have by turns had charge of the district.

*As particularised in Captain Vardon's report.

4th. Considered simply with reference to the natural supply of the Vellaur, the proposed annicut was thought to be well worthy the attention of Government, and different sites were suggested for its construction; but Major Cotton, then Civil Engineer of the 5th Division, having declared his opinion that by means of the new work, if properly placed, the surplus waters of the Veeranum tank might be conducted across the Vellaur to the lands suffering from the uncertain supply above described, that officer was requested in concert with Captain Vardon, the Civil Engineer of the 4th Division, to investigate the subject.

5th. The result of their joint labours is now submitted, and the Board cannot but believe it such as to deserve the most favourable consideration and support of the Most Noble the Governof in Council.

No. 523. 6th. His Lordship in Council has been made aware by my letter of the 26th October last, of the greatly increased body of water poured from the Coleroon river into the Veeranum tank since the construction of the lower Coleroon annicut, and enlargement of the Vuddavar. This was so apparent in 1841, immediately after the execution of the latter work, that 29th October, 1841, para. 6. Cons. 5th No. vember 1841. Mr. Hallett, the Collector, visiting the Chellumbrum and Manargoody Talooks, so late as September in that year, "could not but remark that the only difficulty was the superabundance of water," the Veeranum then discharging large quantities by both its calingalas, as well as by the northern outlet into the Vellaur: and it appears from the report of Captain Vardon that this discharge had commenced in July and continued till December. Major Cotton further shows that this great supply of water was wholly independent of local rains, as the tank was dry when the rivers came down, and was filled entirely from the Coleroon.

7th. The levels taken by Major Cotton and Captain Vardon show that the calingalas of the Veeranum are 3 feet 2 inches above the highest calingala of the Wallajah tank, the first on the north bank of the Vellaur into which it is required to throw the Veeranum surplus; and as all the other tanks, of which the most considerable is the Permaul, are much lower, the question of command is at once disposed of; and it only remains to show how it is proposed to carry the Veeranum surplus waters across the Vellaur, maintaining them at a sufficient level. An aqueduct would of course effect the desired object to a certain extent, but with less completeness than an annicut, which would also serve to retain the waters of the Vellaur itself according to the original projects, and is in other respects a work much to be preferred to an aqueduct.

8th. It is proposed, therefore, to construct an annicut, the crown of which will be 9 feet above the bed of the Vellaur, and 4 inches above the high calingala of the Wallajah tank. Its site will be a short distance below the junction of the Veeranum surplus with the Vellaur, and on the opposite or north bank of

that river a new channel will be opened communicating directly with the Wallajah tank. It will be furnished with a head-slucice having six vents, each 2, 9, by 4, 6, and a surplus sluice for discharging water when it can be spared at the lowest level for the purpose of clearing the bed of the channel from accumulations of soil. The Comarum Oodapoor (or breach) affords a convenient channel for carrying the surplus again to the Vellaur, at a point considerably below the annicut.

9th. Where the new channel intersects the present Kinnanoor channel, it is proposed to construct a sluice; and to widen and deepen the Kinnanoor channel for the supply of that of Meraloor; and as this measure will make the former too deep to supply as it does now, the small tanks of Pinnalore and Meraloor, a branch for their benefit on the former level will be taken from it at a point above its junction with the new channel, and carried under the latter by a tunnel. The only other masonry work required is a sluice in the bund of the Wallajah tank, for the supply of the Permaul tank.

10th. The foregoing para. briefly describes the project as it has been submitted to the Board. It has, however, appeared to them necessary, after careful revision of it in this office, to add to it some works designed for the security of the Veeranum tank, which might without such additions be exposed to danger, from the reflux of the Vellaur waters in high freshes of that river. To effect the required purpose, it will be necessary to cut a new channel from the Veeranum surplus, to be carried to the annicut for the supply of the tanks on the north bank of the Vellaur; and at its point of separation from the old channel close to the new Veeranum calingala to build a sluice which will be shut when the freshes of the Vellaur come down. The tank surplus will then fall into the Vellaur by the old channel at a point below the annicut. To complete these improvements, it will be necessary to embank the Vellaur on both sides above the annicut, but principally on the south side.

11th. The following specification will show the extent and character of the work.

12th. The length of the annicut will be 225 yards, which is something more than the natural breadth of the river. The section is perpendicular in rear, and the water falls upon an apron covered with cut-stone, which is partly on a level with the bed of the river, and partly raised one foot above it, and is altogether 16 feet broad; the rear of the apron is to be defended with cubical blocks of brick work, which will accommodate themselves to the natural bed and gradually form an impregnable barrier similar to that of the loose stones used at the Coleroon annicuts, but which could not be obtained for the present work but at a disproportionate expense. The cubes will however answer perfectly well, if the mortar with which they are cemented has sufficient time to harden before they are used.

13th. The front of the annicut it is proposed to make sloping towards the stream, so as to obtain a broader base where the pressure is greatest, with the same quantity of material that would be required for a rectangular section, and at the same time to facilitate the passage of sand over the work. It is proposed to build a set of sluices in the work, for keeping clear the head of the new channel; an object of great importance, and which there is no doubt from the experience derived from the Coleroon annicuts will be fully effected by a judicious use of these works. They are so designed as to be accessible at all times, and it is intended to close them when necessary with horizontal balks of wood, which are the most easily managed. They will be defended in rear by a wider apron than that of the annicut, and will have another apron in front, with wing-walls to prevent the current, which passes through them from first sweeping along the face of the annicut. The foundations of the dam and apron will be laid in the usual manner upon wells, which have answered very well for the Coleroon annicuts, where the soil in which they are sunk is of the same description as that of the Vellaur.

14th. It will not be expedient to build the dam to its full height at first. The safety of the work will be placed beyond risk by proceeding gradually, and the necessary height of water may meanwhile be easily obtained by an earthen dam above the masonry; to which, as an expedient for one or two years, there is no objection.

15th. As the communication across the Vellaur in the direction of the annicut promises to be hereafter of importance, a bridge over the work has been added to the design, but the cost of it is entered separately in the estimate; except that small portion of it which provides for extending the foundations of the pier on each side of the dam; because should the bridge be built at any future period, it could not conveniently be connected with the annicut without such prior arrangement.

16th. The project has received the fullest support from Mr. Hallett, the late Collector, who was present at the consultation of Major Cotton and Captain Var-don, and was perfectly satisfied of the great improvement to the country and the revenue which would result from the introduction of an unfailing supply of water to lands of very considerable extent.

17th. The site of the proposed work was also visited in December, 1842, by the professional member of the Board, Colonel Sim, in company with the Collector of the district, and present Civil Engineer of the district, Captain Lawford, and the practicability and advantages of the project inquired into on the spot. Lieutenant Colonel Sim concurs entirely in the opinion entertained of the expediency of the annicut, and of the extensive benefit which it would confer on the lands lying on the north bank of the Vellaur, which are very scantily supplied at present; while it would at the same time prove advantageous to Manargoody

by relieving it of part of its superabundant water. Thus the opinion of every one who has had an opportunity of examining the proposed work is highly in its favour.

18th. The expected increase of revenue is stated at about 40,000 Rupees. It is evident that where a great part of the land has been long waste, the full extent under command of the new irrigation cannot be cultivated for some years; but at the same time there is no situation, where there is greater promise of early profit from the construction of new works, both on account of their being intended to support others already productive, and of the certain dependence that may be placed on the sufficiency of water.

19th. Detailed statements of the expected increase of revenue accompany this report. They were prepared under the directions of Mr. Hallett, after investigation of the lands and resources of the several villages dependent upon the reservoirs to which the new supplies of water will be conducted, and it is expected that lands still farther to the eastward will in course of time be brought under cultivation.

20th. The project above described is, as will have been observed, of much simplicity in its character. It has no relation to existing works or interests, such as might raise doubts as to the consequences to them of carrying it into execution, and the Board therefore trust that it will appear worthy of being submitted with the strong recommendation of His Lordship in Council to the Honorable the Court of Directors, to whom it is hoped it will appear to present superior advantages for improving the irrigation of South Arcot. The amount of the estimates for which sanction is solicited is

Annicut without Bridge,.....	Rupees 56,877 1 6
Do. with do.....	63,599 6 7
Sixty-three thousand, five hundred and ninety-nine, annas six, and pice seven.	

REVENUE DEPARTMENT.

No. 270.

Extract from the Minutes of Consultation, under date the 1st March, 1845.

“The Most Noble the Governor in Council proceeds to take into consideration the letter in this Department from the Honorable the Court of Directors, dated 24th December, 1844, No. 32.

Para. 1. This Dispatch will be communicated for the information and guidance of the Board of Revenue in the Department of Public Works, with reference to their Acting Secretary's letter, dated 15th February, 1844, No. 89.

2. The Board will make all proper arrangements for the prosecution of the work under efficient superintendence, and report upon its progress periodically to Government. They will also instruct the Collector of South Arcot to give his attention, on the completion of the work, to the state of the cultivation under the tanks, the supply of which is contemplated in the con-

struction of the annicut, and to submit with his reports on the settlement, a statement showing how much of the anticipated increase of revenue has been realized in each year.

Extract from a Letter from the Honorable Court of Directors, dated 24th December, 1844.

“In your letter dated 9th April, 1844, No. 4, in the Department of Public Works, you solicit our sanction to an expenditure of Rupees 63,599 6 7 for the purpose of constructing an annicut and bridge across the Vellaur river, with auxiliary works designed to conduct the surplus water of the Veranum tank across that river, for the supply of waste land under the Wallajah, Permaul, and other large tanks in the district of South Arcot.

Lieut. Col. Sim, Chief Engineer; C. H. Hallett, Esq., late Collector and Magistrate S. D. Arcot.

Major H. C. Cotton, Acting Civil Engineer 5th Division; Captain Lawford, Acting Civil Engineer 5th Division. Lieutenant S. Vardon, Civil Engineer 4th Division.

2. The proposed plan has been investigated on the spot by the officers named in the margin, by all of whom it has been strongly recommended for adoption.

3. The anticipated increase of revenue from the construction of this work is stated at Rupees 34,480 per annum.

4. Under these circumstances, and relying on the accuracy of the statement of the officers to whom we have referred, as to the advantages to be obtained from the work, and to the facility and economy with which it can be accomplished, we shall willingly comply with your strong recommendation in its favour.”

LETTER FROM CAPTAIN E. LAWFORDE, CIVIL ENGINEER 5TH DIVISION, ON THE SUBJECT OF THE EFFECT OF THE NEW REGULATING DAM TO THE CAUVERY, AND THE GENERAL BENEFIT DERIVED FROM THE COLEROON ANNICUTS.

The following very valuable paper has been prepared at my request by Captain Lawford, now Civil Engineer 5th Division, and to all those who take an interest in these important works, I feel that I need not offer any apology for inserting it, though at a distance from the other documents on this subject. It gives, what has long been desired, an unprejudiced and fair statement, coming from an unbiased person of the actual bona-fide results, in increase of cultivation, and money returns, which is now experienced from the construction of these works; and it is most gratifying to find that Captain Lawford estimates the latter to be not less than 2½ lacs of Rupees per annum, being at the rate of 35 $\frac{1}{2}$ ths per cent. even upon the outside sum of 700,000 Rupees assumed as the aggregate cost of the whole undertaking.

It may be useful that I should mention, that the regulating dam referred to by Captain Lawford is a work recently built at the head of the Cauvery, where it separates from the Coleroon, and intended to establish its bed there upon a permanent level. It was found after the annicut in the Coleroon came into operation, that the large body of water diverted by it into the Cauvery, had the effect of deepening its bed; and the relative levels being thus disturbed, the whole body of the river was gradually withdrawn from the former and thrown into the latter river, to the great danger of its banks; while the Coleroon was subject to be filled with shoals and sand-banks. It was expected that this evil would be obviated, the relative levels of the two rivers permanently maintained, and the supply of each made more uniform, by a masonry dam defining the proper level of the bed of the Cauvery at the point of separation, and it appears from Captain Lawford's statement that this object has been attained.—ED.

In compliance with your request, I proceed to relate briefly the operations at the head of the Cauvery, and their apparent results subsequent to the last report of Colonel Sim; and I shall then endeavour to show as plainly as possible, the actual advantages which have followed the construction of the Coleroon annicuts, up to the latest period.

During 1844 the enlargement of the head of the Cauvery continued as it had done in the previous year; the direction of the main current was altogether along the south side, and the stream washed away upwards of 30 yards of the land. The north bank, though greatly relieved by the improvement of the Coleroon annicut, yet suffered considerable injury, and demanded incessant labour for its preservation.

Materials for the Cauvery dam were under preparation during the latter part of last year, and the work was commenced on the 9th February following, and

completed on the 20th April without the slightest accident, although the occurrence of most unusual freshes in March threatened to interrupt the undertaking. The head of the Cauvery was kept closed until the middle of May, when the embankment across it was cut, and the stream suffered to flow.

During the whole of May and the early part of June, the river remained extremely low, but on the 25th of the latter month, the freshes suddenly commenced with great violence; and as the stream filled its former deep bed, it attacked the defences of the banks which were as usual immediately repaired and strengthened. As the water subsided, it was evident that a material change had commenced in the Cauvery, and that the current had no longer that irresistible force, so severely felt in former seasons. A deposit of sand was formed along both sides of the river immediately below the dam where the stream had been hitherto extremely deep. This deposit has since gradually

extended itself lower down the river, and effectually secures the banks in these important parts.

In the early part of October the local rains began to fall, and the Cauvery was again filled, but the stream caused no damage to the works near the river head, except to the exposed defences at the outlets, which suffered some injury; and after another subsidence the river has again risen, without causing material injury to any of the defences.

The continuance of the favorable change in the Cauvery is now quite manifest in the uniformity of the section, the regularity of the current, and the absence of masses of sand and deep holes. The stream, spreading over the entire bed, has lost its violence, and the banks, no longer corroded and scarping, have assumed a moderate slope; and although the first burst of the freshes caused a considerable outlay in the repair of defences, yet not one new spot on either bank has been attacked by the current.

This remarkable change in the Cauvery has been accompanied by a corresponding improvement in the Coleroon, the bed of which is clearer and deeper than I have ever before seen it. A strong current sets on the centre of the annicut, and so great has been its effect on the bed below, that I am obliged to close the main sluices to prevent further deepening.

In 1842 the sands of the Coleroon, to the westward of the annicut, were higher than the work itself; but where that accumulation existed, the bed is now six feet lower; nor have other sand banks been formed; but the Coleroon, like the Cauvery, has acquired much greater uniformity than it has had for many years.

It is impossible to account for these changes otherwise than as the effects of recent improvements, and especially of the dam at the head of the Cauvery; as it is evident that after each succeeding fresh, the beds of the rivers become improved, and their regulation more perfect. The body of water which formerly passed in a deep concentrated stream into the Cauvery, is now diffused over the two beds, each receiving its just share; the thread of the stream is more direct, and the banks are less exposed to violent currents, circumstances which establish the correctness of Colonel Sim's anticipations.

In the endeavour to show with precision and distinctness the actual returns in money, which have been realized by the State from the construction of the Coleroon annicuts, I have experienced some difficulty in consequence of the system, which renders the land revenue dependent on the current prices of grain. A succession of favorable seasons, and the improvements effected in other districts, together with the extension of the Arracan grain trade within the last ten years, have had a material effect in depressing the markets, and consequently the revenue of these Provinces; and hence the apparent effect of the annicuts is by no means so great, as that which they have in reality produced.

But the annicuts have in no degree contributed to this effect on prices, as any increase of produce within the provinces is insufficient to cause such result, and therefore the real amount of the profits arising from these works must be calculated by applying the average prices and rate of assessment which prevailed before their construction to the subsequent increase of the extent of land in cultivation. In South Arcot the increase of land yielding two crops has raised the rate of assessment greatly above its former amount.

On the grounds above stated, I come to the conclusion that the following is a correct summary of the returns from the Coleroon annicuts up to the present time.

	Increase of Land.		Increase of Revenue.	
	Acres.	Rs.	A.	
Tanjore,	27,705	1,41,954	0	
Trichinopoly,	1,343	7,984	8	
South Arcot,	7,298	1,00,634	0	
Total for one year,	36,344	2,50,572	8	
Aggregate of nine years,	3,27,096	22,55,152	0	

The aggregate outlay which these works have occasioned directly or indirectly may be roundly stated at 7,00,000 Rupees, so that they have produced in nine years a clear profit of Rupees 15,55,152.

I remain,

Your's sincerely,

EDWARD LAWFORD.

NEGAPATAM, }
5th December, 1845. }

Coleroon Annicuts.

Statement showing the Cultivation and Revenue dependent on River Irrigation in Tanjore, from the year 1830 to 1844.

	Years.	Extent of land. Acres.	Net Revenue. Rupees.	Price of Grain per Cullum.		Average rate of Collections per Acre.			Remarks.
				Dns.	Cash	R.	A.	P.	
Before the Construction of the Annicuts.	1830	542301	2631427	2	30 1/2				
	1831	544251	2732126	2	29 1/2				
	1832	558730	2998184	4	4				
	1833	545772	3117291	4	26 1/2				
	1834	564674	2840689	3	14				
	1835	559881	2669023	2	30 1/2				
	Total.		3315609	15988640	21	24			
Average.		552601 1/2	2831440	3	16 1/2	5	1	11 1/2	
After the Construction of the Annicuts.	1836	532476	2869487	4	23 1/2				
	1837	573170	2875844	3	12 1/2				
	1838	578417	2994744	3	17 1/2				
	1839	583491	2991747	3	12 1/2				
	1840	584932	2798976	2	16 1/2				
	1841	593785	2573458	1	23 1/2				
	1842	592145	2799411	2	13 1/2				
	1843	590440	2941484	3	6 1/2				
1844	595901	3024200	3	11 1/2					
Total.		5222757	25869351	28	9 1/2				
Average.		580306 1/2	2874372	3	4 1/2	4	15	3 1/2	
Deduct.		552601 1/2	2831440						
		27705	42932	0	0	0	0	0	Apparent Increase.
		27705	141954	0	0	5	1	11 1/2	Real Increase.

Statement showing the Cultivation and Revenue dependent on Channels influenced by the Coleroon Annicuts in the Lavalgoody Talook of Trichinopoly District from the year 1825 to 1844.

	Years.	Irrigation of Iyen and Perovully Channels.		Average rate of Collections per Acre.	Remarks.
		Acres.	Net Revenue.		
Before the Construction of the Annicuts.	1825	31733 1/2	190080	4 7/8	
	1826	32154	190872	14 0	
	1827	32078	178045	14 10	
	1828	31871	189428	4 7	
	1829	32004	183600	14 9	
	1830	33401	200659	15 11	
	1831	33248 1/2	194498	10 5	
	1832	33125 1/2	196554	15 9	
	1833	33073	209958	6 8	
	1834	33517	194320	15 8	
	1835	33708	204857	12 8	
Total.		359913 1/2	2139865	1 10	
Average.		32719 1/2	194533	3 1 5/8	1 1/2
After the Construction of the Annicuts.	1836	33886	201145	6 10	
	1837	33575	200263	2 10	
	1838	33643	200601	9 10	
	1839	34230 1/2	200233	10 2	
	1840	33809	200692	0 0	
	1841	34909	205004	14 5	
	1842	35219	197778	14 1	
	1843	33083	190009	13 3	
	1844	34206	185974	0 2	
Total.		306561 1/2	1781703	7 7	
Average.		34062 1/2	197967	0 10 5/8	11 1/2
Deduct.		32719 1/2	194533	3 1	
		1343	3433	13 9 0 0	0
		1343	7984	10 8 5 15	1 1/2

Statement showing the Cultivation and Revenue dependent on Channels influenced by the Coleroon Annicuts in Chellumbrum and Manargoody Talooks of the South Arcot District, from the year 1825 to 1844.

	Years.	Nunjah Revenue exclusive of Jaghire.		Kussur or Revenue derived from the irrigation of Poonjah Lands.		Total.	Average rate of Collections per Acre.			Remarks.	
		Acres.	Revenue.	R.	A.		P.				
Before the Construction of the Annicuts.	1825	23,644	1,82,998	3	8	8	2	8	1,83,001	6 4	
	1826	22,634	1,71,478	12	8	20	7	1	1,71,498	3 9	
	1827	17,567	1,14,182	10	7	3	5	11	1,14,186	0 6	
	1828	15,649	1,08,228	9	11	29	6	4	1,80,258	0 3	
	1829	16,614	1,19,273	0	0	108	0	11	1,19,381	0 11	
	1830	12,846	84,613	15	0	461	15	2	85,075	14 2	
	1831	10,283	62,769	11	4	402	13	0	63,172	8 3	
	1832	14,560	95,926	14	0	1,632	0	11	97,558	14 11	
	1833	16,808	1,14,189	0	8	1,898	3	5	1,16,087	4 1	
	1834	22,697	1,10,966	3	5	2,205	6	11	1,73,172	12 4	
	1835	25,063	1,82,670	8	7	2,040	1	10	1,84,710	10 5	
Total.		1,97,865	14,07,297	9	9	8,906	2	2	14,16,103	11 11	
Average.		17,988	1,27,936	2	4	800	9	0	1,28,736	11 4	
After the Construction of the Annicuts.	1836	25,150	1,92,706	4	9	4,201	11	2	1,96,707	15 11	
	1837	29,411	2,21,450	13	6	4,595	3	8	2,26,046	1 2	
	1838	32,164	2,47,576	14	0	9,851	6	0	2,57,428	4 0	
	1839	27,678	2,80,922	9	11	0	0	0	2,80,922	9 11	
	1840	27,146	2,67,374	0	7	0	0	0	2,67,374	0 7	
	1841	21,810	2,03,673	8	8	0	0	0	2,03,673	8 8	
	1842	19,318	1,75,526	1	6	0	0	0	1,75,526	1 6	
	1843	21,689	2,02,834	12	3	0	0	0	2,02,834	12 3	
	1844	23,189 1/2	2,16,593	3	4	0	0	0	2,16,593	3 4	
Total.		2,27,555 1/2	20,08,658	4	6	18,648	4	10	20,27,306	9 4	
Average.		25,284	2,23,114	0	0	6,216	1	7	2,29,370	1 7	
Deduct.		17,988	1,27,936	2	4	800	9	0	1,28,736	11 4	
		7,296	95,247	13	8	5,415	8	7	1,00,633	15 3	
				0	0	0	0	0	0	0	Net increase.

MEMORANDUM REGARDING A NEW SYSTEM OF ADJUSTING COINS TO THE STANDARD IN WEIGHT, BY CAPTAIN J. T. SMITH, F R S. F R S N A.

1. Some allusion was made in the description of the weighing machines lately brought into use in the Madras Mint, to a new system of adjusting the coins to standard weight, to which those machines are especially adapted, which it is there stated would be afterwards described; a purpose which I now proceed to fulfil, in the hopes that although the peculiar circumstances which rendered such a departure from the ordinary practice necessary here, may be but rarely met with elsewhere, still that a description of the difficulties which it was intended to overcome, and a detailed statement of the results which we have met with in a four years' experience of its application to business on the large scale, may not be altogether uninteresting.

2. When first the new system about to be described was adopted, it suggested itself as the most practicable remedy for the deficiencies in the establishment and imperfections in the Mint machinery, which will presently be described; and after it had been successfully brought into operation, I long thought of it as a contrivance, which although it had certainly afforded us most timely aid at a juncture of great difficulty, and had subsequently recommended itself by its adaptation to our peculiar circumstances and means, was nevertheless not suited to be brought into competition with the more refined methods which are followed in other Mints favoured with the advantages of the highest order of efficiency and completeness in their machinery, and skill in its management.

3. Further acquaintance has, however, greatly improved my opinion of the system, and the slight knowledge which in the course of my connection with the Mint, I have been enabled to obtain of the results of other establishments, induces me to think that it may perhaps not be altogether without its recommendations elsewhere; and that its claims to regard on the score of being an easy and economical means of effecting a difficult operation of the coinage may be worthy of notice at least in some establishments where the machinery may not be on a higher scale than that of Madras. The reader, however, will be best able to form a judgment upon this point himself, by a perusal of all the details which I shall be able to lay before him; in doing which I shall endeavour, as far as lies in my power, to guard against the bias which might be created by my connection with this system, and to represent as fully as possible, both the defects and the advantages which the plan to be described possesses, in contrast with others now in general adoption.

4. When the operations of the Mint first began in August, 1841, the means for effecting accurate lamina-

tion of the silver straps were very imperfect. Instead of the beautiful case hardened rolls turned by steam machinery, which are now common in modern Mints, we had nothing but brass, or rather bell metal, cylinders fitted in machines worked by bullocks. These cylinders were cast on the spot by the Native artificers of the establishment, and there were no other means of making them exact, than such as were afforded by a turning lathe, also of country manufacture, worked by manual labour. The whole of the laminating machinery indeed was of native workmanship, and in addition to the difficulties and imperfection of work arising from the want of stability and accuracy in its adjustments, the softness of the rollers, and the want of power and regularity in the motion, we had to contend against a fourth difficulty arising from our inability to give sufficient condensation to the straps, for want of mechanical force; which, added to the other three, fully accounted for the unfavorable results which had been previously experienced.

5. When we consider, indeed, what extreme precision is rendered necessary by the conditions of the work to be performed, we can no longer wonder that under circumstances such as are alluded to above, very little success should have been met with. In laminating rupee pieces, the thickness of the strap at the time that it is ready for the pieces to be cut from it, is very little more than about the $\frac{1}{16}$ th of an inch. Each of the blanks which is cut from this ought to weigh exactly 180 grains, and the usual limits of allowed error are somewhat less than $\frac{1}{4}$ grain each way.

6. The weight of the Rupee piece being 180 grains, as above stated, a difference of $\frac{1}{16}$ ths of the $\frac{1}{16}$ th part of the total thickness, would of course cause the amount of error above mentioned. In other words, if the strap were thinner than it ought to be, by more than $\frac{1}{16}$ ths of the $\frac{1}{16}$ th of $\frac{1}{16}$ th, or the $\frac{1}{256}$ th of an inch, the pieces would be unfit for use. The allowed error or "remedy" as it is termed, being in fact less than $\frac{1}{4}$ of a grain, the actual deviation from truth in the thickness of the strap, either way, may be assumed to be less than the $\frac{1}{256}$ th of an inch, or about the $\frac{1}{16}$ th part of the thickness of a fine hair; a degree of accuracy so minute, that it is only wonderful that even in Mints possessing the highest advantages of the most perfect machinery, it should be possible to turn out a large proportion of their work in conformity with it. The Calcutta Mint, for instance, in 1836 turned out no less than 87 per cent. of their blanks within a trifle more than the above remedy, and I believe in the Royal Mint the remedy is the same for silver pieces, and none are filed or alter-

ed in any way, though from what will be hereafter stated it will appear that the general results of the work are not materially better there than in Calcutta.

7. Such results were not obtainable in the Madras Mint at the time the new system about to be described was first introduced; for owing to the causes above stated, and the general disrepair and disorganisation of all its machinery, it is doubtful whether it would have been possible to have turned out more than 10 or 12 per cent. within the above remedies. It had been officially stated some time previously, that about 30 per cent. of the pieces were within the limits of $1\frac{1}{2}$ grain each way, and it is probable that proportion of pieces falling within the limits of that larger remedy would correspond to not more than the per centage above stated for the smaller one.

8. When the pieces as originally cut from the laminated straps are inaccurate in weight, the light ones are returned to the melting pot, and the heavier are filed down to correspond with "standard." This involves an excessive amount of toil and expense, and as the loss of labour is greater when the pieces are light, because then they are not only rejected, but have to go through the processes of melting, laminating, and cutting, again to run the risk of a second rejection, it was customary to leave the laminated straps purposely rather heavy, which though it increased the number of pieces to be filed, yet upon the whole caused the least waste of labour, a larger number of serviceable pieces being in the end obtained. These pieces were thus operated upon.

9. Every individual blank which fell from the cutters was singly weighed by hand, and those which were found to be within the allowed remedies were put aside for the further processes of the coinage. The heavy ones being, in the act of weighing, roughly sorted into classes, by guess, were then passed to the filers who gave them two or three strokes of the instrument according to their supposed deviation from standard. They were then passed back to the weighing man, and usually found still heavy, but nearer the mark; they were then again touched with the instrument, and being returned to the scale, again tested; and sometimes it happened that individual pieces had to be operated on four or five times (especially if the working remedies were small) before being fit for use. In other instances the last stroke of the file having been too violent, the piece became too light, and after all the labour expended upon it, was obliged to be rejected.

10. The above describes the system which, to a greater or less extent, is followed in all Mints where the remedies are smaller than can be attained by the mere use of the laminating machinery, and where consequently, the use of the file is indispensable; but the inconveniences of the system, which are great even with the best machinery, are insupportable when it is to any material extent defective; and it was to obviate, on the one hand the great expense, delay, and uncertainty in

the performance of the work, and on the other to get rid of the disfiguring marks left upon the surface of the coins by the file that my attention was very earnestly directed to this subject, previously to the commencement of the new coinage of silver by the Madras Mint in 1841. The result was the adoption of the system of adjustment now about to be described, which has ever since that period been in constant operation.

11. Before proceeding to enter upon a description of the method above alluded to, I must make a few preliminary remarks, showing its connection with the previous practice, and that followed in other Mints, and the steps which led to its adoption. In order to do this, I must observe, that there are two kinds of difficulties to be overcome in lamination. One is to obtain the ribands, or straps of precious metal, afterwards cut into blanks, of precisely *uniform* thickness in every part; and the second is, supposing the first to be attainable, to hit the exact thickness required. Both these difficulties are doubtless experienced in all Mints, a fact which will not appear remarkable when we remember the marvellous degree of hairsbreadth accuracy which is looked for, and a great deal of management is necessary to obviate the consequences of them, which is in practice effected by various mechanical adjustments and accommodations. In the Royal Mint of Great Britain, which is famed for the beauty and accuracy of its machinery, the equality of the strap is finally brought about, within narrow limits of error, by means of the draw bench; but though this instrument enables the workman to secure a tolerable uniformity in every strap passed through it, it does not seem possible to regulate with great minuteness the exact dimension in thickness to which the strap shall be reduced. The consequence is, that a compensation is frequently required, to make up for the general excess or deficiency in the thickness, over the whole surface of the strap, supposing that thickness to be uniform; and the method of effecting this is thus described in a late lecture of Mr. Brande. "Imagine here again the extreme nicety of these cutters, they must be so adjusted as to cut out exactly the proper weight. Supposing that the bar, or fillet, (strap) which is to be cut into sovereigns is exactly 'standard', it goes through a particular cutter which will cut it 'standard'; but suppose that in testing this way, it should be found a shade too light, it then goes to a cutter which will cut them a shade too heavy, or rather compensate for that lightness. There are in fact a number of cutters of this kind, each varying a mere idea, or mere thought, but still producing a very important result."

12. From the above statement, it is impossible to decide what the exact amount of compensation made by the varying sizes of the different cutters above noticed is; but it may be observed, that in regard to gold coins, even after all the pains which are taken in the establishment above referred to, the result is not sufficiently satisfactory to obviate the necessity for further adjustment, and that the aid of a small file to bring the pieces

to "standard" is sometimes necessary. In regard to silver coins, the whole of the pieces are brought within the limits of the remedy of $\frac{3}{4}$ of a grain each way, in half crowns, which is considered sufficiently accurate without further adjustment.

13. The object of the above notice of the method pursued in the Royal Mint of Great Britain, is that of drawing attention chiefly to the use of a variety of different sized cutters, to compensate for trifling differences in the thickness of various straps supposed to be uniform. The same method of compensation is I doubt not used in other Mints, and was the constant practice at Madras, before the present system was introduced, but the results were very indifferent, owing to the very great want of uniformity in the straps, without which it must be evident, that the mere accommodation of the size of the cutter to the accidental thickness of one portion of the strap, could be of no avail whatever.

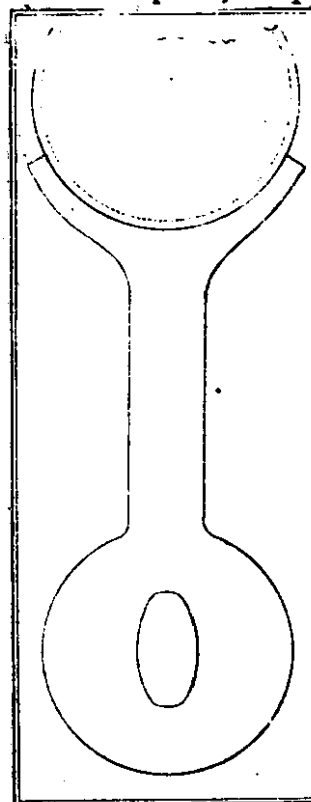
14. On thinking over this subject, the idea which naturally suggested itself in connection with the uselessness of attempting to adjust the cutter to an irregular strap, was that the real desideratum is to apply a different cutter, adjusted to every individual portion of every strap; and it also occurred to me that, as an exact determination of the comparative thickness and density of the different parts, could in no way be so well obtained as by weighing blanks cut by the same cutter, and consequently of equal area, the true object and intent of the above plan of using divers cutters of various sizes would be obtained with certainty if, supposing each strap to be irregular, its different portions could be first cut out and tested by weight, and afterwards brought to the particular cutter exactly suited to them. In other words, if a scheme could be contrived, by which the particular portions of each strap could be first weighed, and then cut in the peculiar cutter suited to them; a condition which it was thought might be fulfilled by first cutting them all out by a cutter somewhat larger than the proper size of the coin; and then, after weighing and separating them into classes, cutting these in a series of different cutters suited respectively, in point of size, to the various thicknesses and densities of the different portions of the strap grouped together.

15. It was a necessary condition of this scheme, that pieces which after being cut with a cutter of one dimension, were equal to one another in weight, should, when afterwards cut a second time with a smaller cutter, yield blanks of equal weight also, and this was easily proved by experimental trial. After this, the arrangement of the practical system was perfectly easy. It must be observed, that when a quantity of laminated metal has been cut up into a great number of extra sized blanks (or as we call them "disks" to distinguish them from the "blanks" which are of the proper size for being fabricated into coins), and these have been carefully separated from one another into parcels of disks of equal weight, we may imagine, that if it were possible to re-combine together all the disks of each parcel, so as to

form them again into new straps, we should then have straps of perfect uniformity, and so exactly true in every part, that all the blanks which fell from the cutter suited to them would be true to standard. Our course of proceeding was therefore very obvious, and the following is a brief outline of the present practice.

16. The laminated straps are rolled down with as much accuracy and uniformity as the machinery is capable of attaining, the object being to bring the average thickness of all parts of each strap, as determined by the weight of disks cut from various parts of it, to true standard. When this is attained in regard to all of the straps, the whole are cut up into disks, that is, into blanks a little larger than the size of the pieces required to form the coins. The next process is that of sorting these disks, whereby the whole mass is separated into different parcels, according to their several deviations above or below the "standard" disk. After this, each parcel is taken to its appropriate cutting press, and one or two of the parcel having been tried, and found to yield "standard" blanks, the whole of the parcel is cut out by that press; and as the disks are all of equal weight with one another, they all necessarily yield blanks equally true to "standard."

17. The difference between the diameter of the disks and that of the blanks is rather less than the $\frac{1}{8}$ of an inch in regard to rupee pieces, and the $\frac{1}{16}$ th of an inch in two anna pieces, and proportionably with regard to



other coins; and I anticipated some difficulty at first in accomplishing in practice the second cutting which this system involves, owing to the nicety which would be required in fitting the disk centrally below the second cutter, so as to admit of the blank being punched out of it exactly in the middle. However, after the trial of a number of contrivances, the very simple one which is shown in the margin, and which consists in the use of a semicircular stop, suited to the size of the disk, and adjusted to the frame so as to lie on the top of the cutter bed, has been found to answer the intended object perfectly; and the little boys who are employed upon this duty are now able to get through the work with perfect accuracy, and with as much

rapidity as in the cutting of straps in the ordinary way. After the piece has been cut, a ring remains, which is separated before another disk is submitted to the ope-

ration. The boy removes the ring with his left hand, while, with his right, he takes another disk from the heap. The diagram is drawn of the full size, and represents a rupee disk, with dotted lines showing the blank to be cut from it, and also the stop which is used to keep the former in its proper position whilst being operated upon.

18. I must now mention, that in speaking of the assortment of the disks into parcels of equal weight, the expression is not to be understood in all the strictness of literal meaning which it is capable of. In fact, when a laminated strap is at all irregular, the number of parcels of disks of truly equal weight into which the disks cut from it would be assorted, must depend upon the nice sensibility of the scale with which they are tested; and if the *utmost* precision be aimed at, it is quite possible that there would be no two disks *precisely* alike. The different parts of an irregular strap vary by imperceptible gradations one from another, and it is therefore only when we are understood to speak within certain reasonable limits, that such a thing as the assortment of a vast number into parcels of disks of equal weight can be considered practicable. Each of the parcels must therefore be understood as comprising all within certain narrow limits each way, and in the existing condition of the machinery of the Madras Mint, we have found it most convenient to form the classes or parcels of rupee disks with differences of half a grain from one another. Of these classes it is necessary to have ten, which thus include all disks within the limits of $2\frac{1}{2}$ grains heavy, and $2\frac{1}{2}$ grains light. In the ordinary course of work a very few fall even beyond these limits, but these are not assorted. They are, however, not at once thrown away, but after being cut in the largest or smallest second cutter, according as they may have transgressed beyond the heaviest or lightest boundary, the resulting blanks are examined, and those which may by chance be within the working remedy are secured.

19. From the circumstance that the several parcels contain disks which are not exactly equal in point of weight, but vary from one another by a trifling quantity, it will have been already inferred that it is impossible that all the blanks resulting from the second cutting can be precisely "standard." Such of course cannot be the case, but, as the second cutter is adapted to produce a piece precisely "standard" from the normal disk, and the whole parcel includes those which vary only as far as $\frac{1}{2}$ grain above and below it, it follows that part of them, namely, those which were nearest to the limit allowed by the class or parcel to which they belonged, would produce, on being cut the second time, blanks $\frac{1}{2}$ grain above or below standard; and all the rest of the disks would within that limit of deviation, produce blanks more or less close to "standard" in proportion to their own proximity or to agreement with the normal disk. Were the system therefore reduced to perfection, and carried into effect without those many blunders and omissions inseparable from Native management, we might reasonably expect, with reference

to the conditions which apply to the Madras Mint, to find all the rupee pieces within quarter of a grain of "standard," and I have no doubt that this is very nearly, if not altogether, possible. Under many disadvantages, the actual results on the large scale, as shown by the result of the Assay Master's examination of the six coins have lately given three-fourths within the above amount of deviation; and if, instead of an infant scheme, every step of which is novelty and experiment, we had been carrying out the details of a thoroughly established system, I think the proportion might have been much increased, and very nearly the whole brought within the remedy of $\frac{1}{4}$ grain.

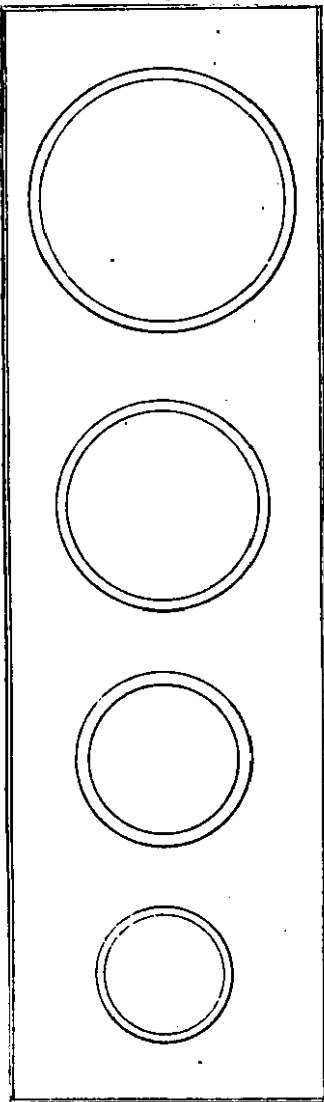
20. But in speaking of the results which have been actually obtained by this method, I only state half the case, if I do not at the same time connect them with the quality of the lamination with which they are associated. I will therefore presently state them more at large, and at the same time give tests of the amount of the errors of lamination, in order that a more definite opinion may be formed regarding the value of the system of adjustment whereby they are compensated. In the mean time, without venturing to enter upon the question as to the advisableness of the adoption of my scheme where the most perfect machinery is at hand, I may observe, that in proportion as the lamination is more perfect, so are the results produced by the second cutting also. For instance, if the lamination effected by the rolling machinery were so true, that very nearly the whole of the disks were produced within $1\frac{1}{2}$ grains each way, it would be possible then to divide them into classes varying from one another by $\frac{1}{2}$ grain only; and after the second cutting the individual blanks would be, only the $\frac{1}{2}$ th grain above and below standard. If the lamination were so perfect as to produce nearly all the disks within the limits of $\frac{1}{8}$ ths of a grain either way, then the individual pieces might be brought to within $\frac{1}{8}$ th of a grain of deviation from "standard."

21. In considering, therefore, the benefits which would ensue from the adoption of this system of adjustment in any other Mint, it is necessary to compare the relative qualities of the lamination produced by the machinery of each, and calculate upon proportionate results accordingly. Now, during the last half yearly settlement of the Madras Mint, the out-turn of the rupee pieces, as produced by double cutting, was as follows. Eighty-two per cent. were within $\frac{1}{2}$ grain of "standard" either way, and of the remaining eighteen, sixteen and a half were within $\frac{1}{2}$ grain, and the rest within $\frac{3}{4}$ grain; which with very rare exceptions is the greatest deviation ever met with, and the following statement, showing the average result of a number of experiments made upon the whole out-turn of the laminating mills, as tested by the accuracy of the disks produced by the *first* cutting, on various days when the mills were judged to be performing their average quality of work, will give as nearly as possible a fair judgment of the accuracy of the lamination with which the above results are connected.

22. On the occasions specified, the disks, taken as they fell from the (first) cutters, gave the following results: 20 per cent were within $\frac{1}{2}$ grain each way, 54 per cent were within $\frac{3}{4}$ grain, and 77 $\frac{1}{2}$ per cent fell within 1 $\frac{1}{2}$ grain on either side; three per cent being beyond the limits included in the sorting for adjustment, which as above stated takes in all within 2 $\frac{1}{2}$ grains over and under the "standard" disk. These results it must be remembered apply to *disks*, which are heavier than rupees by 20 grains, but making allowance for this, they show the state of the laminating machinery very well; and with such lamination, the whole of the pieces which by the first cutting were delivered within the limits of 2 $\frac{1}{2}$ grains, were by the second, brought within the working remedy of $\frac{3}{4}$ grain, the greater part being within one-third of that amount of deviation from "standard." Thus the number of serviceable blanks amounted to 96 or 97 per cent.

23. The same process is followed with the smaller coins, and the results are equally satisfactory, but the blanks are not brought within a degree of proximity of standard proportionate to their weight, in consequence of the difficulty of separating the disks with any thing like rapidity, when the difference between the classes is less than $\frac{1}{2}$ grain. The following are the weights of the disks and blanks for all the coins, of which full sized drawings are given in the margin.

Rupees.	Disk.	Blank.	Ring.
200	200 grs.	180	20
$\frac{1}{2}$ R.	100 do.	90	10
$\frac{1}{4}$ R.	50 do.	45	5
$\frac{1}{8}$ R.	27 do.	22 $\frac{1}{2}$	4 $\frac{1}{2}$



It will be observed here, that the last or smallest coin has a larger proportional ring than the rest, and this is owing to the great difficulty of correctly cutting out so small a coin, if the margin to be separated from it, were so very narrow. We have found that it could in practice be reduced below 4 $\frac{1}{2}$ grains, but the reduction has been thought of too little consequence, to make it worth while to diminish the facility of work, to effect it.

24. Perhaps it will tend most to the thorough comprehension of all the details of this system, if I enter at once upon a comparison of its merits and defects with those which are already fully established; and as this will give me an opportunity of stating facts, which require to be known to judge of it fairly, and anticipating

objections which might be made against it, I will at once enter upon a fair investigation of all the chief points of comparison.

25. On first beginning business upon this plan, I was chiefly apprehensive that the differences in diameter which essentially belong to the different blanks after adjustment, would be the occasion of some trouble or imperfection in the pieces in the after processes; but this is now proved not to be in the least degree the case. My fear was, that the stamped pieces would differ from one another, but this has since been proved to be impossible, owing, partly to the exceeding minuteness of the differences in question, and partly to the compensating effect of the processes subsequent to the second cutting. Although there are ten different classes of rupee disks, and the difference in weight between the heaviest and lightest is not less than 5 grains, yet, the difference in diameter between the largest and smallest blank produced after the second operation of cutting has been proved by accurate measurement to be only the $\frac{1}{16}$ th part of an inch.

26. The blanks, after milling, are all brought to the precisely same diameter, and it might be supposed, that as the difference in diameter vanishes after that operation, the defect of metal in the smaller blank ought to be shown in a want of elevation in the raised edge, produced by the operation. Even this, however, is almost imperceptible, as I have ascertained by careful measurement that the difference in thickness of the rim between the largest and smallest Rupee blanks milled to the same gauge is only the $\frac{1}{16}$ th part of an inch. And I may add, that in taking up a parcel of the mixed blanks after milling, it is not at all perceptible.

27. It is evident, that as the pieces after milling do not sensibly differ from one another, there can be no difference, from the supposed cause, in the pieces after stamping. Indeed even if such a thing were to happen, as that any of the pieces differed in a trifling degree in their diameter, or the thickness of rim, the expansion of the metal, and its moulding to the form of the die must necessarily efface the defect. It is therefore unnecessary for me to say more, than that we have never had the slightest inconvenience on this head, even although we have been obliged to include within the limits of adjustment so wide a range as 5 grains of deviation; were our means of lamination more perfect, so that the differences in weight to be compensated were less, and consequently the differences between the greatest and least diameters of the blanks less also, the possibility of such an inconvenience being felt would be still further removed.

28. But although we have had no practical difficulty whatever on the score of the differences of size, and it would not have occurred to myself that any such could arise from it, a difficulty has been suggested to me, to which we, in Madras, are not liable. All our pieces are milled by two or three operations, which method has been in use for many years, having arisen probably from the circumstance that the force necessary to raise

the edge by one process is too great to be done with facility and despatch by manual labour. The rupee pieces are milled three times in general, but the smaller sized blanks merely pass through the first time unaffected, by the machine. When different sized blanks are attempted to be milled by one stroke, as is usual in Mints worked by steam, I am informed that some difficulty is experienced, from their very various behaviour under the operation. This evil would certainly require correction, and it would probably be most easily done by keeping distinct in three classes the medium, large, and small blanks, and milling them separately; but if no other plan could be found, it is certain that the utmost extent of the inconvenience resulting from it must be this, that to carry on the new system with steam machinery, a threefold number of milling machines would be required. They are of so little cost, that this would be a matter of no moment; and the whole extent of the evil would be comprehended by the first cost of purchasing, and the wear and tear in working, the larger number of these machines; for it is not probable that the same operation of milling, if performed in three stages, would consume more power than when done by one.

29. Another objection was suggested to me as the consequence of the new method of adjustment, and this was founded upon the consideration, that in contrasting its results with those of other well known methods of proceeding, it would be necessary to add the weight of the *rings* left after cutting out the blanks from the larger disks, to that of the rejected blanks, in estimating the loss per cent. I think this objection is valid, and that it would not be fair to contrast merely the proportion per cent of good blanks gained, out of the number of pieces cut, without such addition; but the most perfect method of obtaining a fair test of the system in this respect, is that of taking the actual practical results on a large scale, in respect to the proportion of good coins out of the whole weight of bullion laminated, and contrasting it with similar results obtained by other means; on doing which it will be seen that there is no need for apprehension on this score.

30. In the Calcutta Mint, where the plan adopted is that of repeated lamination in a separate series of the most exquisitely finished rollers, and where the results are considered to be as perfect as in any Mint in the world, the out-turn of correct blanks within the working remedy of $\frac{2}{3}$ grain each way, has been above stated to be 87 per cent, as ascertained by careful trial made for the purpose. The heavy blanks which exceed that remedy are filed down, and the lighter ones rejected; and taking the average of ten years' work, viz. from 1833-34 to 1843-44 both inclusive, and comparing the bullion laminated with the coins issued from the Mint, the proportion of the latter to the former is very nearly 53 per cent. By comparing together the melters' accounts of the quantities of solid bullion and scissel melted during the same period, the proportion obtained

rather exceeds 54 per cent, as the ratio of coins to bullion laminated, which is somewhat in excess of the above. During this period the rupee pieces formed about 94½ per cent of the whole out-turn, the half rupees about 3½ per cent, and the quarter rupee pieces, 8 per cent. The importance of noting this, will be seen hereafter.

31. In the Bombay Mint, which I believe is also supplied with English machinery, kept in the highest state of efficiency, I have no means of stating the result from the experience of a series of years, but from an official statement given by Captain McGillivray, in a letter dated 11th November, 1835, it appears by comparing the "ingots received from the melter, gross weight" with the "good coin to Mint Master, during one year's work, that the proportion per cent of good coins to bullion laminated, was nearly 54 per cent. I have lately received private accounts of the performance of the same Mint, in which the result of a few months' work has reached as high a ratio as 62 per cent, in rupee pieces singly; but in other coins it was very much below this, and therefore taking all together it is probable that, though the result last mentioned is highly favorable, still that the general average of a long course of years applicable to all coins may not be materially in excess of the per centage shown by Captain McGillivray's statement above referred to.

32. In the Royal Mint of Great Britain, where it must be supposed that the highest possible advantages of mechanical efficiency are to be found, it appears from Mr. Bingley's evidence before the House of Commons, No. 2589, by comparing the solid bullion and scissel melted during the course of 15 years, that the proportion of coins to bullion laminated is 53½ per cent.

33. Taking, therefore, the whole of the above facts in connection with one another, it seems to be pretty clearly indicated, that in the ordinary course of business on the large scale, in the best Mints, the proportion of the good coins issued to the bullion passed through the laminating mills, may be safely assumed at about 54 per cent, as applicable to all descriptions.

34. In contrasting with this the actual results on the large scale by the new process, I must preface the statement by an explanation, why it is impossible with fairness to appeal to the experience of a larger period than one half-yearly settlement. The truth is, that the new system of adjustment was begun at a time when the Mint was in the greatest disorder in every respect, and until a late period, there were many serious unremedied defects, which materially affected the result now under inquiry, but which were in no way connected with the *system* to be tested by them. Thus, for some time the department not being furnished with dies for any other than the coinage of rupees, all the straps which became too light for that coinage were unserviceable, and were necessarily added to the scissel, instead of being, as usual, rolled down for smaller coin. Again, till very lately, for want of proper implements, all the

ingots were of one uniform breadth, no matter what were the coins which were to be cut from them. To this I need only add, that the use of the *stop* in the cutting presses has been only very recently adopted, to show, that if the experience of the Mint were to be taken during the existence of all these drawbacks, a very fallacious comparison would be made of it, when placed side by side with that of other Mints in all respects fully provided with implements and means, and in perfect working order.

35. I take the results, therefore, of the latest settlement, because it is the only one in which some one or more of the above most serious drawbacks has not been experienced; and it is on this account the only one from which even an approximately fair comparison can be drawn, but even this I consider to be far from just to the system, owing to the injurious effect upon the result under inquiry which an usually large proportion of small coins has, as will be seen hereafter; and in this settlement the proportion of small to large coins very greatly exceeded that usual in most Mints, and probably that of the Mints above mentioned, certainly that of Calcutta.

36. The actual result on the large scale now spoken of, as having been experienced during our last (8th) settlement was, comparing the bullion laminated with the good coins issued from the Mint, 59. 4 for the rupees taken alone, and 56. 87 for all the coins taken together; the whole weight of ingots worked during the settlement having been 31,47,784 tolas, and the weight of the finished coins actually remitted to the Government Treasury being 17,90,150 tolas. During this time the proportion of whole rupee pieces was only 73. 4 per cent, half rupees 15½, quarter rupees 7, and one-eighth rupee, or two anna pieces, 4 per cent.

37. The importance of taking into consideration the relative proportions of the larger and smaller coins will be at once seen from the following statement. The out-turn of finished good coins actually remitted to the Government Treasury, as compared with the bullion laminated was, as above stated, in regard to rupees 59. 4 per cent. In half rupees it was only 53 per cent, in quarter rupees only 52. 65 per cent, in one-eighth rupees, or two anna pieces, only 44 per cent. Combining all these ratios in the respective proportions in which they formed part of the remittances of the settlement, as above stated, they will be found to come to within a fraction of the same per centage as has been given as the actual result of the whole, viz. about 57 per cent; but it is evident that, had the proportion of the smaller coins been less, the per centage would have been nearer to 59. 4 per cent, which is that properly belonging to the rupee pieces. In contrasting, therefore, the experience of this system with that of others, an injustice is done when, as in the present case, the comparison is made between unequal ratios of large and small coins.

38. The results above given are sufficient to show that the new system of adjustment is not liable to any

objection on account of its occasioning a greater production of scissel than is usual by other methods; and I do not wish at present to say more. I must observe, however, in regard to the rupee pieces, in reference to a contrast of the per centage of out-turn of those coins with the superior produce of the Bombay Mint, that a strict comparison of the two systems would only be just were the conditions of acceptance and rejection of the pieces the same in both. In Madras, not a single piece was filed or altered in weight in any way, and every piece in the smallest degree beyond the working remedy of ¾ grain, heavy and light, was rejected and added to the scissel. In the Bombay Mint, the remedy is, I believe, 1½ grain each way; and I am of opinion, that had the same allowance been made in Madras, a large part, if not all of the difference would have been done away with.

39. It is perfectly true, however, that there is an increase in the scissel in the smallest coins, if the results of the new system, working with very limited remedies, be compared with the old methods and more easy ones. The remedies within which the whole of the above coins were confined, were as follows:—Rupees, ¾ grain, each way; ½ rupees, ¾ths grain; ¼ rupees, ¼th grain; ¼th rupees, ¼ths grain. If these remedies were rigidly insisted upon, I am doubtful whether, even in regard to the smallest coins, the common methods of adjustment would be able to effect more than is above stated, as the actual result of the new one; and it has been seen that on a general average of all work, even when the small coins were in an unusually large ratio, the latter has the preference.

40. I now come to a third objection, which is of a practical nature more easily to be understood, and this is the necessity for a large number of cutting machines. This is true, as an indispensable condition of the system, for it is necessary to have, not only the usual number required by the old methods of coinage, but I am of opinion that it would be desirable in every Mint adopting the new principle of adjustment, and having a large amount of varied business, to have a separate set of 10 cutters for each of two, or perhaps even three of the coins most usually in demand, to avoid the necessity of dismounting and changing the punches frequently. We have hitherto managed with only a single series of 10 cutters besides the original set of first, or "disk" cutters, not having had leisure and opportunity to provide ourselves with others, but this has subjected us now and then to the inconvenience of delay in dismounting one series and mounting that belonging to a different species of coin, which is usually a day's work for a couple of men. The defect will soon be remedied, and it may be here noticed, that it is not necessary that these instruments should involve all the cumbrous and elaborate complication to be found in Boulton's or Hague's Mints, much more simple apparatus, even for steam power, having been found perfectly efficient. In regard to the very small coins, the series of ten second cutters, when mounted in a single machine, may be easily worked by a couple of men, the whole forming a compact and efficient work-

ing instrument, of a size not exceeding that of a common four-foot lathe. We have lately constructed a machine of this kind, which is not yet sufficiently advanced to have been put to regular work, though enough has been done to test its efficiency; and the results have been very satisfactory.

41. It is fortunate that in the second cutting, which requires such a number of instruments, there is the greatest facility in bringing them into work, and indeed of making them automatic, so that the whole labour may be transferred to the steam engine; for as the metal to be cut is no longer in straps, but in circular disks of uniform shape and size, nothing is easier than to supply the cutter with a continual succession of them, in a manner somewhat similar to that in which the Boulton stamping press is fed, and the power being transmitted merely in the ordinary way, by a horizontal shaft working a pair of eccentrics, with another pair to work the feeders; the only thing which is further required is the attendance of a boy on a set of 10 cutters, to keep the hoppers holding the disks full, all the rest being done by the machine.

42. In taking into consideration the amount of disadvantage entailed by the increased number of cutters, it must be noticed, that although for the sake of comfort, and the most luxurious facility in the execution of business, it would be desirable to have many sets of second cutters, say even 3 or 4 sets of 10 in addition to the number at present allowed; still, that with the exception of the money required for first providing these instruments, and the interest upon the outlay, the expense is not proportioned to their number, the real additional number absolutely required for all kinds of coins being only one series of ten, with which provision only, in fact, the whole of the business of the Madras Mint, with a very varied coinage, has been carried on for the last four years. The multiplication of instruments is merely a facile way of providing for the ready application of the second process to various species of coins; but however numerous they might be, it must be remembered that the whole amount of *cutting* is only once more, in addition to the once common to all systems of coinage. Of the expense of this addition I shall have to speak presently, but in the mean time I may observe, that the cost of a machine such as that we are just completing, containing a set of 10 cutters, would be I should judge, if executed in the best manner in London, about £150; and that taking all sizes of coins together, a Mint might be perfectly furnished with three or four such machines for £1,000.

43. In the same way, four weighing machines, upon the principle of that described in a former paper in this volume, (page 169), and which I should conjecture would cost an equal sum, would render a Mint completely independent in that part of the process, and thus the whole first cost of construction of the necessary machinery would be represented by £2,000; or if three or four hundred pounds be added on account of extra milling machines, say £2,500, a sum which I should imagine was not much in excess of the cost of the

draw benches, or finishing mills now employed in other establishments.

44. I am aware of no other peculiarities which come under the head of disadvantages, and I may therefore proceed to consider the question of the current expenses of the new, as compared with the old system; but here I labour under a difficulty which I am altogether unable to surmount. It is impossible to make a fair estimate of the comparative expense by this and other methods, except by first deciding for which part of the former processes the new are to be substituted, and it is in this that the difficulty lies. My belief is, that the process above described must be considered not merely as a substitute for the *adjustment* which pieces require after the straps have undergone the elaborate rolling in the exquisite machinery of a set of finishing mills, or have been rendered accurate and uniform by the toilsome and difficult operation of the draw bench; but that it is to be taken as a new means of effecting the same object as is attained by these operations, in addition to adjustment with a file when that is used; because I think it probable that the condition of the strap previous to the cutting of the "disks" which are by the new system brought within the limits of accuracy above stated, is not superior to what it is in other Mints previous to the use of the finishing mills and draw bench. However this I must leave to be judged of by the average statement of the tests of the lamination, which I have before given; and it is evident that if my supposition be correct, and if the condition of the straps usually operated on by us is not superior to that of the straps in other Mints, previous to the use of finishing mills or draw bench, then the whole of those operations are saved by our method of adjustment.

45. From the description given by Mr. Brande of the vast pains taken in rolling previous to the use of the draw bench, I have no doubt that the whole of the latter expense is saved by our method, in which case the difference of expense must be very great indeed. In other Mints where adjustment by the file is used, the saving is also very considerable, putting out of consideration the expense of "finishing" the straps. The cost of adjusting the cut pieces by the file has been officially stated to be about 28 Rupees per lac, and this includes all the cost from the time the blanks fall from the cutters to the time that the whole lot is delivered, the pieces being singly weighed and adjusted to within the prescribed remedy. By the new system, the operations which the blanks (disks) would have to undergo, would be, weighing or assorting, and second cutting. Speaking of rupee pieces, which are the most expensive by our plan, the cost of the weighing, supposing it done by a machine of only 50 beams, worked by hand, would be as explained in art. 56, page 179, only 14 annas 1 pie, per lac of pieces. The second cutting, if done by coolies and the pieces supplied by feeding boys, as has been practised by us, would be 3 rupees 10 annas 8 pie; a man and a boy, whose joint pay is 11 Rupees, finishing 12,000 daily, or 3 lacs per month of 25 working

days. The whole cost of adjustment is thus shown to be 4 rupees 8 annas 9 pie per lac of pieces; but the estimate might be reduced to less than half that sum, in regard to a Mint worked by steam instead of manual labour. A trifling addition may perhaps be made to this estimate to account for the wear and tear of a three-fold number of milling machines, but it is doubtful whether the wear would be much increased, since the force exerted by each would be only one-third of those with which the comparison would be made.

46. If the comparative expense be as $4\frac{1}{2}$ to 28 in regard to rupee pieces, it is much less in regard to the smaller coins. The expense of assorting small coins in a machine of 100 beams, would be less than 8 annas per lac; and it appears certain, by the experience we have thus far had with the cutting machine before alluded to, that the cost of that process may be reduced to about 12 annas per lac, making the total expense $1\frac{1}{2}$ rupee. Indeed as regards very small coins of the precious metals, I can hardly help feeling that if they should be required to be brought within limited remedies, such as those which are required by us, viz. $\frac{1}{8}$ th grain for the two anna pieces; it would be quite impossible to get through a coinage of them in a large Mint, by any other means than those I have above described; for the infinite labour and time requisite for the individual examination and adjustment of the innumerable quantities comprised in an extensive coinage, would demand such a multitude of men as to create the greatest inconvenience to find accommodation for them, and a still greater trouble to keep them in order.

47. It has been before stated, that the weight of the rings is comparatively more in the small coins, so that the yield of the straps is less; and I question whether the out-turn of two anna coins can by the new process be made to exceed 50 per cent of the bullion laminated. Nevertheless, I cannot help thinking that the system of double cutting is peculiarly suited to the fabrication of small coins, when these are required to be brought near to standard, on account of the great ease and expedition with which the whole of the business of lamination, cutting, and adjustment is effected; indeed I am convinced that the regularity and certainty with which the desired effects are arrived at, could not fail to be a great relief to any department charged with the fabrication of these coins, when contrasted with the confusion, uncertainty, and disorder, not to mention also risk, involved in the employment of such a number of men as would be required to adjust them by the ordinary means.

48. Nothing can be simpler, indeed, than the routine followed in the adjustment of coins to the most limited remedies by the processes above described, and it seems to me that this is a strong argument in favour of the system. During the four years that it has been followed at Madras, the desired results have been attained with the greatest uniformity and ease; the number of pieces which have been rejected in consequence of exceeding the remedies being, according to a late average, less than $\frac{1}{4}$ per cent. This is the practical de-

duction from the experience of a system still in its infancy, and very imperfectly supplied with means; but the $\frac{1}{4}$ per cent refers only to the pieces actually lost in adjusting, and does not include the loss of pieces which owing to bad lamination fell beyond the limits capable of adjustment, which were about $2\frac{1}{2}$ per cent more. During this time the management of the processes of adjustment as well as the lamination of the straps was done entirely by Natives under the direction of an East Indian Superintendent, and though, I doubt not, that they were conducted with utmost care and attention of which they were able, yet there was nothing at all, even in the most remote degree corresponding with the difficulties spoken of in the following paragraph of Mr. Brande's lecture; which indeed it will be evident from the state of the straps after lamination, as shown by the tests before given, were not attempted nor required to be removed.

49. The following is Mr. Brande's statement regarding the rolling given to the straps in the Royal Mint previous to the use of the draw-bench. "The rolling of the Mint is perfectly distinct from the rolling of iron, copper, or other metals commonly carried on. The utmost nicety is required to proportion the edges and parts of the ribbon (strap) to the particular thickness, which is determined by very nice gauges; above all, to take care that there shall be no inequality in the pressure, so that one side of the bar should become thinner than the other. It is necessary, further, to take care that the ribbon is perfectly true, not curved or curled in any way, and that the edges especially are correctly squeezed out. All these are matters of extreme difficulty in practice, but most highly essential, in order to avoid a great deal of trouble which must result if points of this kind are not attended to in the earlier process of manufacture." The points here specified are, I think, all of them attended to, but most probably not with that minuteness and precision which are necessary when any irregularity in the strap once created is so difficult to rectify. According to our system, all these irregularities being subsequently compensated for, are of little consequence, provided the whole out-turn of "disks" can be brought within the broad limits of remedy established by us; and the only question as to the propriety of bestowing any more care upon this part of the operation is, whether with such machinery as we have, the additional trouble necessary to bring the $2\frac{1}{2}$ per cent of "disks" lost by bad lamination within the reach of our adjustment, would be well bestowed; a question which the Natives have practically answered in the negative.

50. I think I have now touched upon all the peculiarities of the new system, and fully stated all its defects as well as advantages. Amongst the former, in treating of the expected difficulties, I have stated that the minute differences in size of the various blanks are quite imperceptible in practice, and that they are not felt by us in the only way in which they could manifest themselves, viz. in milling, in consequence of our

independently being in the habit of performing that process by three operations. That the evil of adopting this course, where it is not already followed, amounts to the cost of purchasing a three-fold number of milling machines, to be worked at the same expense as before, but that this cost is so trifling as to be of no moment. I have shown also, that on contrasting the new system with the old, as to the produce of the straps, counting the rings and rejected pieces, and every thing except the good blanks within the working remedies, as scissel, the new system gives results upon the large scale quite as favorable as any other at present in use. In other respects, that as regards accuracy, uniformity, the certainty with which the results are obtained, and the ease of obtaining them, it is to the best of my judgment superior to any other system that I am acquainted with; and lastly, that in point of expense the cost is less than $\frac{1}{10}$ th in regard to the large coins, and probably less than $\frac{1}{20}$ th in the small ones; and that too, as determined by experience under circumstances wherein steam power was not available, which would materially add to the economy of the processes.

51. I might add to these recommendations, the fact that owing to the absence of filings, and the perfect cleanliness of the whole business, there is no possibility of the occurrence of waste, which as it might occur to a trifling extent by the old process, is apt to be made an excuse for a regular allowance for loss. I shall however only say in conclusion, that although, owing to the incessant demands of a constantly increasing coinage, and the very defective state of the machinery of the Mint in general on our first commencing work in 1841, we have never yet had leisure to provide the department with a complete set of instruments to carry out the system, yet still, with the most inadequate means we have found the advantages so great as to have been constrained to follow it exclusively ever since it was first adopted; and every day's experience has confirmed and added strength to the opinion, which induces me to recommend it for trial in other establishments placed in similar circumstances with ourselves.

December, 1845.

J. T. S.

POSTSCRIPT TO THE MEMORANDUM ON WASTE IN THE VARIOUS PROCESSES OF
COINAGE, BY CAPTAIN J. T. SMITH, F.R.S. F.R.S.N.A.

Since the paper on this subject passed through the Press, I have been favored with the criticism of a friend, whose opinion I value most highly, based as it is upon a thorough knowledge and long practical experience of the subject. The remarks which he has kindly made, were not written with any intention that they should be thus noticed, but as the subject is an important one, and as they state difficulties which might naturally present themselves to others as well as the writer, I have taken the liberty of entering into the explanations to which they give rise, to guard against the misconception which might otherwise exist in the minds of others. My correspondent writes thus: "I admit to the full most that you assert, but with reference to the loss in melting, I cannot make up my mind that the quantity of silver remaining in the dross is so small a fraction as you suppose it to be; it could only be ascertained by some most careful experiments; for instance, if in your assays of bullion any allowances are made for cupel loss, for refining in muster melting, &c. &c., and that estimated quantity is greater than it really is, so much more silver has to be accounted for from the dross. It is true that most of the silver in the dross is recoverable, but when the quantity is very minute, it is practically out of the question, as the expense of the process becomes greater than the value of the bullion recovered." Upon this I must explain, that my arguments as to the absence of any essential waste in coinage are based upon the supposition that the bullion is truly and fairly debited to the department, according to the "trade assay;" in which case, as I have stated, instead of a waste by the processes, there ought necessarily to be an actual and considerable gain. If owing to an inaccuracy in the cupel allowance, or the allowance for refinement in muster melting, more or less than what is proper should be left in the dross, then, in that case this gain would be greater or less according to the amount of error, but it appears to me to be unadvisable to embarrass the question by the supposition of errors in the assay, which may tell either way, because the conditions under which the argument is stated exclude that supposition, and they are not affected by it.

The quantity of silver which has been stated by me to remain in the dross at each settlement, is not a matter of inference or deduction, but is ascertained by actual experiment by the Assay Master; every separate dross belonging to each department of the Mint, being ground to impalpable powder, and after being thoroughly mixed, a sample recovered with the utmost possible care, as a specimen of the whole. It has, however, been stated, in the Memorandum, (para. 62) that while the drosses usually contained these amounts of bullion, the accounts of the department during seven

settlements had been made up, and showed a considerable excess. If it were possible that the drosses contained more than was supposed, the same having escaped the scrutiny of the Assay Master, we should be forced to conclude from that circumstance that had the recoveries been made more perfectly, a larger excess of the deliveries beyond the accounts would have been the consequence.

My friend proceeds: "Again there is a slight irrecoverable loss in all the Minting processes; minute particles of silver are separated from the ingots under the rolls. In annealing, very thin laminae are melted, and lost in the furnace: in filing, as in the rolling mill, some of the minute particles stick to the workmen's clothes and felt; and I believe that in pickling, with the alloy, a small quantity of silver also is separated. Even in the coining presses, when a collar begins to wear, I have found particles of silver about the floor, so light as to be easily blown about with the breeze, and so small as to be scarcely worth collecting. It is true the quantity of all these losses, except that of melting, is so minute as to be almost inappreciable; yet it is not correct to say there is not any." Upon the whole of these items, except the filing, in which I have admitted in the Memorandum, that a very trifling amount of loss may be unavoidable (except by adopting a new process of adjustment.) I must observe, that in my Memorandum I addressed myself more to the essential characteristics of the different operations, than to the *accidental* contingencies which might accompany them; and that in showing, generally, that so far from a considerable waste being the necessary consequence of coinage, the opposite ought to be the true result, I did not think myself called upon to enter into those minutiae of explanation which are required to meet these difficulties. I must however now explain, that the principles already given include all these minor exceptions. In regard to every one of the minute losses above referred to, except filing, a complete recovery may be made. In the Madras Mint, the sweepings of every room, rolling mills, &c. are carefully collected together, and recovery made of the silver as far as it is profitable to do so: what remains in the dross is estimated, and is included in the statement of the quantity of bullion contained in the dross before given, and *credit for it is taken in the accounts*. In regard to losses in the furnace, the sweepings of it are fully searched, and there is no possibility of metal escaping, for it cannot be volatilised. In regard to the minute quantity of silver which is dissolved together with the alloy in the pickling liquor, that also is recovered, by the simple method of inserting copper sheets.

It may be objected, however, that spite of all the sweeping and gathering of drosses, particles will re-

main which will defy the most elaborate search and investigation. This objection which I look upon as the very last stronghold of resistance, I feel it to be hardly necessary to meet in support of an argument professedly directed only to the main principles of the question; but I believe that the doctrine I advocate will stand to be pushed even thus far, and that even then its truth, as applicable to the ordinary operations of a Mint, will be vindicated. But in order to perceive this, it will be necessary to enter into some little explanation, and I trust that the following illustration will show my meaning.

If a Chemist makes an analysis of a mineral so accurately, that not a single particle of it is either dissipated by heat, blown away in powder, or left behind in the solutions or mixtures which may have been made of it, we may conclude that he is able to collect every particle of it again, with the exception of such minute quantities as may adhere to the different vessels he has used in the process. I assume that he has not dissipated any part of it, or allowed it to escape unnoticed, mingled with any fluid or solid matters which may have been used in his processes. These solid and liquid "*drosses*" contain nothing whatever, and none has been dissipated; the only deficiency therefore is that which adheres to the vessels. Let us suppose the mineral weighed 100 grains, and that the deficiency is $\frac{1}{2}$ grain.

Another precisely similar mineral is treated exactly as before in the same vessels, and its particles are removed with precisely the same care. Can it be supposed that the deficiency will again be $\frac{1}{2}$ grain? Let us suppose 10 minerals successively treated, and by the use of the same vessels and instruments, can it be supposed that still the half grain of imperceptible adherent matter will in each remain unaccounted for. At the end of 20 operations, there would need to be accumulated in the vessels 10 grains of matter undiscoverable; not thrown away in the drosses, not dissipated, but inseparably adherent to, or absorbed by the instruments employed. Of course this is impossible. After the first or second trial, this source of deficiency must cease; for as it is almost certain that the vessels would be made equally clear of matter on each occasion, so it would follow as a consequence that the amount of imperceptible adherence and absorption would constantly be the same, and that after the first few trials, there would cease to be any further loss from that cause.

And the same is the case with regard to the sweeping up of successive coinages of silver or gold. The whole Mint may be looked upon as a vast laboratory, and each successive room as a large vessel for performing certain processes upon bullion passing through it. On the first occasion of a coinage of any metal, we might expect the sweeping of any and all the rooms to be partially defective, and to leave behind a certain trifling amount of undetected particles; but after two or three such sweepings, it may be concluded that the room will be *saturated*, if I may use the term, and have no further capacity for holding them out of the reach of the sweeper. After this, which must

happen on the first establishment of a Mint, not even the trifling loss from the minute particles which have eluded search would be experienced. All the remaining coinages would be free from any loss, for although it is very possible that some of the particles of each might escape discovery, yet if, as is probable, the total amount of latent bullion always remains the same, it is evident that the losses in each succeeding coinage would be replaced by recoveries from some of the former ones.

The practical advantage of this principle may however be lost when coinages of the precious and base metals are made to alternate frequently with one another, and the drosses are not carefully separated. In this case, the trifling remnant of unrecovered particles of gold and silver might be confounded with that of the base metal; but this is not the state of things contemplated by me as the ordinary routine of a well conducted Mint; and even this, though certain to occasion trouble and inconvenience, ought not to be the necessary occasion of any loss.

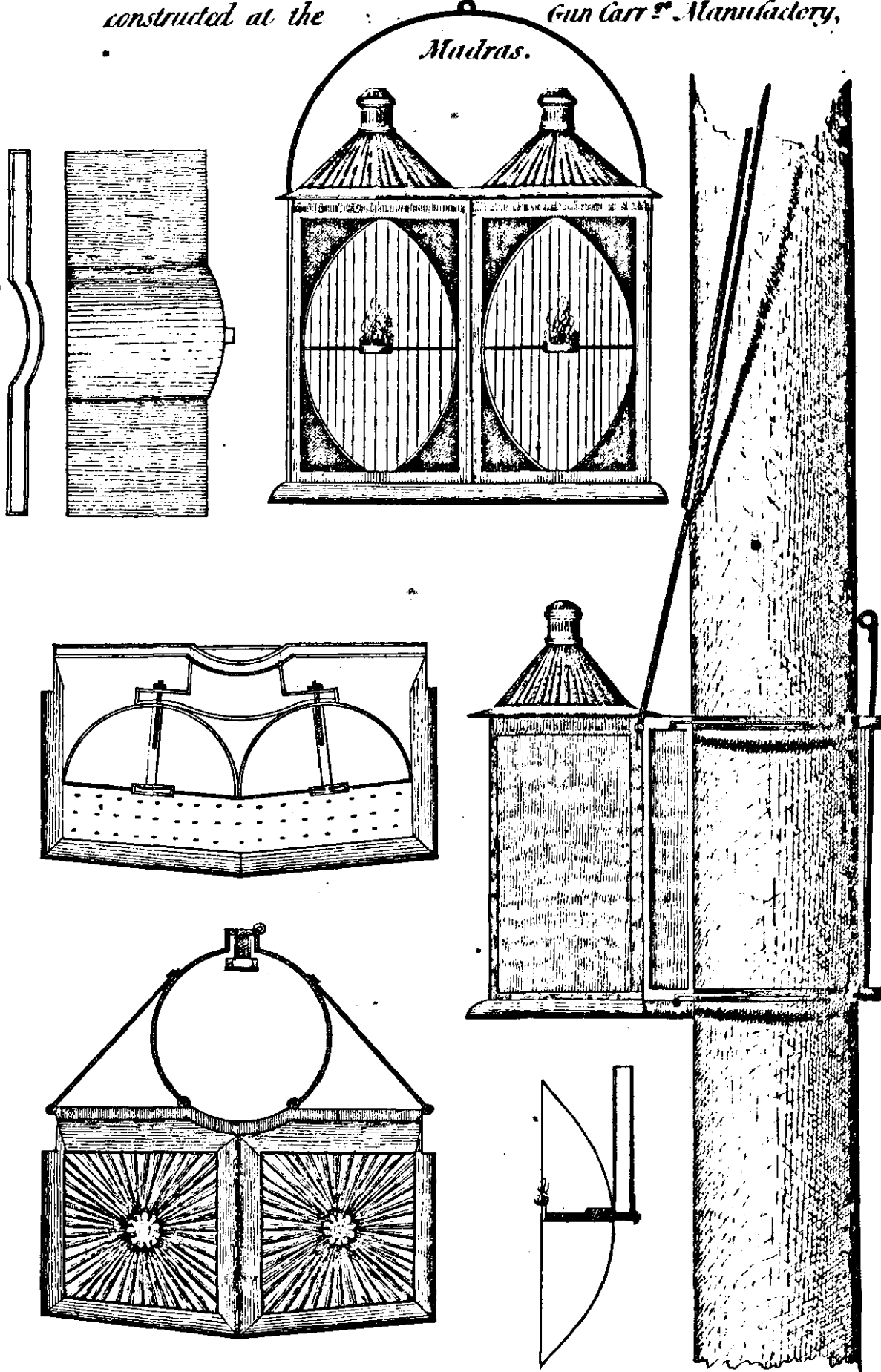
Moreover, if the possibility of the occurrence of waste be pushed to such an extreme, it would be necessary to do the same in regard to the various causes of a surplus. I have shown, I trust satisfactorily, that on general principles, in the large way, a considerable excess ought to be met with in the operations of every Mint; arising from the fractional difference in value between the "trade assay" and the true fineness of bullion. As a set-off against any minute possible exceptions against the general principle, such as those above noticed, I might appeal to the benefit by the trifling gain in *weight* arising from a similar cause to the above, and additional to it, viz. owing to the purchaser being given the benefit of the "turn of the scale" in weighing as well as assay. In Madras, merchant's bullion is weighed in bars of about 1,500 tolas, and the weight is calculated to the $\frac{1}{4}$ th tola, the benefit of the turn of the scale being given to Government. The gain arising from this source, if the practice were followed universally, would be in a year's coinage, suppose of 50 lacs of Rupees, more than 200 Rupees, a sum which would, I imagine, cover more than ten times all the minute chances of loss last referred to.

I may take this opportunity of observing, in regard to the statement given in the Memorandum, (para. 31) as to the loss of weight in blanching coins, that subsequent experiments have shown that the process adopted for the separation of the grease, also carries with it a considerable quantity of oxide of copper. This circumstance explains the reason of the apparent difference stated in the Memorandum between the experience of the Madras and other Mints as to the result of the action of the acid; for the total loss of weight in regard to blanks cut from straps laminated without the use of oil, we have found during the last settlement to amount, including this oxide, to $11\frac{1}{4}$ annas per mille or 1 anna 1.8 pie per cent, a proportion which does not differ in any remarkable degree from that experienced elsewhere.

December, 1845.

J. T. S.

COAST LANTERN,
with two Reflectors,
constructed at the Gun Carr^y Manufactory,
Madras.



NOTES REGARDING THE EXPERIENCE OF THE NEW SYSTEM OF FIXED LIGHTS.

When the first volume of our transactions was published, the experimental trial of the new system of fixed lights had only recently been made, and it was therefore not possible to appeal to the actual results derived from more than one or two of them.

Since that time, the use of the lanterns, and of larger lights constructed upon the same principle has been much extended, and already more than a dozen lights are in actual operation. Of these the forms and dimensions are different according to the localities to which they are suited, and the number of their reflectors; the smallest being of the pattern of that which was established at Cochin, of which a figure was formerly given; (vol. 1, pl. vii.) and that most commonly used, being a lantern with two reflectors, of which a general idea may be formed from the drawings contained in the annexed plates.

The following notes will serve to make known the chief particulars respecting each of the beacons at present established, and give some idea of the mode in which the system is applied in various situations. The details regarding cost have been kindly furnished to me by Captain Maitland, Superintendent of the Gun Carriage Manufactory, by whose department many of the lanterns have been made; the other particulars, I regret my inability to render more complete, having no other source to apply to for them than my own memory and a partial reference to the correspondence. The first in order as to the date of exhibition is,

Madras Temporary Light—This light has been already noticed in Volume I., it was a substitute for the 12 lamps and reflectors formerly in use in the Madras Light-house. It consisted of 4 lamps and reflectors upon the new plan, and was found to answer the purpose perfectly, the power of the light being increased four-fold. The whole cost of the apparatus was about 200 Rupees. The average consumption of oil previous to the substitution was 370 maunds at the cost of Rupees 3 ,, 2 ,, 10 per maund, or Rupees 1,194 ,, 12 ,, 8 annually. After the change, the cost was less than 8 maunds, at the cost of 24 ,, 14 ,, 3 per month, or 298 ,, 11 per annum. The light continued in use from the date when it was first lighted, 19th June, 1839, till it was superseded by the New Madras Light on the 1st January, 1844.

Coringa Light—This was built for an insular situation, and intended to show a light all round the whole circle of the horizon; it was therefore composed of a set of nine large sized 3 feet reflectors disposed circularly, facing outwards, secured to a strong frame, &c. The cost of this apparatus, including all the charges of freight from Madras to the spot, and the erection and fitting

was 1,144½ Rupees, and it was reported by the Collector of the District on completion, to be admitted by all who had seen it to be "very far superior" to the old light, for which it had been substituted. The monthly cost of the latter in wicks and oil had been 142 ,, 3 ,, 2, afterwards the whole cost for these articles was 37 ,, 6 ,, 3, but this latter sum appears to be somewhat greater than the amount of expenditure of former years, though probably the light was then very much inferior. The lantern stands on a masonry tower 60 feet high.

Masulipatam Light—This is a flag-staff lantern of two reflectors, of which drawings have been given in the accompanying plates. The cost is stated to be 270 ,, 8 ,, 10, and the report on its completion stated that it "perfectly answered the end of a light-house, being reported to be visible, bright and clear 16 miles off." The light was first shown on the 30th November, 1840, and has been exhibited ever since. The consumption of oil is 8lbs. per night, at a cost of about 27 Rupees per month. It has been found necessary to keep a duplicate lantern and apparatus in store, because in the course of years, repairs become necessary, at which time, the lantern in use is removed, and the spare one substituted for it, without this precaution it might happen that the illumination could not be continuously kept up.

Tellicherry Light—Is similar to that at Masulipatam, but in order to distinguish it from other beacons in the neighbourhood, there is in addition to the double light above mentioned, a second lantern containing a single lamp and reflector placed on the same mast 40 feet lower down; by this means as a ship draws in towards the land, she perceives an exhibition of two lights one above the other. The cost of the double lantern was the same as that of Masulipatam 270 ,, 8 ,, 10, of the single one 106 ,, 10 ,, 11. It was first shown on the night of the 15th December, 1845.

Cannanore—Trincomallie—Point de Galle—Negapatam—Are all supplied with lights on the same principle as the Masulipatam flag-staff light, and at the same cost, but the supply of a duplicate lantern to each, which is in progress if not already carried into effect, will raise the cost of each work to Rupees 541, Annas 1, Pie 8.

Cochin—This station was one of the first supplied with a signal lantern of the smallest size, agreeably to the pattern of which drawings were given in Volume I. The cost of a lantern of that description including all the apparatus is stated to be Rupees 106 ,, 10 ,, 11. Including the duplicate the whole cost is Rupees 213 ,, 5 ,, 10.

Calicut—Singapore, and the second light for *Telli-*

cherry above mentioned have been supplied of similar pattern to that of Cochin.

Mangalore—Has been supplied with an apparatus of a large size and considerable power, consisting of three large reflectors of 3 feet in height, placed side by side, pointing in the same direction, and fitted in a substantial well constructed lantern, which is placed upon a wooden frame-work or stage erected on a hill 200 feet above the level of the sea, it being unnecessary in this case to raise it further. The cost of this apparatus is stated to be 1,150½ Rupees, the light was first shown on the night of the 29th October, 1842.

Tuticoreen—Has been supplied with an apparatus of equal power with the above, viz. three large sized reflectors at a cost of 1,283½ Rupees. It was first exhibited on the night of 1st August, 1845.

Paumbum.—This is the largest lantern which has yet been made up expressly to suit periscopic reflectors, the circumstances of the case requiring a light to be exhibited all round the horizon. For this purpose four reflectors are used pointing in directions at right angles with one another, by which arrangement the full effect of two reflectors is visible in every aspect, and the light is therefore on a par in respect to power with those on the pattern of the Masulipatam light; which, with half the number of lamps and reflectors illuminate only half the circle of the horizon. The cost of this lantern which is fitted on the top of a masonry tower about 40 feet in height is reported to have been 2,269 Rupees, exclusive, I believe, of the lamps and reflectors.

The best judgment which can be formed of the general utility of the system upon which these lights have been established, will be formed by a perusal of the following letter from the Secretary to the Marine Board at Madras, to the Secretary to the Superintendent of Marine in Bengal, in answer to inquiries regarding them; to which it need merely be added that it has been thought unnecessary to give the correspondence from the Military Board referred to in it, as it only conveys information which has been given in detail above.

From J. R. BOYSON, Esquire,
Acting Secretary to the Marine Board.

To
J. SUTHERLAND, Esquire,
Secretary to the Superintendent of Marine.
SIR,

With reference to your letter of the 21st December last, No. 2369, I have the honor, by desire of the Marine Board, to forward herewith for submission to the Acting Superintendent of Marine, a copy of a communication received by this department from the Military Board at this Presidency, which affords all the information sought for by the Commissioner of Arracan. A counterpart of the lantern constructed for Masulipatam was forwarded to Calcutta in December, 1841, per Ship *Lord William Bentinck*, consigned to Captain

Boileau. The drawing furnished to this department by the Military Board is transmitted to you by this day's tappal. The light at Masulipatam is under the charge of the Master Attendant. 1 Head man at 10 Rupees per month, and 2 Lascars at 7 Rupees per month each, are employed to attend to it. It consumes about 8lbs. of cocoanut oil nightly, and the only other expense is that for wick and cloth for cleansing it, which the Board thinks may fairly be estimated at about 8 Annas per mensem. The Board desire me to add that the same description of light has been applied to many other stations, and that to the best of their belief, the results have in every case been *most satisfactory*. In all cases the practical management of the light has been entrusted to Natives.

I have the honor to be, &c.

(Signed) J. R. BOYSON.

The only additional information on the subject of these lights which it is in my power to afford, relates to the detailed instructions which it is necessary to give to the parties entrusted with their erection and first exhibition, and perhaps the best mode of conveying a clear idea of the various minor particulars necessary to be attended to, will be that of inserting copies of the instructions which actually accompanied one of the larger and one of the smaller kinds of apparatus. I subjoin therefore copies of the instructions sent with the Coringa and Masulipatam lights; the former an apparatus on a large scale fitted into a full sized lantern already built on the old plan, the latter a flag-staff lantern of two reflectors as above described.

Directions to accompany the Coringa Lighting Apparatus.

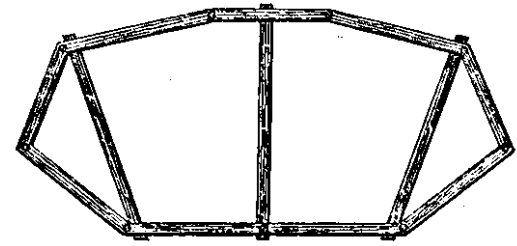
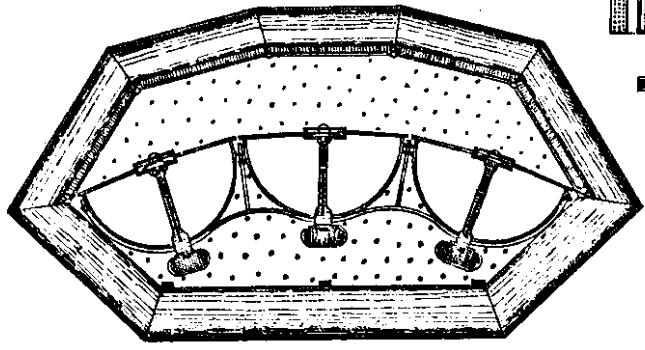
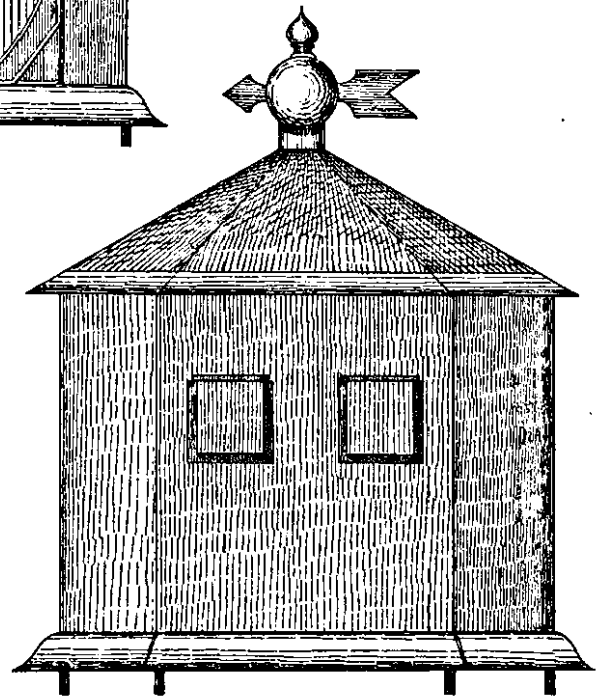
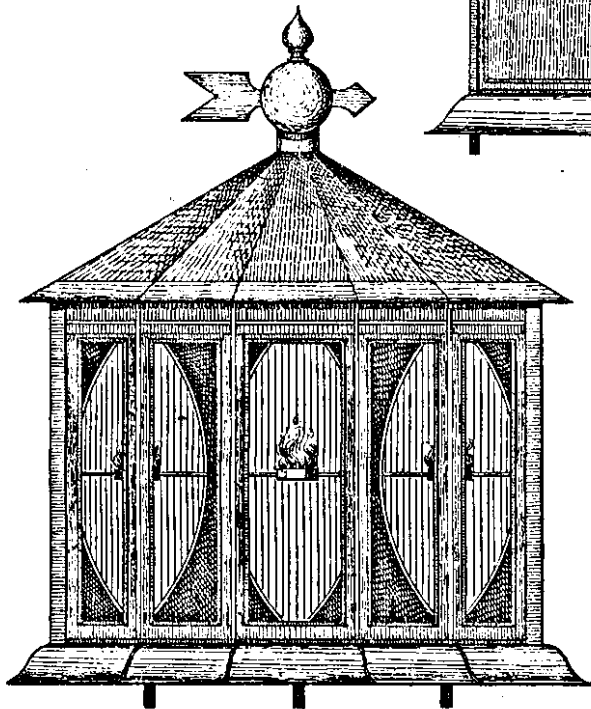
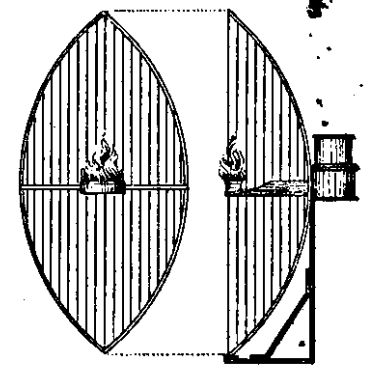
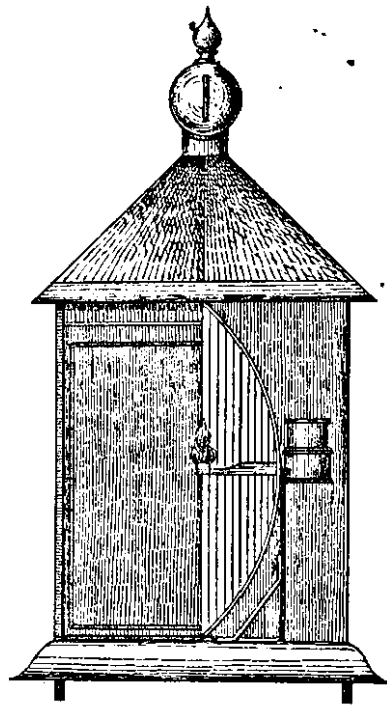
“In fixing these lamps and reflectors two points are necessary to be attended to.

“*First*,—That when the tin reservoirs of oil are filled and dropped into their places, every lamp must be filled to such a height, that the oil shall stand touching the front edge of the burner, or the least thing below it. *Second*,—The reflectors ought to stand perpendicularly, as shown by a plummet hung from the upper point of each.

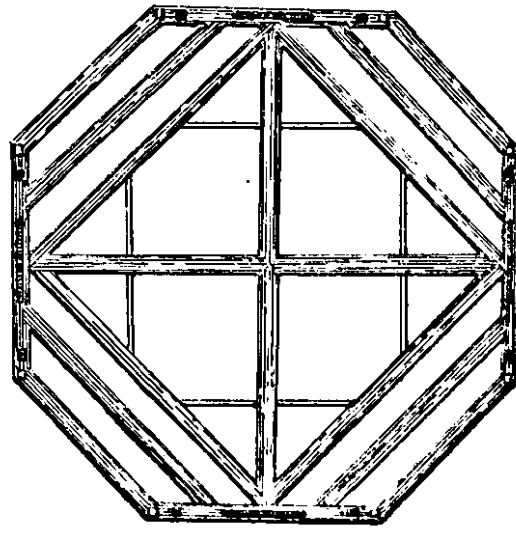
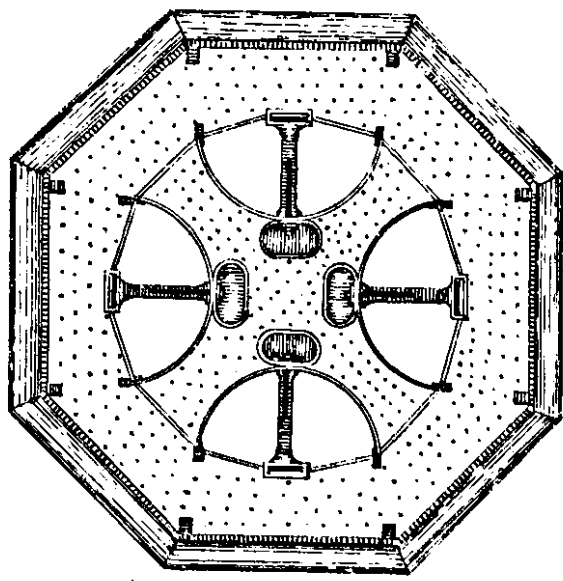
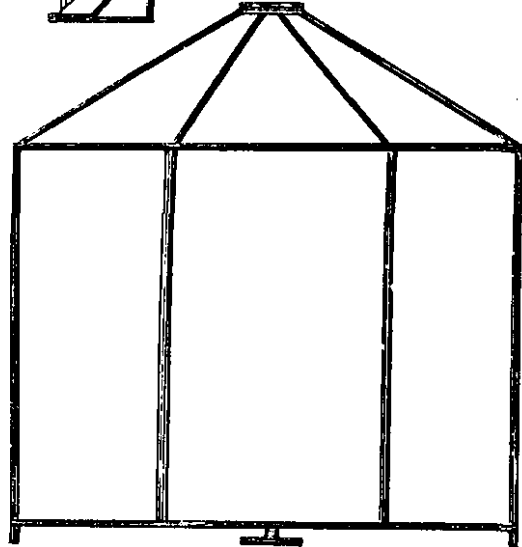
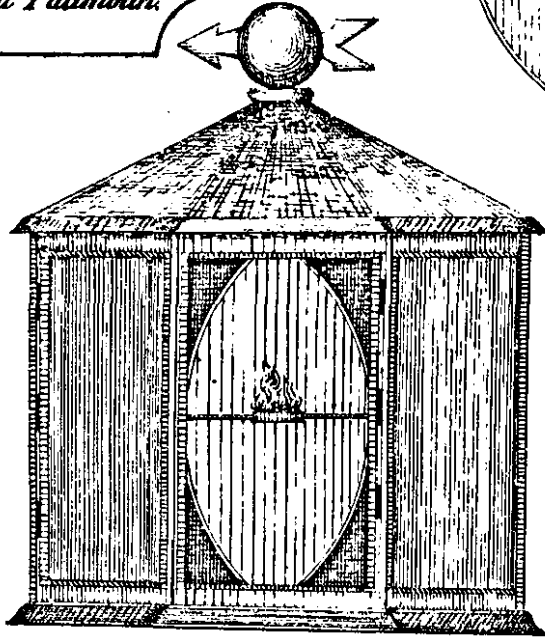
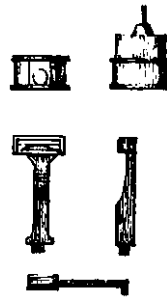
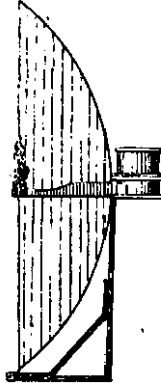
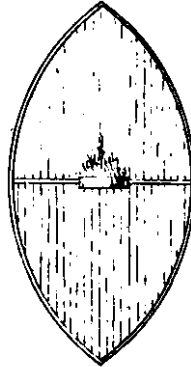
“If these points be not shown to have been correctly attained on the erection of the apparatus, they must be altered until the whole of the lamps and reflectors are exactly right. The lamps ought to be trimmed once in three hours, and particular directions must be given, and care taken, to prevent their being suffered to smoke, which is apt to be caused by the ignorance of Natives who do not understand these matters, by their raising the wicks too high. If this is carefully attended to, and the wicks correctly elevated, the lamps will burn with a clear steady light for a longer period than that named above.

“If there be no openings made already in the floor of the lantern for the purpose of ventilation, two or three dozens ought to be made for the purpose through the boards, of about 1½ inches diameter, with a bent tin tube

COAST LANTERN
with
Three Reflectors
constructed at the
Gun Carr. Man.
Madras,
for the
Port of Mangalore.



*Coast
Lantern
with
Four Reflectors
constructed
at the
Gun Carr. Man:
Madras
for the Island
at Pambour.*



ACCOUNT OF EXPERIMENTS ON REVETMENTS MADE AT SINGAPORE IN NOVEMBER,
1843, BY CAPTAIN BEST, AND LIEUTENANT ELLIOT.

At the foot of a sandy bank, a space 15 feet long by $1\frac{1}{2}$ foot broad was made level, and 3 courses of bricks, 3 bricks thick, were built on it as a pavement with clay.

The bricks used in the experiments were of the ordinary kind in Singapore, averaging $8\frac{1}{2}$ inches long, 4 broad, and $1\frac{1}{2}$ to $1\frac{3}{4}$ thick—9 of them weighed 25 lbs., and their specific gravity is hence about 1807—9 bricks which in air weighed 25 $\frac{1}{2}$ lbs. weighed in water 10 $\frac{1}{2}$ lbs. When soaked in water they weighed 29 $\frac{1}{2}$ lbs. in air, and 13 lbs. in water. When dry they begin to slide on one another with a slope of $6\frac{1}{2}$ base to 5 vertical, or at an angle of 36 degrees with the horizon.

The sand when quite dry and loose weighed 113.4 lbs. per cubic foot, and stood with a base of 3 to 2 vertical, or at an angle of 34 degrees. 27 $\frac{1}{2}$ lbs. of dry sand imbibed 5 $\frac{1}{2}$ lbs. of water. When well shaken down, the dry sand is reduced in bulk about one-tenth, and weighs 124 $\frac{1}{2}$ lbs. per cubic foot. When wet and shaken down 162.8 lbs. per cubic foot.

EXPERIMENT 1.

Upon the pavement above mentioned, a wall of whole bricks, half a brick, or 4 inches thick was built, 15 courses or 25 $\frac{1}{2}$ inches high, sand being used instead of mortar. Sand from the bank was then brought down, and levelled behind the wall. When the sand reached the top of the 12th course, or to a height of 20 $\frac{1}{2}$ inches, the wall fell over forwards, leaving 5 lower courses standing.

EXPERIMENT 2.

A similar wall was built 13 courses or 22 $\frac{1}{2}$ inches high. It fell over when the sand was levelled up to the back of the 11th course, and left 3 courses standing at bottom.

EXPERIMENT 3.

A wall was built with headers and stretchers alternately to a height of 20 courses, or 33 inches. It fell over when the sand rose to the 19th course, or to a height of 31 $\frac{1}{2}$ inches, and left 7 courses standing.

EXPERIMENT 4.

A wall was built 1 brick or $8\frac{1}{2}$ inches thick, and was raised 27 courses = 44 $\frac{1}{2}$ inches. The sand upset it when it reached the top.

EXPERIMENT 5.

This wall was $8\frac{1}{2}$ inches thick with counterforts 4 $\frac{1}{2}$ inches deep, and $8\frac{1}{2}$ inches long at every $8\frac{1}{2}$ inches. The height was 38 courses, or 57 $\frac{1}{2}$ inches, and the wall

fell when sand reached the top. 4 courses remained standing.

EXPERIMENT 6.

A wall half a brick or 4 inches thick was built with mortar composed of sand 1 $\frac{1}{2}$ and lime 1, and plastered on both sides. Its height was 25 courses at 7 courses to a foot. It was built very carefully and allowed 20 days to dry and harden, but it rained 2 days out of 3, so that when the wall had been upset, the mortar was found to have but very little consistency. The sand was raised to the 20th course, or 34 $\frac{1}{2}$ inches, when the wall fell over.

The theory of Colonel Pasley, according to which the part of the earth which tends to overthrow the revetment is bounded by a plane having the slope of the soil, and passing through the outer edge of the base of the wall appears to be confirmed by these experiments; in each of which, some courses of the wall at the foot remained standing. The different ratios of the thickness of these rectangular (in section) walls to the height of soil sustained by them were as follows:— a being the thickness of the wall, and x the height of the earth.

EXPERIMENT 1.	$a = 4. x = 20\frac{1}{2}. \frac{x}{a} = 5\frac{1}{4} = 5\frac{1}{4}$	} average 5.
EXPERIMENT 2.	$a = 4. x = 19\frac{1}{2}. \frac{x}{a} = 4\frac{7}{8} = 4\frac{7}{8}$	
EXPERIMENT 3.	a averages $1\frac{1}{2}. x = 31\frac{1}{2}. \frac{x}{a} = 21 = 21$	
EXPERIMENT 4.	$a = 8\frac{1}{2}. x = 44\frac{1}{2}. \frac{x}{a} = 5\frac{1}{4} = 5\frac{1}{4}$	
EXPERIMENT 5.	a averages $10\frac{1}{2}. x = 57\frac{1}{2}. \frac{x}{a} = 5\frac{1}{2} = 5\frac{1}{2}$	

The experiments are not sufficiently numerous, perhaps, for a safe conclusion to be drawn from them. The conclusion to which they point, however, seems to be, that for a counterscarp wall with a rectangular section, a thickness of one-fifth the height is sufficient, the material of the wall not being of less specific gravity than 1807, and that of the soil not more than 113 lbs. per cubic foot, standing with a base of 3 to a vertical of 2.

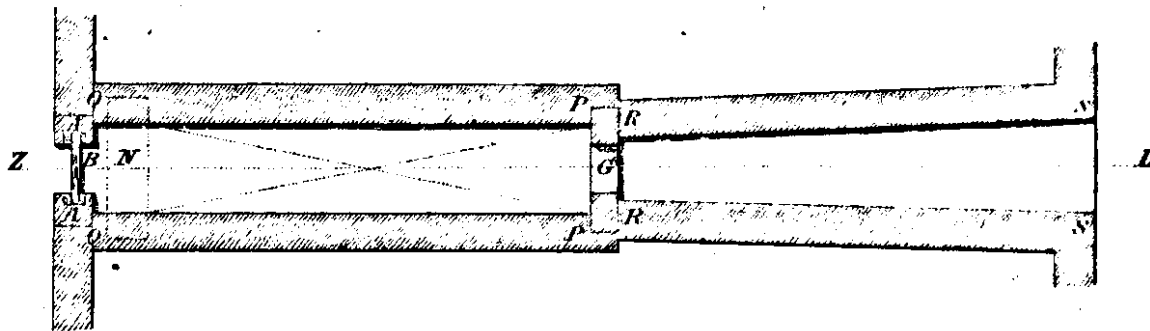
But if the wall be built with good mortar, and attached firmly to a massive foundation, the pressure of the earth must either uproot the foundation, or break the cement, and the power required to do either the one or the other is to be added to the strength of the wall supposed to be built without mortar. In the 6th experiment, the wall had no foundation, and the mortar was but very slightly cohesive. It nevertheless seems to have added considerably to the strength of the wall.

EXPERIMENT 6.	$a = 4. x = 34\frac{1}{2}. \frac{x}{a} = 8\frac{1}{4} = 8\frac{1}{4}$
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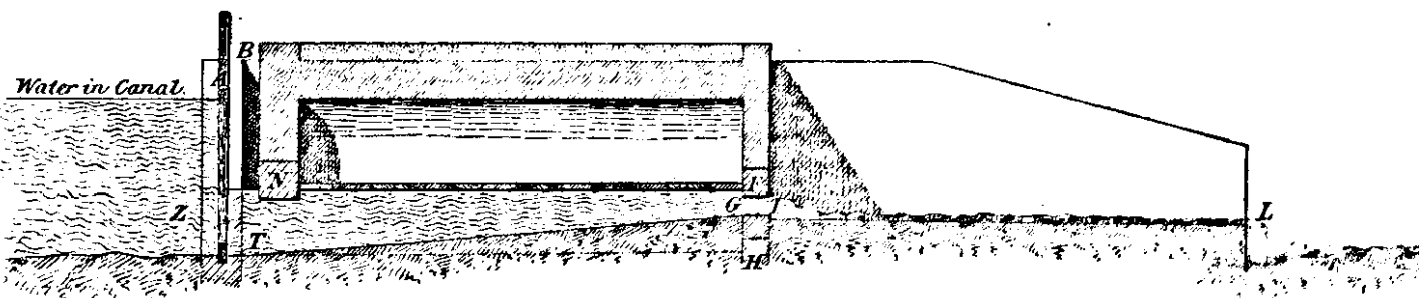
THE MODULO MAGISTRALE

used in Italy for measuring
WATER FOR IRRIGATION.

Plan on the level ZL.



Section through ZL.



DESCRIPTION OF THE SLUICE OF IRRIGATION, CALLED THE MODULO MAGISTRALE,
 PREFACED BY REMARKS ON THE TAXATION OF IRRIGATED LANDS,
 BY CAPTAIN BEST.

However difficult it may be for me to discover or admit the merits of a permanent settlement of land revenue in *this* country, where the characteristic improvidence of the people seems to preclude the hope of their saving in seasons of abundance, a provision against those of famine,* even in their own behalf; (and it is still more improbable that they should do so for the purpose of paying their taxes,) where the home trade is but an aggregate of village monopolies, where, the revenue being barely sufficient to meet ordinary expenses, if *one* order raises a new regiment in the North-West, *another* puts a stop to improvements in the far South, where great resources are neglected for want of capital which none but the State will ever furnish, and in which the State has a claim to the first share, a professional Memoir would not be the fittest place to bring forward my opinions, even though they could be supposed worthy of attention when at variance with the standard authority of those whose business it has been to investigate and deliberate upon a subject which I have only casually and cursorily noticed. But I do not see any reason against my making a few remarks upon a part of the land revenue management in which objections are likely to be more obvious to an Engineer accustomed to study the best means of irrigating the country, than to the Collector who looks chiefly to the most effectual manner of getting revenue from it..

Lands, under the old Governments were classed as *dry* and *wet*.† To these has been added *garden*. Land entered as *dry* may be converted to *wet*: *dry* or *wet* to *garden*, but *wet* can never revert to *dry*: while, in defiance of theories of rotation, land once capable of yielding tobacco, or other exhausting crop, is held *officially* to retain its powers for ever.

The land and the water (from tanks, &c.) are part of the public capital. Since any given amount of labour bestowed on good land will yield a greater profit than if given to soil less naturally productive, it is fair that the best lands should be highest assessed. If the State lends the land and the water, it has also a

* Under a permanent money settlement, the Collector comes down upon the ryot, whose crop has failed *this* year, and takes the *kist* in virtue of the profits of *last* year, long since expended; or of *next* year, to anticipate which the ryot must buy the Soucar's aid at a high discount. But, if the land tax varied in *just* proportion to the crops and the prices of the year, instead of being fixed by averages made up of questionable data and incorrect arithmetic, the agreeable and easy task of the Collector would be to look to the advantage of the ryot as the *primary* object, and to trust to the increase or facility of collections being the never failing result of his welfare.

One very easy test of the correctness of an assessment may be deduced from this consideration. In ordinary circumstances, if lands have been correctly classed, and the tax fairly rated, land of each superior class will *all* be cultivated, before that in the lower classes will be taken up.

† Dry or Poonjay.
 Wet or Nunjay.
 Garden or Bagayat.

fair claim to expect a proportionate return, greater when it grants land and water too, than when it grants the former only.

But, in consequence of the permanence of the classification above mentioned, it often occurs that the same tax is leviable when water is *not* given, as when it *is* given; for, land which was irrigated when it happened to be assessed, has been saddled with the water tax ever after, upon the erroneous assumption that the water of a tank which once sufficed to irrigate a thousand acres will always continue to do so.

The supplies of water from the large rivers which flow right across the Peninsula, and fill with both monsoons, especially with the more copious western rains, are tolerably regular. Tanjore, now that its works of irrigation are good, and provision is made to keep them so, is never likely to suffer from drought, and its superiority to the other districts in regard to its supplies of water makes scarcity elsewhere beneficial to it. It is, perhaps, the only district east of the Ghauts in which a settlement can possibly be permanent.

Rivers filled by the drainage of the eastern country alone are very uncertain in their freshes, and that nothing can be more precarious than the filling of *mānāmāree* tanks by the rains which fall in their immediate neighbourhood may be understood, when it is remembered that the annual fall of rain varies from 18 to 88 inches.* In some cases, the repairs of one tank have lessened the supply of another: generally, tank banks are mended in an inefficient and slovenly manner, but it may be said that almost universally, tanks do from natural causes wear out with old age, and the land to which they once supplied water, in process of time, is wholly or partly deprived of it. This land, rich in alluvial deposit, is the very best in the country, but our Collectors' records will show, that of the *Ayacut Nunjay*, † not three-fourths are on the average cultivated, and that the remaining fourth which would yield better dry crops than any ordinary dry fields, is left almost always and entirely waste, in consequence of the restrictions imposed on the culture of *Nunjay Mēl poonjay*. ‡

To say that if *Nunjay* land were under any circumstances to pay only *poonjay* tax, a door to abuses would be opened which could not be shut, is a very poor excuse for permitting the far greater actual abuses arising from the present system.

Most tanks receive with water, large quantities of sand, silt, and mud; and, as from the usual form of the wasteweirs (*calingulas*) the *clear*, surface water only escapes, when there is a surplus, and very little silt

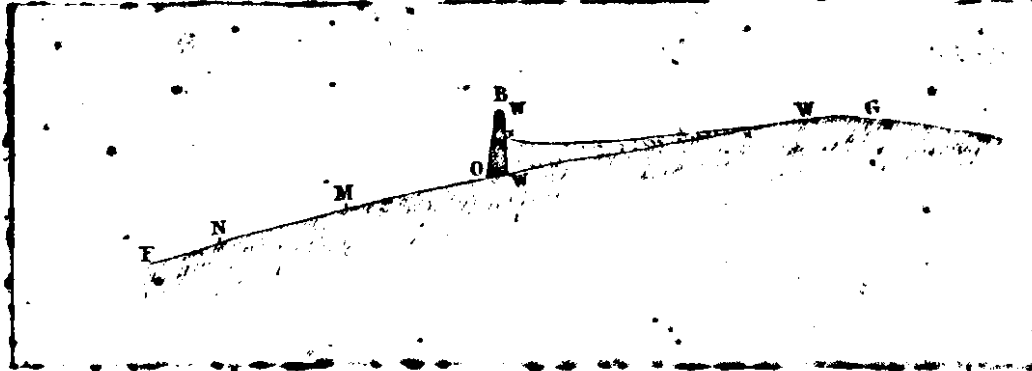
* 18.45 inches in 1832, } at Madras.
 88.66 inches in 1827, }

† Entire wet land.

‡ Dry crops on wet lands.

makes way through the sluices which feed the fields, the bed of a tank has a continual tendency to fill up. There are many tanks in, which the operation of this process is very manifest to any one standing on the

bank when the tank is empty. It is then perceived that the exterior or rear of the bank is very much higher above the fields, than the interior is above the bed, the section being somewhat as follows :



This section represents a tank bank *B* thrown across a valley, of which the fall is in the direction *G F*. When the tank is new, the water of this valley is withheld by the bank and fills the whole space (*W W W* in section) the quantity being then sufficient to irrigate the *nunjay* ground below the tank, say 1000 acres, (represented by *N O*;) but, in the course of time, by accumulation of silt, part of the hollow which ought to hold water only is filled up. To remedy this, the bank *B* is raised, but the accumulation still goes on; and it is clear that after a certain height has been obtained (that of the source *G* whence the water flows) no advantage can be obtained by raising the bank further. The silt at last gains the victory, and the tank which was once capable of holding water enough for 1000 acres (*O N*) now holds water enough for 500 (*O M*) and no more. Part (*M N*) of the ground entered as *nunjay* in the accounts, and which is too highly taxed to yield a profit if cultivated as *poonjay*, becomes waste.

This would be bad enough; but the actual result is still worse. The land *N M* belongs to ryots who have as good a claim to share the water of the tank as those who cultivate *O M*. They, therefore, insist on having part of the water, so long as there is any. If the season is unusually favourable, the water that is drawn off is replaced; but, in an unfavourable year, if the water which, properly economized would have been sufficient for a fair harvest from *part* of the ground, be distributed over the *whole*, no part receives enough for the perfection of the produce, and the whole crop perishes.

Then come the clamour for remission, the bribe giving of the richer ryot, the ruin of the poor one, the gain of the dishonest *Tasildar*.

In every important tank there should be standards by which observation of the quantity of water in it should be made at *some fixed date*, when rain can no longer be reasonably expected. In all large tanks, there are long stones, built upright in the bed at the head of the sluices, and it would be easy, at such *fixed dates*, to mark on these stones the height of the surface of the water, and *at the same time* to note the quantity of land under cultivation, and the number of months for which it *requires* water.

In the following table, given as an example, the first three columns show what quantity of water was supposed necessary to complete the irrigation of the crops on the ground. The next nine show how the water was actually distributed, and the actual supply of water in a tank afterwards ascertained from the record of that distribution.

State of the cultivation under—Tank taken on the 21st of January, 184—, water at 5 feet 6 inches on the—sluice.

1	2	3	4	5	6	7	8	9	10	11	12
Acres.	Number of days water required for the crop.	Product of the two preceding columns.	Acres which yielded full crop.	Number of days that water was supplied.	Product of the two preceding columns.	Acres which yielded half.	Number of days that water was supplied.	Product of the two preceding columns.	Acres which yielded no crop.	Number of days that water was supplied.	Product of the two preceding columns.
120	15	1800	100	15	1500	80	10	800	0	0	0
60	30	1800	30	30	900	30	20	600	0	0	0
45	40	1800	33	40	1400	10	30	300	0	0	0
80	60	4800	0	0	0	80	80	1000	80	25	2100
300		10900	163		3900	80		2100	80		2100
			40		+ 2100						
			203		+ 2100						
					8000						
											Total supply of water.

The evaporation in the hot season is about half an inch a day, or from an acre (4,840 square yards) about 67. cubic yards of water. The quantity of water required for the whole 300 Acres would thus have been 67 × 10,200 or 6,83,400 cubic yards, but the tank yielded only 67 × 8,000 or 536,000 cubic yards. Omitting to take into consideration the less total evaporation had the water been used on the crops soonest gathered, it appears that [had the statement existed beforehand] the distribution of the water might have been as follows :

Acres.	Days.	
120	15	1800
60	30	1800
40	45	1800
43	60	2600
37—No water.		
300		8000

Knowing that the water in—tank at the end of the rains would suffice for only 263 Acres out of 300, the remaining 37 should have received no further supply, the full crop of 263 Acres might have been gathered in lieu of what is equivalent

to that from only 205 Acres, while the labour would have been bestowed to the fullest advantage on 263 Acres instead of being in great measure thrown away upon 140 out of 300.

In the year 1835 in a Memorandum which was afterwards reported on by the Board of Revenue, I endeavoured to draw attention to the subject of the preceding observations; but as I did not enter into this or similar detail in explanation of my proposition, I doubt if it was understood. Some objection was made, on the score of the Natives being well acquainted with the necessity, and well versed in the practice of obtaining from the water in their tanks and channels the greatest possible benefit, and some, on account of the alleged difficulty of adopting standards or *Nilometers*. The proposition fell to the ground.

As for the second objection, the detail above entered into is sufficient to show that there is no insuperable nor great difficulty in making such standards; for, if it were known that water up to 5 feet 6 on the stone of—sluice in—tank signified a supply represented by 8000, as is shown by the resulting cultivation, in any other season when it was at the same height on the same date, a remission of revenue on 37 cawnies might at once be given, and the remainder of the crop secured: and, with similar record made through a series of years, the standards might by gradual additions and corrections be made nearly perfect.

Surely, it is not to be supposed that the recollections and opinions of Native agriculturists, let their wits have been ever so much sharpened by their necessities, are to be compared with such records as these.

We are too much in the habit of supposing the Natives of India to be beyond improvement in the art of farming, merely, because they know more than ourselves of growing *rice* and other crops of warm climates; and we have allowed this opinion too great influence in judging prematurely of the *cotton* experiments. Though an Italian or Carolina rice-planter might *not at once* succeed in farming the swamps of Bengal or the fields of Tanjore, either, no doubt, could give useful hints to the brightest Vellalun that ever followed a yoke of buffaloes; and it were absurd to suppose for an instant, that more advantage could not be taken of the seasons, by men who should form their judgment from data such as real science affords, than by those who are guided by the occultations, conjunctions, and quadratures of Jupiter, Venus, and the Dragon that swallows the moon.

Yet, though I believe that standards measuring the water, by simple inspection showing to how much land it can be prudently given, and from how much it is wise to withhold it, serving to regulate remissions by better rules than the ryots' supposed ability to pay (the revenue to the Government or the bribe to the *Tasildar*, as

the case may be) can at once be adopted, and with very considerable immediate advantage, no measure would, in my opinion, so fully, so fairly and so beneficially remove what I have represented to be objectionable in our land revenue system as the entire separation of the *land* tax and the *water* tax.

Instead of classing land as *dry* and *wet*, the *land* should be assessed as good land or bad land, and the *water* should be *sold* to those who cultivate the adjacent fields and might wish to irrigate them, whether for paddy, sugarcane, or any other crop.

This is the system which prevails in Lombardy, where, instead of interfering with the agriculturist, taxing him so much for growing rice, and so much for tobacco, &c., and driving him from all attempt at improvement, by the apparition of a Harpy which his fancy, guided by his experience, represents to him in the act of watching for the first fruits of his superior intelligence and industry, the Milanese farmer is left free to cultivate whatever he may expect the greatest profit from.

It would occupy too many pages, and might now be useless, were I to suggest how such a change of system could be introduced here. Suffice it to say, I am convinced it can be *easily* introduced, and that I shall be glad to learn what difficulties have to be overcome ere the change is brought about. For the present, I will content myself with a short description of the

MODULO of SOLDATI,

the sluice of irrigation used throughout the Milanese for measuring the water sold to the farmers there, an account of which cannot fail to be interesting to my brother Officers employed in the Civil Engineer Department.

Great part of the province of Lombardy is cultivated with rice, and the produce, as in warmer climates, depends upon a sufficient supply of water. Besides the rice fields, there are meadows called *Marciti* which require much water during the winter months. The frost is prevented from being injurious to these by a gentle current of water flowing constantly over the grass; and, the herbage continuing to grow abundantly during the whole year, serves as food to numerous cows, from whose milk is made an enormous quantity of Parmesan* cheese.

The canal of Pavia, called Naviglio Grande, and the Martesana, led from the Ticino and Adda, serve to connect the towns on the banks of those rivers and of the lakes Maggiore and of Como, with the city of Milan. These canals yield a considerable revenue to the state, derived from not only the tolls of the merchandize which is borne on them, but from the *sale* of the *water* used for *irrigation*. The Oglio, the Muzza, and other great artificial drains are chiefly valuable on account of the fertilizing effects of their waters.

* Parma being a principal market for it, it is named from that city, but the reputation of this famous production rather belongs to the province of Lodi.

However surprising such ignorance may now seem, it is the generally received opinion that, until a period considerably later than the construction of the first of the Milanese channels, Engineers did not know how much the pressure or *head of water* above an orifice augmented the velocity with which the fluid issued from it, and it was not till a comparatively recent period that the method of estimating this was discovered. Yet it could not have been long ere practice must have shown the Lombards, that the quantity of water that their fields received did not depend only on the dimensions of the orifice through which they received it.

Their measurements continued to be inaccurate for many years, and much contention was occasioned by the erroneous decisions of the tribunals, in cases of water privilege. It was about A. D. 1575, that a Milanese Engineer, Giacomo Soldati, invented the sluice called the *Modulo* or *Modello Magistrale*, so simple yet so admirably suited to its object, that it has been almost ever since, and is now used throughout Lombardy; while in other forms, on the same principle and differing only in details, it has been introduced in other Italian states, and authorized by law to be used in the measurement of water.

The principle of the sluice of Soldati is this. The water passes from the canal or reservoir under a shutter into a chamber, from which it issues through a measured orifice. Were it allowed to pass *directly out* of the canal, it is evident that, as the depth varied in droughts or with the melting of the Alpine snows, the velocity and quantity flowing through an opening of a fixed size would vary too; but by the intervention of the shutter which is lowered as the water in the canal rises, and of the chamber, in which the water is thus kept always at one level above the holes from which it issues, the velocity is easily regulated, and is in fact, kept perfectly constant.

The shutter is made to slide up and down in two upright grooved stones *A A*, which are placed in the line of the bank of the channel with an opening between them, the width of which is regulated by the number of ounces* for which the sluice is made. The walls of the chamber join to these vertical stones, while a sole of stone is placed below them, on or a little above the level of the bed of the canal. The chamber consists of two walls, *O P*, parallel to each other, 20 feet long and 20 inches wider apart than the grooved stones, *A A*. At 2 feet height above the floor of the chamber, a stone, *N*, is placed across from wall to wall, and the chamber being covered by an arch which springs from the walls *O P*, a gable end is built upon the stone *N*, which, with the arch and another similar gable, built upon another stone, *F*, at the other end, completely cover and close it. An interval, *B*, of 4 inches is left between the shutter stone and the cross

* The quantity of water that will flow through an oblong orifice 6 inches wide and 8 inches high under a pressure of 4 inches is called an ounce or ounce, and this quantity is the unit of measure of water in Lombardy. According to Professor Tadini, it equals 2.1168 cubic metres per minute, or in 24 hours 107,653 cubic feet English.

stone *N*, which allows the depth of water at the entrance of the chamber to be ascertained by sounding. Four inches above the bottoms of the stones *N* and *F*, a horizontal ceiling or soffit, of planks or of masonry, is fixed: and immediately below *F*, is the *modello* or orifice *G*, through which the water issues. This is always 8 inches high, and its width at the rate of 6 inches for each ounce of water. Its floor is formed by a wall, *G H*, 16 inches high, which is usually of stone. The sides of the orifice are also of stone, and it is generally surrounded with iron to prevent the dimensions from being fraudulently altered. The floor of the chamber is of brick-work, and either horizontal as *T H*, or sloping upwards as *T G*.

Beyond the chamber, is an open channel which has a masonry floor and side walls. The former at *I*, is two inches lower than the sill of the modello *G I*, and it slopes two inches more as far as *L*. The side walls, *R S*, are vertical, 18 feet long, and at *R*, four inches on each side from the outer edge of the modello, and they diverge each six inches more, so as to be three feet eight inches apart at *S*.

The water being admitted, by raising the shutter until the depth above the floor *T* is exactly 28 inches, which is ascertained by sounding in the interval *B*, while the height of the top of the modello is $16 + 8 = 24$ inches above the same floor, the pressure or head is always equal to the difference = 4 inches; and all disturbance of the water is most effectually prevented by the contrivance of the ceiling in the covered chamber.

When the water has passed the point *L*, it is at the disposal of the buyer or renter of it, and care is taken to let it fall freely into a hollow, or down a slope from *L*, lest regurgitation *there* should be communicated to the water inside the modello and diminish the supply.

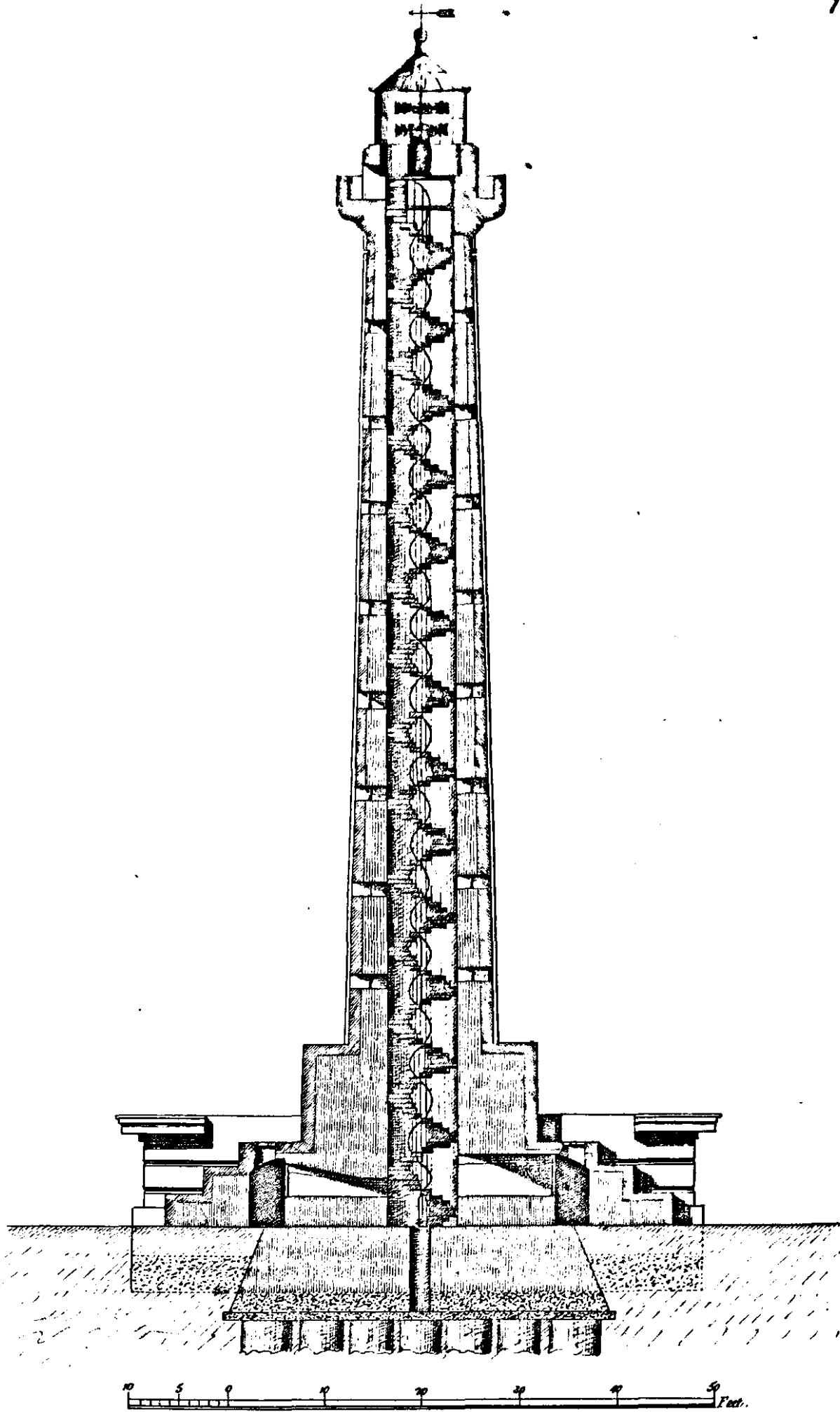
Most of the sluices are put up to auction and sold for the season or for the year. In some cases they are let on leases for season or year. In others sold in perpetuity. The buyer or renter of a sluice then disposes of the water to the owners of the land adjacent at so much for one or more hours per day, per week,* &c.

The water being purchased, its value is well known, and of course, it is not wasted by its purchasers. The Government derives the advantage that is its due, from the works made at its expense for public benefit, while the farmer pays exactly in proportion to the advantage he derives, and buys the water or not at his own option.

* The following is a Memorandum of the average prices of water let and sold from the canals in Lodi, Pavia, and Milan, from 1809 to 1814.

	Lire.	£.	s.
No. 1. Sold absolutely for the whole year, -	33628.	656.	3.
2. Do. for the summer (1st April to 7th Sept.)	31289.	610.	9.
3. Do. for the winter (1st Oct. to 15th March.)	2342.	45.	14.
4. Rented (livello perpetuo) at per annum, -	1710.	33.	7.
5. Do. for the summer season, -	1611.	31.	8.
6. Do. for the winter season, -	125.	2.	9.
7. Do. (fitto or temporary lease) at per annum, -	2164.	42.	2.
8. Do. for the summer, -	2032.	39.	6.
9. Do. for the winter, -	131.	2.	11.

N. B.—The prices are per oncia Milanese. The Milanese lira is equal to English £ sterling '017.



NOTES REGARDING THE CONSTRUCTION OF THE NEW MADRAS LIGHT HOUSE, BY
CAPTAIN J. T. SMITH, F. R. S. F. R. S. N. A.

1. I cannot close this volume without a few brief remarks upon the construction of the new Madras Light House, of which drawings have been prepared for insertion. It will be out of my power to give more than the chief particulars, but I trust that they will be sufficient, with the assistance of the drawings, to give a general idea of the nature of the work, and the principal points of interest connected with it.

2. The excavation of the foundations was commenced on the 17th July, 1838, and carried down to a depth of 10 feet below the surface. Beneath this, wells 8 feet deep were sunk, the insides of which were filled in the usual way with brick jelly and sand, and laterite jelly and sand in every other well alternately. The intervals between the different wells were filled up with the same materials, and the whole level surface thus formed, well soaked with water and hardened by beating with heavy rammers. After every part of the area had become sufficiently compact, a platform of laterite of 40 feet square was laid, upon which the brick work of the foundation rested. This was a solid block of masonry 38 feet square at the bottom, tapering to the dimension of a side of 30 feet at the level of the ground, and about $8\frac{1}{2}$ feet high. A well of 3 feet diameter was left in the middle for the purpose of increasing the fall to be given to the weight by which the machinery is kept in motion, with this exception, the whole was one solid mass, and great attention was paid in laying the bricks, that they should be firmly bedded upon one another.

3. The *first stone* of the building was laid in the presence of Lord Elphinstone and a number of other Gentlemen, on the 17th September, and the foundation was completed as far as the level of the ground, by the 15th of October following. It became then necessary to close the work for the season on account of the monsoon, and before the operations were resumed, it had been determined to apply to the Honorable Court of Directors for permission to add to the expense of the work, by facing it with granite, instead of common plastering, pending which reference, the work was slowly proceeded within the early part of 1839, in the hopes that the decision of the Court would arrive before it would be necessary to take measures in the construction of the building, which were contingent upon the nature of the reply. A block of masonry of 28 feet square stands above the brick foundation, and above this stands the block which is seen as the pedestal of the column. The last is visible from outside, and therefore, as it was necessary that, if a granite facing should be sanctioned, it should be built together with the masonry; we were soon at a stand for want of instructions, and thus although the work had only been resumed in May, 1839,

we were not able to continue long at it, for the utmost height to which it could be carried, without the use of the granite facing, was reached on the 20th July, and the operations were then temporarily put a stop to.

4. In May, 1840, the instructions of the Honorable Court, sanctioning the use of granite, having been received, the work was again proceeded with, and from that time it advanced uninterruptedly till its conclusion, but the use of stone greatly added to the difficulties and delay of the work, owing to the limited number of stone-cutters procurable for employment at the building, and the constant disappointments in the supply of the materials, owing to the quarries being at a distance; and the contractors a poor and miserable race, incapable of entering upon any business with energy and spirit, and very troublesome to deal with, owing to their poverty rendering the advance of cash an indispensable preliminary to their undertaking any work, and their dishonesty making it exceedingly difficult to avoid loss by such an arrangement.

5. It will be observed by the figures, that the four flanking buttresses are buildings quite independent of the shaft, and its pedestal and foundations, and although the foundations of these were laid at this time, it was thought most advisable in order to expedite the completion of the column, and thus the exhibition of the light, that the whole of the workmen procurable should be employed upon the column only, and on this account nothing was done either to the four buttresses, or the steps which connect them, till after the whole of the business of the shaft had been completed, and it had been crowned by its capital, surmounted by the lantern and its machinery.

6. The four buttresses just referred to form four convenient rooms for depositing the oil, stores, tackling, and apparatus belonging to the work, &c., and as it would have quite ruined the appearance of the edifice, in an architectural point of view, to have had any windows in them, visible from outside, the object of lighting and ventilating them was attained by sinking their roofs below the level of the cornice, and constructing a sky light in the middle of each, which although sufficiently high to give abundance of light to the apartment, is still low enough to be quite undiscoverable from the outside. The communication between the different rooms is made by passages which connect every two of them, and thus encircle the whole of the block of masonry. They are formed under the highest step or that which adjoins the block, and are sufficiently spacious to be very convenient. Light is admitted to them by bull's eye lenses inserted in the granite stones which form the roof, and besides this, at those points opposite to the middle of each face where there are passages

leading into the interior of the block; larger openings, of about 18 inches square, are made for the purpose of admitting a larger supply of light to aid in removing the darkness of the staircase at that part.

7. The entrance to the building from outside was made, by leaving open a small part of the lowest and middle step next adjoining one of the buttresses, in the least observable point, where a door is made which admits a person into one of the corner rooms; from thence he is led into the passage above described, from the middle of which an arched communication leads direct to the centre of the block, whence he may ascend by a flight of 200 stone steps to the summit of the column. The lower part of this staircase is lighted by the rays admitted partly by the opening from above, for the geometrical stair does not wind round a solid newel, but leaves a well in its centre, as a passage for the machine weight; partly by windows pierced through the block into the outer passage, when light is admitted to them through the openings above-described, and partly by light admitted by openings cut from the centre of the building horizontally outwards towards the face of the die or pedestal, and then continued upwards vertically, so as to open into the air on the upper surface of the die, the right angle formed between the vertical and horizontal portions of the cut being replaced by an inclined plane at an angle of 45 degrees, by the means of which some light is reflected into the interior.

8. By these contrivances the difficulty of supplying light for the interior of the lower 20 feet of the column, which is totally shut out from any direct communication with the external air, is overcome, and the staircase is sufficiently well lighted to occasion no inconvenience. Above that point there are narrow windows in each of the four faces of the column, which give admission to more than a sufficient supply of both light and air.

9. It required our utmost efforts in the first season to complete the pedestal upon which the column stands, owing to the great delay in procuring, finishing, and fitting the granite stones facing it; the first of which did not make their appearance, even in their rough state, till near the end of June. Great difficulties were also experienced with the contractors for the supply of other articles, with whom a constant warfare was obliged to be maintained, in order to ensure any thing like a tolerable fulfilment of their engagements. In regard to the bricks I found it at last the best plan, while constructing the large solid masses of masonry, of which the foundations, pedestal, &c. were composed, to contract with the supplier to furnish the *very best* materials, and to leave it to me to take such as suited me, and leave what I pleased, paying, not in proportion to the number said to be delivered, but by the cubic foot of masonry actually finished, and in this way a large part of the work was built of very excellent material at the rate of 10 cubic feet for 17 annas, for bricks only. The season closed with the completion of the pedestal, preparations being made and continued during the monsoon for the commencement of the column after the rains.

10. The shaft of the column consists of 48 courses of cut stone, each of which contains 16 pieces, each 3 feet by 2 feet by 1 foot. The shaping, cutting the flutes, dressing and accurately fitting these, was a work of great labour and delay, but by keeping up a constant succession of labour, by a large number of workmen, some increase of expedition was brought about. The average time of fitting each course was upon the whole nearly a fortnight, but under the most favourable circumstances, three and almost four courses were completed in a single month. In the first few or lowest courses, iron cramps were introduced for the purpose of securing all the different stones of the course more firmly together, but these were soon afterwards abandoned on account of its being observed, that in spite of all the pains which could be taken, the Natives inserted and fixed them so inefficiently, that they could in fact be of but little real benefit, and it was hoped that the system of bonding would be sufficiently secure without them.

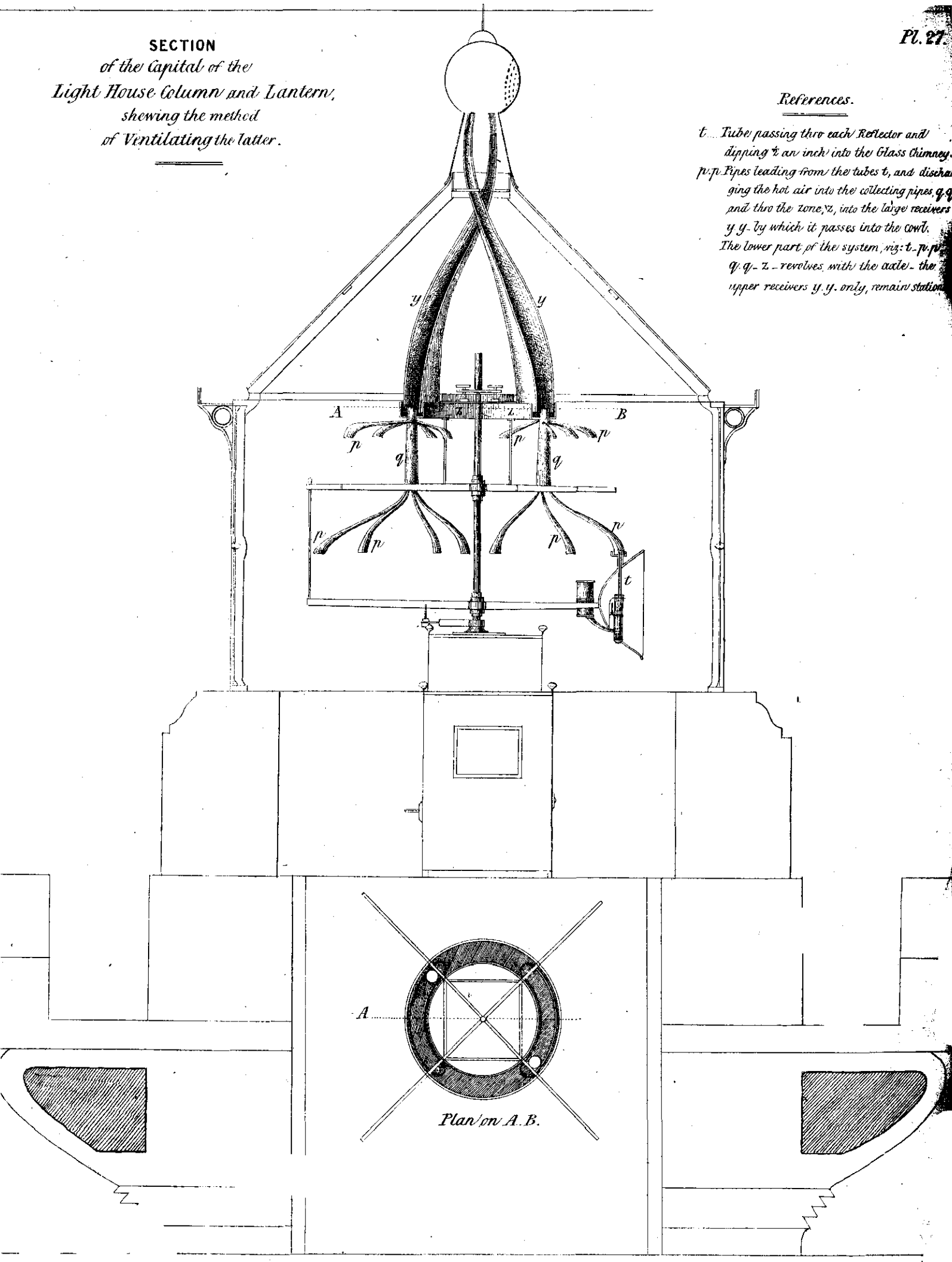
11. The bond introduced was that of making every fourth stone in each course of half the height of the rest, but of such a thickness as to reach inwards towards the centre of the building three or four feet, the deficiency in height was made up by a false half block placed above or below it, so that the two combined, presented the same appearance (excepting the horizontal joint) as the rest of the single stones of the course. In every succeeding course, the precaution was taken of choosing for the bond stone a block which did not lie vertically above any other bond stone in either of the three preceding courses; to effect this, the bond stone in each successive course in height was next in advance laterally or rather circularly, of that beneath it, and taking all the bond stones throughout the building, they would be found disposed in the form of spirals regularly winding round the shaft of the column. By this arrangement it will be seen that the weight of every third course is supported by a complete set of thorough stones, as certainly, though not so evidently, as if the three courses had been constructed without a bond, and their support derived from a complete course of bond stones inserted beneath them.

12. Towards the neck of the capital, the brick-work is reduced to nothing, and the few last courses are entirely of stone. Here iron cramps were again resorted to, and the stones which form the capital are secured together by a solid iron ring, let into a channel cut in the middle of the upper surface of each course, after it had been laid and fitted together. The capital was composed of four courses; the fillets and the ovolo of two courses, and the abacus of two more. It was arranged that the whole of the stones forming the capital should be of such a length in the direction of the centre that on their being placed in position previous to fitting the inner end of them much preponderated, there is therefore no tendency in any of them to fall over or downwards, even were they not fitted to one another, or cramped as they afterwards were, and secured by the insertion of the circular iron ring.

SECTION
*of the Capital of the
 Light House Column and Lantern,
 shewing the method
 of Ventilating the latter.*

References.

t... Tube passing thro each Reflector and dipping 2 or 3 inch into the Glass Chimney.
p. p. Pipes leading from the tubes *t*, and discharging the hot air into the collecting pipes, *q. q.* and thro the zone, *z*, into the large receivers *y. y.* by which it passes into the cowl.
 The lower part of the system, viz: *t. p. p. q. q. z* - revolves with the axle - the upper receivers *y. y.* only, remain station



13. Above the capital stands a blocking course of larger sized stones, each of which weighed upwards of $1\frac{1}{2}$ tons, these were fitted and cramped together in the form represented by the drawings. The lower curb of the lantern serves the purpose of the bond for the upper course of these stones, as it was let into a groove cut into it for the purpose. The stanchions of the lantern had been originally intended to be fitted to a wooden frame, and were provided with long bolts fitted into the foot of each, and tapped to receive a nut, which was intended to be screwed home underneath the wooden frame so as to bring the foot of the stanchion into firm contact with its upper surface. The same arrangement was made to answer very well with the granite blocks also by boring a hole in the proper position for receiving the bolt, and cutting out a horizontal cavity in the side of the stone corresponding with it, and carried inwards until the lower part of the bolt was cleared, and there was room all round it to receive the nut to be screwed upon it, as well as a circular washer interposed between the nut and the granite. This plan was adopted in preference to running the stanchions into their places with lead, on account of the great facility which it afforded in adjusting the different parts and the lantern together on first putting it up, and also the ease with which it might at any future period be dismantled, in part or altogether, for repairs or any other purpose.

14. The rest of the lantern was put together with great facility, ample precautions having been taken by the makers in England, to obviate any mistake; previous to fixing the last two or three stanchions, the larger parts of the machinery were hoisted from below into the lantern and fitted into their places, though the final adjustment of the apparatus was of course postponed till after the lantern had been closed in and glazed. The hoisting of the machinery as well as of all the stones used throughout the work was done by the means of a crane of a peculiar kind, of which a description has already been given at page 106, and was effected without the smallest accident to any part. The whole was completed and ready for illumination in the month of December, 1843, and the light was first exhibited on the 1st January, 1844, since which time it has been in uninterrupted use.

15. The box containing the machinery of the light rests upon two cast iron beams placed across the building, bars of wrought iron connect them firmly together, and form a support for the wooden flooring of the lantern room. This floor is provided with ventilators, which can be opened or closed at pleasure.

16. It was found necessary to contrive means for carrying off the heated air from the interior of the lantern, and some difficulty was experienced in doing this in consequence of the apparatus having to be applied to a machine already constructed, and to its being a revolving one. In England this would be easily effected by making the central spindle of the revolving apparatus hollow, and leading all the conducting tubes of hot air into it, but as such a spindle could not be construct-

ed in Madras, it was necessary to devise some other means, and that was done as follows. Taking the hint from the ingenious method invented by Mr. Faraday for the British Light Houses, the hot air of each lamp was carried off by a small tube dipping into the inside of the glass chimney and passing through the reflector, and a number of these being led to one point, the currents of hot air carried by them were united in a tube of larger capacity, the upper edge of which projected about three or four inches above the highest part of the revolving apparatus, which carried the lamps and reflectors, and to which the whole was secured. Here it dipped, or rather rose into, a circular trough which formed the lower mouth of a funnel shaped receiver, the bottom of which corresponded with the circular track of the hot air pipe above-mentioned, and the upper part tapering away to the dimensions of a similar but larger pipe reached up into the ball of the lantern. As the motion of the reciprocating machine only extends through a quarter of a circle, the mouth of the funnel was shaped as a quadrant, and there were two of these on opposite sides of the lantern, because it was found most convenient to collect the hot air from the various lamps in two streams on opposite sides. The two hot air pipes were connected together by a flat circular copper-plate, shaped like a zone, with a lip round its outer and inner edges, and through which on opposite diameters the hot air pipes passed, while the zone itself being in every position of the movement in close contact and correspondence with the mouth of the two funnels, kept them close, and prevented the entrance of any other air than that conveyed by the hot air pipes, and also precluded the exit of any hot air into the body of the lantern. This apparatus gave every satisfaction on trial.

17. A memorandum will be found in the appendix on the subject of the conductor which was fitted to the building to secure it against the effects of atmospheric electricity, detailing the principal points necessary to be attended to in applying such an apparatus, and a description of the particulars of that which was made use of on this occasion. It was kindly drawn up at my request by Captain Ludlow, whose familiar acquaintance with these subjects led him to take a peculiar interest in this part of the work, and to study the principles connected with the best methods of precaution, and by whose design the arrangement was carried into effect. There will also be found attached a number of useful suggestions and memorandums of dimensions and prices respecting the stone work, which Captain Ludlow has recorded, and which are likely to be highly valuable in any future undertaking of this kind. I have already mentioned that I was indebted to Captain Ludlow for his valuable assistance during the construction of most part of the edifice, the chief superintendence having devolved upon him almost immediately after the commencement of the shaft of the column, and the building having been completed by him; and it is to his close attention and unwearied pains that we must attribute the great accuracy and solidity with which the work was put together.

**SOME REMARKS RELATING TO THE MATERIALS AND CONSTRUCTION OF THE NEW
LIGHT HOUSE, BY CAPTAIN LUDLOW.**

The granite used in the building was procured near the four villages of Tahmurrum, Palaveram, Trichellum, and Treeneermullay, all situated in the neighbourhood of the Palaveram cantonment. The stone found at Tahmurrum is of a lighter colour and more easy to work than that procured elsewhere, and on account of the latter quality is more in demand. There is also a species of stone of a much darker colour and harder grain found at Assanapooram, in the same neighbourhood, but its extreme hardness renders it quite unfit for building purposes, and it is only used for making stone hammers, mortars for rice beating, &c.

There are not more than 40 or 50 men in these villages, who gain their living by quarrying stone, it is in consequence very difficult to procure a large quantity of it for any work unless a long previous notice is given. They are always in the habit of demanding advances upon receiving an order, and being a very drunken, dissipated, and dishonest set of fellows, will, unless proper precautions are taken, make away with the money without fulfilling their engagements.

The following is their method of quarrying. Having selected a part of the rock where there appears to be a sufficient depth of good stone for their purpose, the upper crust which generally consists of stone of an inferior quality is removed by blasting to the requisite depth, about 1 or 2 feet, and the solid mass below thus laid bare. Holes of about 4 inches square and from 3 to 4 inches deep (according to the thickness of the stone required) are then cut at distances of from 4 to 6 inches in the line of the intended fracture. Iron wedges are inserted, and being repeatedly struck with a large hammer formed of the hard stone I before mentioned, slung in a pliable wooden frame, a large mass is thus detached. This mass, (except in cases where very large stones are required) is again broken up into smaller ones by inserting wedges along the intended lines of fracture as before, with this difference that the wedges are much smaller and placed much closer together. The stone then receives two dressings with heavy chisels, by which the greater inequalities are reduced and is then ready for transport to the work.

As the fracture is frequently very irregular, in order to avoid all risk of the stone being *short* of the requisite dimensions, they are constantly in the habit of making it much too large, whereby the labour of reducing it to the proper form is materially increased. By driving the smaller wedges rather deeper and with more care, a more regular fracture would be produced and indeed it would be well worth while to run the risk of spoiling many stones rather than make those which are sent

to the work so much in excess of the requisite size. But as affairs are managed now, this is no business of the stone quarry-men who only engage to supply stones not smaller than the required size. It would be advisable hereafter to have the stones finished (with the exception perhaps of the final dressing) on the spot, by contract, and if possible by the same parties who furnish the rough stones.

As the price paid for the rough stone supplied for the Light House included the cost of carriage to the beach, I am not able to state how much this latter item amounted to. The mean distance from these quarries to the beach is $14\frac{1}{2}$ miles, the smaller stones were brought on bandies drawn by 1 pair and in some cases 2 pairs of bullocks, but the largest stones were placed on heavy carts, and dragged in by coolies.

The 12 large stones at the top of the column to which the stanchions of the lantern are fixed, were conveyed in the latter manner. They measured almost exactly one cubic yard, each weighing about 2 tons. For each of these 25 coolies were employed. The contractors paying them 4 annas per man for the job, that is, loading, conveying, and taking back the empty carts, thus making the cost of carriage in this instance, 6 Rupees 4 Annas per cubic yard, or about 22 per cent of the price paid for the stones. The average cost of carriage however was doubtless much below this.

The price of the rough stone (in which were included the two dressings it receives at the quarry, and the cost of transit to the beach), was considerably diminished during the course of the work. At first it amounted upon an average to as much as 1 Rupee 11 Annas 6 Pice per cubic foot. The following is a statement of the average price of the different kinds of stone from 1842 to 1844, after the reduction was made.

Slabs 9 inches thick,			
	Ft.	Ft.	
Varying from	$5\frac{1}{2}$	to 6	in length.
" "	$3\frac{1}{2}$	to $2\frac{1}{2}$	in breadth.
" "	15	to 12	square feet Supl. measurement.
Containing from	12	to $9\frac{1}{2}$	cubic feet.
			R. A. P.
Price per square foot,	-	-	0 12 6
" " cubic foot,	-	-	1 0 6
<hr/>			
Slabs 6 inches thick,			
	Ft.	Ft.	
Varying from	5	to 4	in length.
" "	$2\frac{1}{2}$	to $1\frac{1}{2}$	in breadth.
" "	14	to 6	square feet.
Containing from	7	to $3\frac{1}{2}$	cubic feet.

	R. A. P.
Price per square foot, - - -	0 8 4
" " cubic foot, - - -	1 0 8

Blocks No. 1.

	Ft.	In.
Average Length, - - -	4	10
" Breadth, - - -	2	9
" Thickness, - - -	1	8
" Cubic contents, - - -	18 cubic feet.	

Varying from	6	to	3	in length.
" "	3½	to	2½	in breadth.
" "	2½	to	1½	in thickness.
" "	35	to	15	cubic feet.

Average price 15 Annas and 2 Pice per cubic foot.

Blocks No. 2.

	Ft.	In.
Average Length, - - -	4	3
" Breadth, - - -	2	4
" Thickness, - - -	1	3
" Cubic contents, - - -	8.87 cubic feet.	

Varying from	6	to	2½	in length.
" "	3	to	1½	in breadth.
" "	2½	to	1	in thickness.
" "	8	to	14	cubic feet.

Average price 12 Annas and 10 Pice per cubic foot.

Blocks No. 3.

	Ft.	In.
Average Length, - - -	2	11
" Breadth, - - -	1	10
" Thickness, - - -	1	1
" Cubic contents, - - -	5.67	

Varying from	3½	to	2	in length.
" "	2	to	1½	in breadth.
" "	1½	to	1	in thickness.
" "	3	to	7	cubic feet.

Average price 8 Annas and 3 Pice per cubic foot.

It would appear from the above statement that slabs from 6 to 9 inches in thickness are the most expensive kind of stone (reckoning by cubical contents) which can be used. This arises from the difficulty of splitting off pieces of so little thickness, without breaking the stones. This difficulty is greatly increased as the length and breadth of the stone become greater. In a granite building therefore the use of such thin stones, even on account of the expense should be avoided as much as possible, but moreover as they are very apt to be broken in moving there is still stronger reason for not employing them.

The price per cubic foot of blocks of granite, increases of course with their size, but not in so rapid a ratio as might be supposed. The difference between No. 1 and No. 2 for instance being only 2 Annas 4 Pice per cubic foot, although that between No. 2 and No. 3 is 4 Annas 7 Pice.

The objections to the use of large stones are their higher price and the difficulty of handling them. The former it appears is not a very formidable item; with regard to the latter it would be impossible to say what it exactly amounts to; experience however has shown that

even with the defective apparatus procurable in this country, the difficulty of managing moderately large stones is not very great. The principal objections to the use of small stones are the greater number of joints required, the additional surface requiring to be dressed and the loss of material in dressing.

If the surface of a stone of the form of a parallelepiped, be reduced by dressing a quantity in depth represented by $\frac{1}{x}$ of a foot, the quantity cut off in cubical feet will be represented by the formula.

$$\frac{ab+ad+db}{x} - \frac{a+b+d}{x^2} + \frac{1}{x^3}$$

ab and d being the length, breadth, and depth of the original stone in feet.

Now if we take a single stone measuring 6 feet \times 2½ \times 2 and dress it to a depth of 2 inches. (The quantity cut off the rough stone supplied for the Light House exceeded this, and I believe it was nearer 3 than 2 inches,) all ways; the loss in dressing calculated by the above rule will be 9½ cubic feet out of 30, and 20½ cubic feet of finished stone will be left.

If on the other hand we take 3 stones measuring originally 2 \times 2½ \times 2, or in all 30 cubic feet, the loss on dressing the 3 will be 12 cubic feet, and we shall only have 18 cubic feet, of finished stone left.

The price in the rough of the large block was 15 Annas 2 Pice per cubic foot, or 2 Annas 4 Pice per foot more than the small blocks.

The price per foot of the large block when finished is 1 Rupee 6 Annas 1 Pie, that of the small block 1 Rupee 5 Annas and 5 Pice. In this case therefore by using one large instead of 3 small blocks, while the price of the material is only increased 8 Pice per cubic foot, we save 2 joints and 20 square feet of surface dressing, matters of no small importance, besides adding both to the strength and appearance of the building.

When the size of the stones increases beyond a certain point, a limit is doubtless imposed upon us by the difficulty of handling such large masses, but I think that no stones of less than 10 or 12 cubic feet should be used in a granite building when it can be avoided.

An instance of great waste both of material and workmanship, owing to want of attention to these considerations, may be seen in the piers of the groined arches of the gateways under the ramparts of the Fort, where the stones are of a very small size, and where not only must the expense of the work have been much increased but its strength is also materially diminished.

The pillars of the railing which encloses the road round the Light House were mostly procured at a quarry near the Seven Pagodas. They were supplied in a finished state at 14 Rupees each—they are 6½ feet long of which the lower 1½ feet are undressed. They contained in the rough state about 10 cubic feet, and their dressed surface is about 24 square feet. The price paid for them included carriage for a distance of about 35 miles. The price paid for the carriage of each was nearly as I could ascertain was 4 Rupees.

Some pillars were lately supplied from the same quarries for some Native building in Triplicane. They were 18 feet in length of an octagonal shape and two feet in diameter. They had received an extra dressing before leaving the quarry, and were therefore more than half finished. They contained 54 cubic feet, and cost 59 Rupees 8 Annas each including carriage. They were conveyed a distance of 33 miles, and the carriage of each cost 31 Rupees 8 Annas. Each stone required two bandies and eight pairs of bullocks.

Stone may be procured at the Seven Pagodas of a much larger size than at Palaveram, it is of a lighter colour and much more easily dressed. I am credibly informed that pillars of 50 feet in length and proportionate thickness have been procured at these quarries, whereas at Palaveram they cannot procure stones of half the length, if that, and at a much greater expense. If communication by water were established between the

Seven Pagodas and Madras, (a project of no very difficult execution seeing that a backwater already exists for a considerable part of the way,) I have no doubt but that stone of a quality and size better adapted for building might be procured and at a more reasonable rate than that brought from Palaveram.

I may here mention a circumstance which is but little known, viz. that quarries of sand stone admirably adapted, both in point of beauty of appearance and economy of workmanship for building purposes, exist within a distance of about 20 miles from Madras, at a place called Coopoor. As the line of the proposed Madras and Arcot railroad runs within a few miles of these quarries, it may perhaps be found advisable to introduce this stone in building which has never yet been done, the cost of the carriage at present being the chief objection.

MEMORANDUM ON THE LIGHTNING CONDUCTOR ATTACHED TO THE MADRAS LIGHT HOUSE, BY CAPTAIN LUDLOW, MADRAS ENGINEERS.

The necessity of providing a lofty isolated building, such as the Light House, with a conductor, in a climate like that of Madras, so frequently visited by Thunder Storms, of a serious nature, will be apparent when it is stated that two out of three of the Church spires here (those of St. George's and the Scotch Kirk) have, within the last 6 years, been more or less damaged by lightning; the 3d, that of St. Mary's in the Fort, having only probably escaped owing to its being provided with such a safeguard.

In event of a discharge of the electric fluid taking place on a building of this kind, it would in all probability fall on the lantern, that being the most elevated point and possessing a large conducting surface of copper. To secure the machinery and building therefore it is necessary to provide a sufficiently capacious and direct channel for the conduction of the fluid from the lantern to the moist soil below, where the discharge would be innocuously dispersed.

The conductor is formed of a bundle of 22 copper wires varying from $\frac{1}{4}$ to $\frac{1}{8}$ of an inch in diameter, strongly bound together, and running in a straight line, through holes pierced in the steps, from the top to the bottom of the building along the inner surface of the wall. At the top it is connected with the frame of the lantern, the machinery of the light and all the principal masses of iron by broad bands of copper; at the bottom it is joined to a rod, 2 inches in diameter, sheeted with copper, which is driven through the well in the foundation of the building, into the wet soil below. It is connected moreover both above and below with the iron rail of the stairs.

This form of conductor fulfils all the conditions con-

sidered requisite by those who are supposed to be the best authorities on this subject, such conditions being,

1st. That the metal employed should be copper, it being the best conductor.

2d. The quantity of metal should not be less than that represented by the section of a solid cylinder half an inch in diameter. The united sections of the 22 copper wires exceed this.

3d. The metal should be placed under as great an extent of surface as is consistent with strength, and should be perfectly continuous. A maximum of surface is obtained by using a number of cylinders, and the strength of wires of the size used is amply sufficient especially when bound together, as these are; each wire runs unbroken from top to bottom of the building; all these conditions are therefore fulfilled.

4th. The conductor should involve in its course the principal detached masses of metal in the building. This is the case also.

5th. It should be placed as close as possible to the walls which are to be defended and not at a distance from them, and be carried at once directly into the ground; both these points are fully attended to.

6th. It should be attached to the most prominent parts of the building. This is done if being attached to the frame work of the lantern.

7th. If the length is considerable, its dimensions should be increased. It does exceed in some measure the required dimensions, and moreover the iron rail with which it is connected above and below form a supplementary conductor greatly increasing the conducting channel.

GLOSSARY OF INDIAN TERMS MADE USE OF IN THIS VOLUME.*

<i>Aumauny</i>	Under the immediate management of Government; or applied to a settlement under which the Government receives its share of the produce of the land from each cultivator, in kind, instead of stipulating for a pecuniary commutation, (in contradistinction to <i>Ezarah</i> ?)
<i>Anna</i>	The sixteenth part of a Rupee, or of a yard.
<i>Annicut</i>	A masonry or earthen dam across a river.
<i>Apron</i>	That part of an annicut on which the water falls after passing over the top of the work.
<i>Ayacut</i>	Total cultivable land; also signifies the whole of the lands of a village.
<i>Bamboo</i>	A large species of reed or cane, used for making baskets, frame work of boats, mats, &c. &c.
<i>Bandy</i>	A cart, usually drawn by two bullocks or buffaloes.
<i>Bazaar</i>	A market.
<i>Boetul</i>	A species of the pepper vine, the leaves of which are commonly chewed by the Natives of India.
<i>Beriz</i>	Rent, revenue.
<i>Bund</i>	The artificial bank of a tank, lake, pond or other reservoir for water.
<i>Cadarumbum</i>	Dry or waste lands.
<i>Culingula</i>	A masonry work in the margin of a tank, or in the bank of a channel, to allow surplus water to flow freely off.
<i>Candy</i>	500 lbs. avoirdupoise.
<i>Catamaran</i>	A rude raft, made usually of three logs tied together, on which fishermen sit and paddle about in the water.
<i>Casney</i>	A land measure equal to 6,400 square yards.
<i>Chatty</i>	An earthen pot.
<i>Chumba</i>	The name of one of the rice crops in Southern India, the Chumba harvest begins about the middle of July, and ends about the end of January.
<i>Chunam</i>	Lime, or Mortar.
<i>Circar</i>	The state; or Government; head of affairs.
<i>Codamoorty</i>	The name of a branch of the Cauvery river; also a small river in the Trichinopoly district.
<i>Corumboo</i>	A temporary dam of mud or sand and grass, stretching obliquely across a river, to turn a portion or the whole of its waters into a side channel.
<i>Cuddoopoo</i>	The name of one of the rice crops in Southern India.
<i>Cuddoopoo-car</i>	A species of coarse rice—the harvest for which begins about the middle of August, and ends about the beginning of December.
<i>Cullum</i>	A dry measure, equal to about 19 gallons and 1 quart, or 12 marcalls.
<i>Calwah</i>	A channel.
<i>Cutcherry</i>	A building in which public business in the Revenue or Judicial Department is carried on—also a Court.
<i>Dasewandum Tanks</i> .	Tanks which are kept in repair by the cultivators, and for which they agree to give up 1-10th of the revenue.
<i>Dasevinedum</i>	An allowance of land or rent, given as a compensation for the construction of a tank, or assignment for making a tank.
<i>Dhoney</i>	A country coasting vessel of from 10 to 100 tons burthen, used by the Natives.
<i>Dittum</i>	Settlement—literally fixed, applied to the engagement which a ryot makes at the commencement of the year.

* The Orthography of these terms is not to be strictly insisted upon; various modes of spelling being in use, and mistakes having unavoidably occurred in printing them.