

TEA MANUFACTURE

AND

Efficient Working Conditions

BY

CHARLES REID, A.M.I.MECH.E.,

in collaboration with

A. W. F. MILLS.



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FOREWORD.

It is an old maxim that quality in tea is made in the field. It is more true to say that the properties of quality in tea leaf are produced in the field and can only be fully and efficiently developed in the factory by giving great care to manufacturing detail and after careful study.

Although quality in made tea is dependent upon the concentration and development of juices in tea leaf, we do not propose to dogmatise in the following pages, but to show how a combination of Research and Planting experience may help the Planter to extend his study and set about procuring the most efficient conditions in the factory and thus enable him to provide best quality tea from the available supply of plucked leaf.

Much has been written about field work and the problems connected with the best type of leaf, soil condition, cultivation, pruning, manuring, shade and plucking; each of which requires study and balanced judgment in order to produce the most efficient working conditions in the field.

It is common knowledge that the texture of soil can be improved by cultivation and drainage and thus supply proper nourishment to the tea bush. It is also known that pruning and plucking requires much study to determine the suitability of hard, medium or light work, also the interval between pruning or plucking periods, and thus retain maximum health or productivity in the tea bush in combination with its profitable yield per acre.

We trust that the combined Research and Planting experience, which we offer to our readers in this book,

will enable them to lead their thoughts a little further in connection with manufacturing methods and thus, by increased efficiency, help towards the production of highest quality tea from the best possible type of leaf delivered from the fields to the factory.

CHARLES REID, A.M.I.MECH.E.,

A. W. F. MILLS.

10th September 1934.

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CHAPTER I.

INTRODUCTION.

MANUFACTURE OF TEA LEAF.

Leaf from the tea bush can be visualised as a living object which absorbs or breathes in carbon-di-oxide gas from the air, representing a proportion of 0.03% of the atmosphere; the rate of absorption is suggested to be 7.1 cub. ins. of carbon-di-oxide per hour per 100 sq. ft. of leaf surface. Carbon-di-oxide gas, which is composed of oxygen 2 parts and carbon 1 part, diffuses through the stomata into the surrounding intercellular spaces in the lower part of the leaf surface. The cell walls surrounding these parts are stated to be saturated with water in which the carbon from the carbon-di-oxide is dissolved and passes into solution in the leaf juices, after which, it is said to combine with the chlorophyll, and under the influence of sunlight forms a type of sugar and as such is used as the basic food of the plant. For every volume of carbon-di-oxide taken in by the leaf it is thought that an equal volume of oxygen is expelled to the air, thus the plant feeds itself on carbon and expels oxygen as a refuse gas.

After the leaf is plucked from the bush, the process is reversed, the leaf takes in oxygen which is utilised to feed the natural ferments for the purpose of oxidising or fermenting the leaf juices, reducing them from a raw super-pungent taste at the end of withering to a mellow one at the end of fermentation, more suitable to the human palate. As a result of the process, heat is

produced and carbon-di-oxide gas expelled to the air. A typical analysis of tea leaf illustrates that its contents are approximately as follows:—

Water	..	..	..	75%
Dry material—				
Carbon	..	..	..	45 %
Oxygen	..	..	..	42 %
Hydrogen	..	..	..	6.5%
Nitrogen	..	..	..	1.5%
Ash	..	..	..	5.0% 25%
				<hr/>
				100.0% 100%
				<hr/>

The 5% ash may be composed of any mixture of the following mineral salts:—Potassium, Sodium, Calcium, Magnesium, Iron, Manganese, Sulphur, Phosphorus, Silica, or Chloride. In this manner, it can be said that the average leaf absorbs food as follows:—

- (1) From the soil—water 75% and salts 5%.
- (2) From the air—gases 20% by weight.

As previously stated, sugar is formed from carbon, it is not immediately used in the plant, but stored in the form of starch. The assimilation or storage of starch depends upon the energy required to be expended by the plant to produce growth, and fight disease, etc.

A further function of the leaf is to sweat, or evaporate water from its surface in very large quantities. The extent of the evaporation can be gauged by the fact that leaf, which contains 75% water, is stated to retain only 0.15 to 0.2% of the total water absorbed by the plant roots.

The leaf can, therefore, be considered to represent a very active part of the bush, and with a considerable reserve of energy, which, if released in an unrestricted manner, after plucking from the bush, can allow heat to accumulate at a sufficiently great rate to utterly destroy the vital properties in leaf responsible for the production of quality in made tea. The quality can only be preserved by the efficient control of heat production throughout all the manufacturing stages.

CHAPTER II.

TYPE OF TEA LEAF.

Leaf from the tea bush cannot generally be classified into definite types, each of which will react in a pre-arranged manner during manufacture. It would be better to realise that the tea bush has gradually evolved into mixed types descended from the original Japonica and Sasangua types of Camellia tea plant and which react each in a different manner in relation to cultivation, soil, and climatic conditions, therefore, it is better to divide tea leaf generally into two main classes, each of which may vary considerably in the neighbouring estates, or even divisions of one Estate.

(1) Tea leaf that can be subjected to severe treatment in the manufacturing stages, without losing its characteristics of appearance, colour, or quality.

(2) Tea leaf that requires careful treatment in the manufacturing stages, in order to retain the above characteristics.

The first type of leaf can be subjected to much more severe treatment in the rolling stages, and or C.T.C. treatment than the second one, in fact, certain types of leaf in combination with climatic conditions are found to be almost unsuitable for hard rolling or C.T.C. treatment. The two types can be again sub-divided generally into two further classes.

(a) Leaf having a hairy undergrowth on the finer leaf, which reflects light in made tea and attracts attention, it usually commands a better sale valuation, possibly

from appearance only, or as a characteristic which denotes good quality leaf. This type of leaf should be carefully manufactured and the fine hairy leaf extracted from the bulk during the early rolling stages. It is, therefore, best rolled for appearance and retention of quality in the flowery B.O.P. and fanning grades. The hairy growth is more general during dry weather or may be encouraged by wind or by cold monsoon conditions.

(b) Leaf with little or no hairy appearance does not always denote a poorer quality leaf, but may be well worth while manufacturing for fine quality tea. Where the characteristic of tip is lacking and it has been proved that quality is not inherent in the leaf, then the leaf can best be manufactured to suit appearance in the lower grades. It can be harder rolled, or C.T.C. treated, or cut and manufactured for the production of a colourly and strong liquoring tea.

The recent tea trade depression of 1932 forced Planters to discriminate much more closely between manufacturing methods most suitable to different types of leaf, and has, therefore, reacted in a very close study of tea manufacture, and the necessary machinery design to retain quality in made tea.

Note:—The hairy growth on leaf may be found during wet weather in some districts, it varies with leaf and climatic conditions.

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CHAPTER III.

WITHERING OF TEA LEAF.

The withering of tea leaf is not yet fully understood, but it is noticed that quality tea is best made under cool air conditions with a slow movement of night or cool air across the withering lofts. The night air being cool and about 70 to 80% humid. It might be said that cool weather with sun conditions encourages the restriction of growth in the tea bush and allows the leaf to accumulate more concentrated juices from which better quality tea can be made. It should, however, be realised that the leaf could be spoiled by the circulation of heated air of over 70-80°F. through the withering lofts, therefore, cool air conditions in the withering loft appears to represent one of Nature's main requirements.

It is important that the good qualities inherent in tea leaf be fully developed in field work and retained during transportation to the factory and to the completion of the withering stage. Loss of the desired qualities, *after withering is completed*, is often very largely due to shortage of machinery, bad factory conditions, carelessness, or negligence. All the quality characteristics of made tea are inherent in, and dependent on, the leaf, as it arrives at the factory. These are developed to best advantage, or partly destroyed according to the care and facilities offered in the factory.

In the Estate, it is found that depressed or flat ground areas, even if at high or medium elevations contain air, which at night is too humid and more or less stagnant, and thus does not provide ideal withering conditions. This natural point was observed in 1912 and resulted in

a general movement of factories to higher elevations, where cool and more dry night air could be naturally obtained for circulation through the withering lofts. The changed factory conditions provided better withering of leaf and added appreciably to the price of tea, as against that which could be obtained from lower elevations.

It was usual practice in factories erected at low elevations, and with unsuitable humid air for withering of leaf, to create a draught of partly heated air through the withering lofts for the purpose of decreasing the air humidity and accelerating the withering process. Unfortunately this principle of adding heated air to withering lofts was applied when it was quite unnecessary in many factories in their new elevated positions. The circulated air has, in some cases, been increased to a large volume with the aid of large fans placed in a central air or other chamber which forms the foundation for existing reversing and alternating systems of air circulation.

Circulation of Air.

The circulation of air over the withering tats on which green leaf is spread has been gradually increased with the object of more efficiently extracting water from the leaf to produce the withered or flaccid condition necessary for rolling. Some people favour an air speed of 60 to 100 feet per minute but it is usually more safe to allow 10 to 11 cubic feet of air circulated per minute for every one pound (weight) of green leaf spread on the tats. The air increasing about 3% in humidity from say 88 to 91% in passing through one section of the leaf house. If the humidity of the air is too low, that is too dry, it is possible to extract water from the leaf at a higher rate than that at which it can be transferred from the stem and coarser

leaf to the surface of fine leaf from where it is mostly evaporated to the air. In this connection, it is understood that the tender, fine, or new leaf in a plucking of leaf containing two leaves and a bud, is more succulent than the older or coarser ones and, therefore, will evaporate water more easily from the leaf surface. The flow of water for evaporation will, therefore, naturally progress from the coarser to the fine or new leaf. This rate of water flow represents the natural rate of evaporation, or withering action.

Increased rate of evaporation may case-harden the outside of the leaf, or make it tough, after which, the evaporation of water becomes more difficult. The heat from chemical or other changes in the leaf may then accumulate at a faster rate than that which can be balanced by evaporation losses, and if the changes become uncontrolled they will reduce the quality characteristics in made tea.

It would appear, therefore, that considerable thought is required around the original methods by which Nature requires withering of leaf to take place under cool air conditions and at a sufficiently slow rate of air circulation to regulate evaporation of water to that which will balance the chemical heat production and preserve quality in made tea.

The rate of evaporation increases as the circulated air temperature rises and humidity decreases, therefore, it will be necessary to know the local limits of air temperature and humidity that will balance the natural rate of evaporation from leaf without producing the undesired case-hardening effects. The above rate of evaporation is unknown but it is indicated that air should be condi-

tioned in temperature and humidity to suit the local leaf conditions of each tea factory.

A good design of withering loft appears to be that which will retain the leaf water evaporation within definite limits. The lofts being built in sections of not more than 60 to 80 ft. long, and each connected to an air chamber or to chambers in which the air can be heated, cooled or humidified by automatic controls on the air entering and exhausted from each withering loft and also from the diminishing weight of the product itself. In designing the withering loft or house, consideration is necessary to the capital and working expenses in relation to the possible profits to be returned from tea manufacture. A fully conditioned and automatic withering house is expensive both in capital and working costs and, therefore, demands a good manufacturing profit.

Efficient Withering.

It has been usual to calculate a leaf wither as a water loss on the original leaf delivered at the factory, thus a 60% wither represents 100 lbs. leaf withered to 60 lbs. with a loss of 40 lbs. water.

The withering of leaf embraces a process which produces a succulent leaf ready for rolling and with a standard percentage of water content, or dry material to withered leaf, and not to the original leaf delivered to the factory. In this manner, a standardised withered leaf can be passed each day to the rolling machines with every hope of producing a good quality made tea.

Leaf arrives at the factory under all sorts of conditions from 70 to 80% water content and is generally averaged at 75%. It is, however, most important to

regulate each day's supply of leaf, so that a definite standard raw material is provided to the rollers dependent upon local conditions within the limits of 40 to 46% dry material (made tea) to withered leaf.

The following data is arrived at by calculating on 46% dry material to withered leaf, and illustrates the fallacy of calculating the wither as a percentage of the original leaf. Thus leaf delivered at the factory with 70% water content will require a 65% wither, while leaf delivered with 80% water content will require a 43.5% wither in order to produce a standardised withered leaf having 46% dry material to withered leaf, signifying a standardised juice concentration in the leaf delivered to the roller. It is understood that a 43.5% wither represents 100 lbs. green leaf reduced by water evaporation to 43.5 lbs. weight. It is doubtful in some cases if a 43% wither is really practical in monsoon months, but the table shows a much harder wither is necessary at times to produce similar results from varying leaf.

GREEN LEAF.			WITHERED LEAF.			DRY TEA.	
Leaf lbs.	Water lbs.	Dry Tea lbs.	Leaf bs.	Wither %	Water lbs.	Dry Tea lbs.	Dry Tea to Withered Leaf.
100	80	20	43.5	43.5	23.5	20	46%
100	78	22	48.0	48.0	26.0	22	46%
100	76	24	52.0	52.0	28.0	24	46%
100	74	26	56.5	56.5	30.5	26	46%
100	72	26	61.0	61.0	33.0	28	46%
100	70	30	65.0	65.0	35.0	30	46%

Should an estimate of the dry material be required during the withering period, it is possible to attach a small drying oven, with flat trays similar to a chemical desiccator, to the side of the ordinary drying machine. A small circulation of heated air could be provided by

boring a few holes in the drying machine side plates, and in the top plate of the desiccator. 1 lb. of green leaf as delivered at the factory might then be dried in 2 to 3 hours, and after weighing, the dry weight could be divided by the percentage figure of 46 to show the weight to which 100 lbs. of green leaf should be reduced to give a relation of 46% dry material to withered leaf.

The wither of leaf could be checked up in the withering spaces by placing 1 lb. green leaf on the platform of a special Avery or similar scale registered to show small weight differences. The automatic control of circulating air in contact with the leaf might be partly controlled by electrical regulation from the movements of the Avery scale.

It is suspected that the leaf juice concentration, or percentage of dry tea to withered leaf should depend on local conditions of temperatures, thus in a low situated factory with air temperatures of 80–90°F the percentages of dry tea to withered leaf may best represent 38 to 40% as against 42 to 46% for air temperatures of 65 to 75°F in factories situated at higher elevations.

Bright clear tea liquors of good quality are produced from leaf well withered in a sweet condition, the colour of liquors can, however, be strengthened by prolonged wither or by placing the withered leaf in heaps for 10 to 20 minutes, heat is developed in the heaped leaf and changes it to a darker colour, with a varying type of sour smell. This smell is soon lost in the first rolling period and the leaf returns to its sweet scented condition, this is dependent upon type of leaf and local conditions. The tea liquors become stronger, and more colourly, but with

a softer taste and a possible loss of pungency dependent upon the increased colour and strength of the liquors.

Leaf Juices.

It is generally understood that leaf in its natural growing state absorbs tannin and caffeine liquids into certain of the leaf cells. The liquid is supposed to percolate through the walls of the cells and is filtered out from the juice generally circulating in the leaf.

During the withering process, it is understood that the inner coating of the cell walls disintegrates and allows the tannin and caffeine liquids to partly percolate outwards and gradually mix with other juices in the body of the leaf. At the same time, water is evaporated from the leaf until the juice or liquid content reaches a concentration which, when acted upon by oxygen of the air, will produce the most efficient change suitable for the production of flavour and quality, as recognised by the human palate, in liquors brewed from the made tea.

The pungency of tea liquors appears to be related to the efficiency with which the tannin and caffeine liquids, etc., are intermixed before the ferments start to operate with the aid of oxygen. The mixing of the essential liquids is possibly aided by the presence of peptic acid, manganese, and phosphorus, and may be accelerated by continual bruising of the leaf fabric at temperatures below which the ferments will react. The withering process may, therefore, be said to be controlled by two distinct changes:—

- (1) Extraction of water to produce a flaccid leaf, and break down, by disintegration, the walls of the leaf cells.

- (2) Mixing of the tannin and caffeine liquids, etc., from the cells, and their concentration to the extent which will cause the best changes to take place, after the ferments are activated by oxygen. The mixing of the liquids can be extended through the bruising or rolling stages, provided the action takes place at temperatures below which the ferments will operate very slowly.

In green tea manufacture, the withering of leaf is replaced with a sterilising action and takes place in a few minutes with the aid of high temperature steam or humid or dry air, the action of the ferments is then reduced to a minimum during all stages of manufacture.

Practical Withering Conditions.

Factories which experience conditions by which a natural wither is impossible within the generally accepted period of 16–22 hours, have to adopt some artificial means of bringing the leaf into the desired state for manufacture. This applies whether the elevation is high, medium or low.

So far it has not been found possible, or rather practicable, to improve on the ideal natural conditions, and whatever system is installed, the nearer the approach that can be made to the ideal natural condition must be the principle to be aimed at.

The ideal system embodies a cool gentle draught of fresh clean air which has just sufficient spare moisture carrying content to enable it to pick up, and carry away to the outer air moisture evaporating from the leaf. This

process must be as steady and continuous as the leaf itself allows. To wither leaf under good conditions for a few hours and then to allow the evaporation process to cease by non-circulation of air cannot make for the best quality in made tea even if the quantity of moisture evaporated from the leaf is as much as is desired.

Too strong a blast of air is also dangerous for the reason that it tends to case-harden the younger leaves.

Heat is a great destroyer of quality, therefore, the lower the temperature the better.

In attempting to approach this ideal, some of the matters requiring consideration and much study surround the situation and elevation of the factory, and the temperature control.

A study of air humidity tables will show that air at a dry bulb temperature of 80°F, with a difference of 3°F, in the wet bulb has 85% full moisture carrying capacity, while air at a dry bulb temperature of 60°F with the same difference of 3°F in the wet bulb has 82% full moisture carrying capacity. It is, therefore, better not to talk of so many degrees difference between wet and dry bulb but to find the actual percentage of full moisture carrying capacity (humidity) of the air.

Air at a higher temperature, though with the same absolute humidity content as that at a lower temperature, is said to have a better capacity for evaporating moisture from the withering leaf. The figures given above for the withering capacities of air at various temperatures and wet bulb depressions, therefore, require attention to suit local conditions.

The length, breadth and height of the loft, the spacing of the tats, the general air tightness of the floors,

walls and ceilings, the position of doors, partitions and staircases as well as the thickness of the leaf to be spread on the tats will all affect the air speeds, currents and eddies of air passing along, or even across, the loft. These considerations will affect the placing, size and speed of fans. The ideal to be aimed at is still the same ideal natural conditions mentioned previously, a gentle, continuous and even draught over all the leaf.

Fans that give good results over one distance may be found inefficient over a longer one and give too fierce a draught over a shorter distance. Large propeller fans, at their lowest efficient speed, would appear to give the best results, but generally speaking their efficiency is governed by the water gauge against which they work and the distance over which they have to draw or force the air. No fans in a loft can be said to have both a free intake and discharge. They sometimes have one or the other, and very often neither. The water gauge is often considerably more than is suspected.

It will be seen that with all the variations that may occur in lofts it is not possible to do more than outline the direction in which study has to be undertaken in order to approach as near as possible to good natural conditions.

Again, fans and conditioned air that give good results with leaf spread at, say 16 sq. feet or more to the pound, will be found quite unsatisfactory with a thicker spread.

It is not possible to expect a good wither with thick spreading even when the outside conditions are ideal. Leaves overlie each other and must result in unnecessary unevenness.

An absolutely even wither is not quite possible; no two leaves coming into the factory will be exactly the same, therefore, the perfect conditions required for one leaf are not quite the ideal for another. Here we come back to the field work once more, as the more even the leaf that is sent to the factory, the more even will be the wither and resulting infusion of the made tea.

Another matter that is often overlooked is that complication is to be avoided either in an automatic process or for the human element to contend with. As far as possible it is better to aim at simplicity, both in working and material, so that the usual factory staff can deal with and fit new parts when necessary or mend broken ones within reason. Simplicity should be the key-note of organisation, and machinery-equipment, generally.

In conclusion, it should be remembered that Tea manufacture is not an end to itself. Its sole object is to make profits. To equip a factory so fully with withering space and artificial air conditioning machinery that it will cope easily with a maximum day, or even a fortnight may be most uneconomical. This is especially so when at these rush periods the quality of the leaf coming to the factory is so poor that the most ideal conditions cannot do much for it. It is sometimes a case of spending a shilling to make nine pence.

Short Withering Periods.

A new method of manufacturing leaf has been successfully tried in India whereby the green leaf is given only a very short wither dependent upon leaf and local conditions; for instance, it has been found during dry weather conditions that sufficient wither can be given to

leaf during the plucking and transport stages to allow it to be cut into strips on arrival at the factory. The best method to do this is by means of a tobacco or other similar mechanically sound cutter which can produce clean cut strips of leaf about $\frac{1}{8}$ " wide.

During dampish weather, it is necessary to slightly wither leaf on tats or chungs in the usual manner, but only for a few hours, until the leaf shows signs of losing its natural crispness, when the leaf may be cut.

After cutting, the strips of leaf are laid on a good dry clean floor, preferably in a fairly humid atmosphere, and to a depth of 3 to 6 inches, according to type of leaf and local conditions. The leaf must not be pressed down but should remain in as open a manner as possible so that oxygen from the air may percolate to all sections of the spread leaf bulk.

The oxygen from the air produces a rapid fermenting or chemical change which in 18 to 30 minutes completes the chemical stage of withering. As the process becomes complete, a strong scent varying from an apple to a tobacco scent is given off, and the heat generated by chemical change in the leaf appears to provide a sufficiently flaccid condition to allow the leaf strips to be lightly rolled.

The length of fermentation or chemical change allowed to take place in the green leaf is dependent upon the strength of liquor required in the final brewed tea and upon leaf or local conditions.

This method of withering is in its infant stages but it appears to offer very considerable possibility for development by those trained in the study of natural changes in connection with the production of quality tea.

Preservation of Tip.

In a type of leaf which contains a large number of hairy leaves that produce tip, it is often necessary to under-wither the leaf in order to produce the maximum of tip in the finished tea. Too much under-wither will produce silver tip, i.e., a light coloured tip, while a slightly harder wither will produce golden tip.

It must be remembered that a hard wither of green leaf produces flavour, pungency, and colourly liquors, but is not generally good for tip. On the other hand, the maximum preservation of tip with an under-wither is not generally good for flavour, pungency and colourly liquors.

The extent to which leaf should be withered will, therefore, require a constant source of investigation to produce the maximum flavour, pungency, colourly liquors, tip, and appearance in made tea. The extent of wither may require to be varied for different sections or fields of the same Estate.

Note:—Colourly liquor means *bright* colourly liquor.

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CHAPTER IV.

ROLLING OF LEAF.

The object of rolling leaf from a physical aspect is to impart a twist to the leaf, and thus ensure a good appearance to made tea: also to help in the disintegration of leaf cells and spread the juice over the leaf framework, bringing it into contact with oxygen.

The large production of broken grade tea during 1932 reacted on a market already overloaded with stocks of tea and during 1933 a general tendency was again produced for well rolled tea. It, therefore, appears that considerable care is required to retain a balanced production of the various tea grades to suit the market. Thus rolling of leaf appears as if it will remain a definite future stage in tea manufacture and may be divided into two sections:

- (1) Tea with good appearance, colourly liquors and flavour to suit the public demand, and which can be produced from mid or high elevations in S. India, Ceylon, Darjeeling, and Java.
- (2) Tea with increased colourly liquors, greater strength, and often but not always with poor appearance produced with decreased quality inherent in the leaf from low elevations in the above districts.

It is understood that the best pungency, briskness, and flavour in made tea is produced by restricting the accumulation of heat during any of the stages of manufac-

ture, except within certain limits during the controlled fermenting stages; therefore, if strong coloury tea is to be produced, and fermentation carried near to its extreme limits, very great care must be taken to guard against loss of pungency, etc.

During the rolling stages, the leaf is continually being bruised, and the tannin and caffeine liquids, etc., intermixed. The fabric of the leaf becomes more porous and allows the mixed liquids to be expressed to its surface, where the ferments can be more freely activated by contact with oxygen from the air, and work rapidly to make the changes necessary to produce quality characteristics required in made tea. These changes naturally produce heat which, if not liberated, may accumulate and accelerate the changes sufficiently to destroy the characteristics which it is desired to retain for the production of quality in made tea.

As previously stated, accumulation of heat destroys quality production and produces soft liquors, but it is generally found that if the working surfaces of the roller are artificially cooled, the leaf during the bruising action can be reduced to a low temperature, in which state, the work of the ferments will be greatly reduced. It will then be possible to proceed with the bruising of leaf and mixing of the tannin and caffeine liquids, etc., without heat accumulation until they arrive at the most efficient state for the fermenting changes to take place, after which, the temperature of leaf can be raised to produce the best reactions from ferments in contact with oxygen from the air.

Badly fermented leaf is capable of decreasing the value of well withered and cold rolled leaf, but the

best regulated fermentation cannot overcome the defects of badly withered or rolled leaf.

Careful consideration requires to be given to the type of leaf it is necessary to roll. If the leaf bulk contains a large percentage, say 25 to 42% of leaf having a hairy undergrowth or other properties which produce tip and the finest quality teas, it is necessary to proceed in a careful manner, and under the best possible temperature control.

The roller table design is important, it should have a practically flat working surface with a slightly raised or depressed centre. The battens should be curved for the purpose of pulling the leaf towards the centre of the table. The mouth of the batten should be curved forward to the motion of the jacket, and thus act as a scoop, while the root of the batten should gradually curve inwards from the motion of the jacket in order to produce an increasing rolling action to the leaf, and should increase to maximum at the root of the batten. Too many battens are not desired in the first rolling period, as the rolling action would then be interfered with and replaced by a breaking one.

In filling the roller with leaf, the leaf should be added gradually, otherwise too much leaf, added at one time, will cause ball formation, or broken leaf. This is important and undoubtedly spoils tip.

Initial Rolling Stages.

The final appearance of leaf, protection of tip, and quality in made tea depends to a great extent upon the efficient working of the first rolling stage. With under-withered leaf; it is most important that the roller

jacket be not filled too full, and no pressure be applied to the leaf during the first rolling period. With fully withered leaf, the roller jacket in the first rolling period can be more fully filled, and after 20 minutes, the pressure cap can be very slightly depressed for short intervals during rolling periods. The time of each roll and the number of rolls can only be determined after trial for each factory. Starting with the number of rolls in general practice in the district and making such alterations as may be advisable to improve the appearance and quality of tea.

With some types of tough leaf, or leaf which cannot produce fine tea grades, it is possible to further depress the pressure cap and place a fair pressure on the leaf, for short intervals, after an initial 20 minute period of first rolling. The duration of the first rolling stage will be determined by type of leaf and local conditions.

After the first roll is finished, the leaf should be removed from the roller and sifted as quickly as possible, in order to remove all trace of heat accumulation in the leaf, and to separate the fine from the coarse leaf grades.

After sifting the leaf from the first roll, the fine leaf is removed to the fermenting beds, and the coarse leaf treated again, if necessary, in the rolling machine to complete the first rolling stage.

Rolling stages in warm climates are usually two and sometimes three in number. The first rolling stage corresponding with the first two rolls in cooler climates. The second stage with the third and fourth rolls in cooler climates and the third rolling stage to the fifth and subsequent rolls in cooler climates dependent upon the increasing total period of fermentation necessary in the cooler climates.

The fine grades sifted from the first rolling stage in a warm climate and that from the two corresponding rolls in a cooler climate form the flowery grades consisting of 25 to 42% of the total made tea and usually obtain the best market prices.

It should be remembered that the initial rolling periods in a factory above 1,000 feet elevation are very important ones and require every care exercised to see that the roller jackets are not packed too full with leaf or the table battens made in too severe a design, or the roller speed not too great, (around 35-45 R.P.M. at table is usually correct), otherwise the fine leaf may be damaged or mixed to too great an extent with broken pieces of coarse leaf, which detracts from the market value of the fine grade tea.

At elevations of 4,000 ft. and upwards, the initial rolling stage may be increased to three or four rolling periods of short duration and at elevations below 1,000 ft. it may only be possible to include one initial rolling period.

As will be realised, the leaf temperature and consequent rate at which fermentation takes place is the controlling feature, therefore, in factories up to 3,000 feet it may be possible to increase the number of rolling periods with the aid of artificially cooled rollers and thus increase the market valuation of the general tea grades.

A great deal can be done by a careful adjustment of window openings to allow a very gentle natural draught through the fermenting and rolling rooms and humidify the air by means of wet hessian curtains; such simple devices can be made at a very low cost. It is far more important to control the leaf temperature in the rollers

than spend money and care in a perfectly controlled atmosphere.

With reference to the speed of roller tables, it will be realised that rolling room temperatures (unless artificially cooled) are much higher at low elevations, possibly around 80 to 95°F. The fermentation proceeds at a fast rate, therefore, it is often necessary to speed up such roller tables to 50 to 60 R.P.M. as against 35 to 45 R.P.M. at higher elevations, where the rolling room temperatures are more around 60 to 75°F and fermentation proceeds at slower rates.

The advantage of a slow rate of fermentation will be appreciated, but in artificially reducing the temperature of roller surfaces or air temperatures within the rolling room, it is necessary to carefully consider the capital expenditure and working costs of such artificial conditions in relation to the financial gain to be obtained from the sale of made tea by such methods.

The humidity of the air within the rolling room is important and can be corrected at low capital expenditure and working costs.

The best method is to instal a plant which will give a definite circulation of air with the correct degree of humidity. The degree of humidity in the air varies with the temperature and should be around 90 to 95% humid with air temperatures of 80°F and above, decreasing to 70-80% humidity with air temperatures below 80°F. Development work is still necessary on this subject and the above conditions may vary slightly to meet different local conditions.

The design of the arrangements to humidify and cool the rolling room atmosphere varies from the hanging

of wet hessian clothes in a natural air draught to the controlled circulation of natural air and its humidification in water spray chamber. The latter design gives the best conditions if finance is available. The humidity of air in the rolling or fermenting room can be further automatically controlled by electrical methods; this method is more expensive, but very effective and its adaptation altogether depends upon the increased market value to be gained from the effects of air humidification.

In dealing with the initial rolling of specially withered leaf:—It is important to study the first rolling period of leaf withered for long periods or that placed in heaps for a short period at the termination of withering and just before rolling. In such cases, the roller jacket should only be half filled with leaf and the leaf rolled to give the maximum aeration without pressure. All extra care expended in this study will be well repaid by increased quality tea.

With cut and under withered leaf. A much larger supply of leaf can be placed into the roller jacket, and the leaf lies in a more compact mass. During the initial rolling period a study is required to provide the best type of batten and depth of leaf to give a good turning over motion and twist to the small leaf.

Final Rolling Stages.

The coarse leaf, remaining after the fine or more tender young leaf has been removed from the leaf bulk in the ordinary initial rolling and sifting processes, contains a less attractive juice content which, due to the toughness of the coarse leaf fabric, has not yet been

liberated and intermixed with the more attractive juices contained in the fine leaf.

The object of the final hard rolling stages is, therefore, to increase the bruising actions sufficiently to make the coarse leaf fabric porous and allow the juices to become exposed to atmospheric oxygen.

In the writer's opinion, the cells of the leaf fabric are not burst by hard rolling, or bruising action, but are distorted, and the juice content expressed through the porous wall of the cell.

On release of the pressure or bruising action, the cell comes back to its original formation and sucks back part of the intermixed juice content in which the ferments have received an oxygen charge and have become activated. This action goes on until the juice content is ripe. The leaf fabric becomes more and more porous as the bruising action goes on.

It is fortunate that the cells of young or fine leaf are more easily distorted than those in the coarser leaf as the activation of the ferment and ripening of the juice content can proceed with a very light rolling pressure, which has little effect on the cells of the coarse leaf.

The hard rolling of leaf produces an accumulation of heat from leaf friction together with heat produced by chemical or other changes taking place in the fermentation of the leaf juice content, and produces increased temperatures in the leaf which have destructive actions above 80°F, on the final quality of made tea.

The hard rolling of coarse leaf has, therefore, produced rather a problem, especially in factories at low or semi low elevations, say under 2,000 ft. elevations, where

rolling room temperatures are sometimes anywhere between 85 and 95°F.

Under such circumstances, the total fermentation from the first period of leaf bruising in the roller, until its practical completion on stationary fermenting beds, is $2\frac{1}{2}$ to $3\frac{1}{2}$ hours as compared with 4 to 6 hours in cooler and more elevated factories. In factories where quality is more important than colour, the fermentation period is sometimes cut down to $2-2\frac{1}{2}$ hours. It has been found that a short ferment will often give a better flavour than one of $\frac{1}{2}$ an hour longer. This will probably be at the expense of strength and colour and the factory must judge which point it wishes to develop.

In low country factories, where the quantity of leaf is often seasonal in growth and where there are two to three very heavy leaf cropping months each year, it is sometimes difficult to visualise the actual rolling conditions.

The usual tendency is to cut down the rolling machinery equipment below that necessary for the rush months, with the result that during such rush periods the rollers are often overloaded with leaf. Under such circumstances the leaf cannot be rolled properly, it becomes overheated, and cannot be efficiently cooled or aerated when the pressure cap is raised.

In some parts of N. E. India, the tea rollers can each be calculated to deal with leaf equivalent to 80 lbs. made tea per hour and, this during rush periods may be increased to 120 lbs. In comparison with these figures and in districts where rush periods are not so heavy, the tea rollers can each be calculated to deal with leaf at decreasing rates equivalent to a minimum of 40 lbs. made

tea per hour, dependent upon the type of leaf and other local conditions including the number of times the leaf is rolled. The rolling periods in N. E. India are usually 2 or 3 which in cooler climates with decreased roller outputs are increased to 5, 6 or 7.

When one considers that fermenting reactions become uncontrollable between 80 to 85°F and it is realised that overloaded rollers allow leaf to reach 90 to 105°F; one gasps with horror at the loss of quality or market value in made tea which may be taking place by uncontrolled fermenting changes. These changes may produce thick liquors but they lead to a great loss of pungency and softness in the brewed liquors.

On some Estates, this point has been more fully realised with the advent of restriction by decreasing the charges of leaf to each roller, with a consequent better rolling action and leaf aeration, lower leaf temperatures, and a general tendency towards the production of better quality tea.

The lesson to be learned from this change points towards the benefits produced by a reduced depth of leaf in the roller jackets. This allows the great percentage of leaf to come more into contact with the roller table surface where the real rolling work is performed, also when the pressure cap is released, the smaller depth of leaf allows the leaf bulk to be more easily broken up and aerated with the result that it more quickly loses its temperature accumulation, and is controlled within the allowable limits to produce quality tea.

With regard to roller design, the lesson to be learned points to a larger diameter roller jacket, so that greater

quantities of leaf can be economically rolled with decreased depth of leaf bulk.

Cold Rolling.

To those Planters who can afford a larger capital cost in rolling machinery, it will be money well spent to instal artificially cooled rollers in which cold brine is continually circulated through hollow roller tables, jackets and pressure caps. The brine being cooled in a refrigerator, any degree of coldness can be artificially imparted to the roller working surfaces and consequently the leaf temperature can be controlled to suit the necessary rate at which fermentation is required to proceed in order that the degree of pungency, quality and colour may be produced in the final liquor brewed from made tea. The capital cost of the rollers is increased, but also the quality and market value of the made tea is considerably increased. Thus in a low country Estate with a fair quality leaf, the extra capital cost of the rollers can be recovered within one to two years.

It is interesting to note that the temperature of leaf in the roller may thus be decreased from 90 or 105°F to 60 or 70°F, bringing the fermentation reactions from a very dangerous condition to one completely under control. The loss of tannin can be roughly stated to represent loss of quality in made tea and can be reduced from a loss of 1.5 or 1.7% to 0.7%. This is a good guide to the beneficial results to be obtained from cold rolling.

A further beneficial result is found in the possible longer rolling periods and harder pressure which can be placed on the leaf with the result that the coarse bulk leaf remaining after rolling is complete and which

requires to be dry cut, is reduced from 20-23% to 7-8%. This is of very great importance to Estates catering for broken tea grades.

The artificial cooling of leaf is also of considerable importance in the rolling of cut leaf, previously mentioned. This is due to the fact that the fermenting changes are greatly accelerated by the entry of oxygen through the cut edges of the leaf and its more easy absorption by the ferments in the juice content. These accelerated changes produce heat more rapidly and if allowed to accumulate and raise the leaf bulk temperature above 80°F, a serious loss of quality in the made tea will arise.

The loss of quality can be decreased in non-cooled ordinary rolling conditions by reducing the pressure on the leaf and increasing the aeration periods which naturally cool the leaf.

In the writer's opinion it may be possible, with tough or similar types of leaf, to allow heat to accumulate internally within the leaf for a sufficient period to reduce or partly destroy quality production. This action is possibly somewhat similar to that taking place in case-hardening of leaf during the withering action, and may reveal some troubles which at present cannot be properly explained in practical work.

As previously explained, the action of hard rolling is for the purpose of distorting the leaf cells, intermixing the juice content, adding oxygen to the ferments, and the reabsorption of the juices in the leaf cells by reason of the cells returning from their distorted to their original round shape. The leaf fabric thus acts as a sponge which can discharge and reabsorb its juice or liquid content by application and release of pressure.

New Method of Rolling.

During 1931, different methods were introduced to rolling from ordinary procedure by that produced in a special machine termed the C. T. C. machine in which the initially rolled leaf was passed between revolving rolls working at differential speeds, with the object of stretching or opening the leaf surface and thus making it more porous for easy absorption of oxygen.

The surfaces of the rolls were cut with specially formed teeth to give crushing, tearing and curling actions to the leaf. The actions can be visualised as follows:—

1. The leaf is cut in its wet state and thus saves loss of dried juice from the twisted leaf, if cut or broken in its dry state.

2. The cells of the leaf are thoroughly distorted between the rolls and disgorge their full juice content, but the pressure or distortion of the cells is released at such a rapid rate that the juices are mixed and reabsorbed by the cells before they are expressed and fall from the leaf fabric.

3. The outer surface of the leaf is stretched or opened and becomes more porous, which, together with the torn or cut edges of the leaf fabric, allows oxygen to come easily into contact with the ferments in the leaf juices. This action accelerates the fermenting reactions beyond that possible in ordinary rolling manufacture and therefore requires very careful handling of the leaf.

It must now be remembered that an increased rate of fermenting reactions produces heat which may accumulate very quickly and, if not liberated by air aeration, may destroy or change the vital properties in the leaf juices responsible for quality in made tea.

Very considerable care and thought requires to be given to the accelerated fermenting reactions in relation to local leaf and climatic conditions. This is more necessary in young leaf having properties of quality production which often requires a slow rate of fermenting reaction and also with leaf which has been placed in heaps after withering. In both cases the production of heat accelerates fermenting or other reactions peculiar to that stage of manufacture and requires that the rate of fermenting reaction during or after rolling be thoroughly controlled to suit the sensitive condition of the leaf.

The above remarks will indicate that a leaf sensitive to fermenting reactions must be treated with great care and only such leaf, as requires the fermenting reactions to be accelerated, should be so treated.

Development work suggests that all young or tender leaves, sensitive to fermenting reactions, should be extracted from the leaf bulk in the initial light rolling and sifting stages, after which, careful consideration is necessary to the extent to which the remaining coarse leaf can be beneficially treated in a special machine.

In the writer's opinion the C.T.C. machine may be very usefully employed in co-operation with tea rollers, i.e., the coarse bulk leaf can be passed once through the C.T.C. machine and conveyed directly to a roller fitted with a correct type of table and battens to efficiently turn over the leaf without excessive accumulation of heat. After rolling, the leaf should be sifted and the remaining coarse bulk again passed through the C.T.C. machine, rolled, and sifted, after which, both the coarse and fine leaf should be taken directly to the stationary fermenting beds.

Should the coarse leaf be treated entirely in the C.T.C. machine, it is most important that the leaf be handled quickly and passed to the dryer without loss of time. The leaf should, under no consideration, be allowed to over-ferment in heaps, or the fermentation be over-accelerated by more passages through the C.T.C. machine than each particular type of leaf can withstand.

It is also important to increase the vital control temperature in the dryer to suit the extent to which the fermentation is accelerated.

Considerable improvement in quality can be produced in made tea by this method, always provided it is remembered that all fermenting reactions are accelerated and must be controlled with great care.

In some cases, first flush leaf from the early seasonal growth of the tea bush in Assam can be improved in quality by passing it all twice to three times through the C.T.C. machine with or without an additional stage in the ordinary rolling machine. The reason for this exception in the heavy treatment of first flush green leaf is possibly explained by the circulation of juice not having properly started in the tea bush, and a rank growth of new leaf formed in which the oxidising actions require to be accelerated by the drastic C.T.C. treatment, which opens up the leaf fabric and brings the juices more easily in contact with the oxygen of the air. This application must not be generally applied but suited to local leaf, soil and climatic conditions.

Roller Design.

There would appear to be nothing wrong with the general design of rollers, they are mechanically good as

they do the work required of them very efficiently, in the simplest way, and are easy to control.

In some instances, benefits can be obtained by the automatic application of pressure to rolling leaf, but it is more often better to employ intelligent native supervisors who, when properly trained and encouraged, can more efficiently gauge the degree and length of pressing periods required to suit the changing requirements of a variable leaf supply.

Thus when leaf is manufactured by mass production methods without relation to maximum quality production, the use of automatic pressing devices may be found useful.

In general, where quality production is important, it is usually better to rely upon expert supervision to regulate the pressing periods and incorporate a device in the roller which will indicate the necessary number of pressing or release periods with the amount of pressure applied to the leaf.

Generally speaking, the roller tables are individual preference but it is sometimes thought that a well type table with a few rounded battens, in the well and door surface only, is best suited for the light rolling of leaf, but flat tables can also be utilised, provided the battens are not too severe and designed with the object of turning over the leaf and not breaking it.

For hard rolling purposes the table will usually be found best when made almost flat and preferably with a slightly raised dome-shaped door in the centre.

The battens must be suited to the type of leaf, the top of the batten surface should be level with the outer circular rim of the table partly swept by the lower edge

of the jacket. Most Planters will have their own particular ideas for roller tables and battens; therefore, this can only be taken as a guide to anyone wishing to make a change, or vary their manufacture.

The battens must not be too severe for the production of well twisted leaf, they should be few in number and designed to pull the leaf towards the centre of the table and efficiently turn over the leaf.

For the production of broken grades, the battens should be increased in number and made with a sharper or more severe surface which will efficiently break or tear the leaf as well as turn it over.

It is of considerable importance that the roller parts in contact with leaf be easily accessible for washing down purposes. Any leaf of over 4 to 5 hours accumulation will lead to putrefaction and production of a bacteria harmful to the production of quality tea.

Sliding or drop doors are largely a matter of individual taste and for the type of leaf to be dealt with. What is important is that the amount of pressure being applied should be seen at a glance from across half the rolling room. This is given by the pressure cap spring in most cases but every roller, of whatever type should have some simple indicator.

Emphasis has been laid on the fact of pressure generating heat and what damage this heat can do, hence the necessity of a very rapid and simple pressure check especially when rolling for quality in the coarse bulks.

The perfect roll breaker has yet to be designed. Opinions regarding the battens of the revolving cage, through which the leaf passes to the sifting tray, are

mixed. For finer leaf, and for tip, they would appear to be detrimental, for the remainder of the leaf, they probably do as much good as harm and are often difficult to clean.

By passing the leaf of the first two or even three rolls, first over a roll breaker of No. 4 mesh and then over another of No. 6 mesh, will ensure that only the finer and more equal leaves come through. Tea made from this will usually have a far more even infusion.

It is not necessary here to do more than touch on the necessity of having all floors and machines clean and constantly washed. A plentiful water supply that is easily get-at-able, which is not always the case, is essential. Disinfectants should be used very sparingly and very diluted.

Rolling Room Working Conditions.

For a man who spends long hours in a rolling room a stale smell is difficult to detect, but to one coming in from the fresh air it is the first thing that ought to be noticed.

It is of importance to give great attention to the withering of leaf in order to produce in the rolling leaf a constant degree of concentration in the leaf juices, this being obtained by regulation, as previously explained to provide a constant dry material in the leaf in relation to the actual withered leaf. It can easily be understood that an under-concentrated juice will ferment at different rate to over-concentrated juice, and one must remember that the best quality tea is very largely dependent upon the efficient control of juice fermentation. The leaf is only a spongy material to absorb and carry the treated juice

but it requires to be manufactured in a form attractive to the eye and taste of the purchaser.

It has been rightly said that the margins of temperature, and other factors, in most stages of manufacture within which good tea can be made, is wide; however, it should be remembered only a few factories are so situated that they can carry out their normal factory working methods in the middle of this margin, and even these fortunate ones will find themselves at one edge or other in some of the manufacturing processes. It is necessary, therefore, to watch detail throughout, particularly in those factories which start, under natural conditions, very near the boundary of safety.

Attention can well be fixed, chiefly at those points that are known to be near these boundaries and relaxation allowed where a fair amount of safety is assured.

As has already been emphasised, considerable care is necessary in all stages of rolling and it should be remembered that rolling and fermentation are, to a great extent, one process.

Supervision is most important and anything that tends towards the efficiency and simplicity of routine should be encouraged. Supervision is assisted by a careful lay out of the rolling room so that an uninterrupted view of the work of all rollers and roll breakers can be obtained from several places in the room. If, for purposes of getting a cool and damp atmosphere, the room is already dark and extra machinery is crowded in, the room becomes congested, making it difficult to see what is being done in more than one or two machines at a time. This also generally tends to obstruct the movement of fresh air and the heat generated by the leaf in

the rollers hangs about the room, helping to destroy quality, unless expensive cooling and humidifying apparatus is installed.

Belt drives to rollers, etc., should be eliminated, when possible, and where this is unavoidable should be as unobtrusive as it can be.

It is often not only difficult to arrange, but sometimes not desirable or even possible, to have all the rollers in practically the same stage of 1st, 2nd, 3rd rolling stages at the same time. A slate or indicator fixed to each roller with its own times marked on it will enable anyone passing through the rolling room to check up the work being done and to determine whether the pressure cap should be up or down on any machine which he passes. With an uninterrupted view he can also see several other machines, note the pressure being applied, and draw the attention of the assistant in charge to anything that is wrong. All the operatives can be seen at a glance and all are kept up to the mark.

It cannot be emphasised too much that good tea making consists of constant attention to detail. Where this attention is made difficult by a complicated routine, and work can only be checked by a careful study of a large blackboard in one corner, things tend to become inefficient, especially towards the end of the day. This constant attention can be made so simple as to be nearly automatic and if the routine followed by the operatives is simple and straightforward, the work will go on far more smoothly and infinitely better results will be obtained throughout the day. A little study of psychology will prove of benefit to both employer and employee.

An extension of a verandah at the end of the rolling room at comparatively low cost will often turn a dark, hot and congested rolling room into a cool and airy one, make supervision easy and simple and allow of a far better routine of work to be arranged, than is possible with machines scattered all over the rolling room wherever places can be found for them.

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CHAPTER V.

FERMENTATION OF TEA LEAF.

It is generally recognised that fermentation of leaf is represented by reactions caused by the activity of natural ferments in leaf juices coming into contact with oxygen from the air, and that until such contact is established by bruising or cutting or breaking action on the leaf fabric, the juices within the leaf or its cells will not change except in the manner described for withering, in which oxygen is slowly absorbed by the leaf.

Fermentation in Withering of Leaf.

It is thought that, during the withering process, fermentation proceeds in an unbroken leaf at the rate at which oxygen can be slowly absorbed through the stomata of the leaf fabric and appears to have an increased effect as the cell walls break down after withering has started to take place.

This appears to be borne out by the fact that green leaf must show a little flaccidity, or withering effect, in which the cell walls are partially broken down, before the leaf can be cut for the purpose of providing a quick and easy means for oxygen to permeate throughout the cut leaf fabric.

The fermentation of green leaf will then complete itself in 18 to 24 minutes as against as many hours, in natural withering, always, provided the leaf is placed on beds to a sufficient depth and in contact with humid air.

The type of fermentation, at this stage, is dependent upon a regular flow of oxygen throughout the cut leaf fabric and becomes defective as soon as the cut edges of the leaf dry up, and retard the free absorption of oxygen by the juices within the leaf fabric.

Fermentation in Rolling.

After the rolling action starts, the juices are mechanically brought to the surface of the leaf and its fabric made more porous; therefore, the fermenting reactions can proceed naturally at accelerated rates. The best temperature condition being found around 80°F, above this temperature the fermenting reactions are dangerously accelerated up to 105°F, and below 80°F, the reactions are retarded to practically nil at around 50°F.

It is shown in practice that improved fermenting reactions can generally be obtained in the rolling of leaf by retarding the reactions during the bruising period by reducing the leaf temperature to around 68–70°F. In this manner the leaf juices can be more thoroughly mixed and fermenting reactions delayed until the leaf is spread on the stationary fermenting bed and exposed to regulated air humidity and temperature conditions, which encourage fermenting reactions to take place in the most efficient manner.

It is well to remember that fermentation of the leaf juices will take place most regularly if the concentration of the juice content is regulated to a similar extent each day. This is accomplished as previously stated by regulating the extent of wither to produce 38 to 46% weight of made tea to weight of withered leaf. This

refers to normally withered leaf and no particulars are available regarding the best concentration of juices in leaf cut during the early stages of withering.

As an explanation of standard juice concentration in normal withering, let us assume the normal output of made tea in a factory is 23% of green leaf weighed in to the withering loft, that is 1,000 lbs. green leaf produces 230 lbs. made tea.

If it is found that the percentage of made tea to withered leaf is 46%, that is 1,000 lbs. of withered leaf produces 460 lbs. made tea, then the necessary green leaf can be calculated as 1,000 lbs. withered leaf multiplied by 460 and divided by 230, giving 2,000 lbs. as the quantity of green leaf normally required in this particular instance.

The percentage of wither is shown by dividing by withered leaf by the green leaf and gives 50%.

In a similar manner and under the same conditions it will be found when the percentage of made tea to withered leaf is 38% that 1,652 lbs. green leaf is required to produce 1,000 lbs. of withered leaf requiring 60.5% wither.

It will be realised that, if the leaf temperature is between 65 and 80°F, fermentation will start in the rolling action, at rates dependent upon the leaf temperature and it should be noted that great care is required during the rolling of leaf to prevent the leaf temperature rising beyond 82 to 85°F, otherwise the aroma will not be developed in a pure state, pungency will be lost, and, a soft taste produced in the tea liquors. It is suggested that heated bruised leaf in contact with oxygen allows fermenting reactions to proceed too quickly in relation

to the mixing of the juices or liquids released from the leaf cells, with a consequent production of insoluble substances and decreased value of made tea.

Creaming.

The best fermenting conditions are possibly produced when the reactions provide a large quantity of soluble substances in the freshly brewed liquor. The changes should partly extend towards insolubility to allow a considerable part of the soluble substances to deposit out (Creaming) as the brewed liquors cool. The partly soluble substances are of a curious nature as they can again be made fully soluble by raising the temperature of the liquor, this is not thoroughly understood. If the reactions are not efficiently produced during fermentation, the creaming effect may not take place with consequent loss in the broker's valuation.

It should be noted that teas that will show a heavy creaming down in one factory and with one type of water may show a marked decline in creaming down in the same or another factory with a different type of water. It is, therefore, better to use distilled water, or carefully collected fresh rain water, and thus allow a standard comparison of tea to be made from day to day. It will repay a Planter to go to considerable trouble on this point as teas that cream down well are sought after by buyers, as representing good liquors. The creaming down properties are, to a great extent, though not entirely so, inherent in leaf and may vary with type of leaf, soil, and climatic conditions.

Stationary Fermentation.

During fermentation, it is important that the reactions should be directed, as far as possible, towards the production of tannin reds to the exclusion of tannin browns. The tannin brown is shown in the addition of milk to the tea liquor, in the production of a coffee colour, not desired by the market. In producing the maximum tannin reds, it is important to study the following practical points:—

1. Eliminate all temperatures above 82–85°F.
2. Eliminate evaporation from leaf, i.e., leaf must be fermented in contact with air regulated in humidity according to temperature conditions.
3. Eliminate thick spreads above 2½ inches, which may produce temperatures above 85°F.
4. Eliminate thin spreads, if they allow evaporation to take place.
5. Eliminate bacterial action (putrefaction) which encourages discolouration of leaf, and produces a dark coloured liquor.
6. Do not allow leaf to come into contact with iron which produces a dark coloured liquor.

It must be remembered that all tannin liquids in the early stages of fermentation are very pungent, raw and brisk, and that all changes which produce colour and strength in liquors take place at the expense of pungency, briskness, etc.

During the fermentation of leaf, which is spread about 2½ inches thick, and having an initial temperature of around 73°F; reactions will produce, in 2½–2¾ hours,

an increase in leaf temperature to 82 or 85°F. At this point, the first nose is produced and represents the best time for removal of fermented leaf to the drying machine. The greatest pungency, briskness, etc., is thus produced in made tea.

If the leaf is left undisturbed, the reactions will proceed with temperatures retained around 85°F for a further period of 1 to 1½ hours, when the leaf reaches the stage of second nose. At this stage the leaf has increased in strength and colour in the brewed liquor but has lost pungency, etc. Loss of pungency, etc., continues for approximately a further one hour with a temperature retention around 85°F. after which the temperature drops, and the leaf will then be found to have become exhausted, and the brewed liquors soft, with no pungency or briskness, etc.

It is not possible to indicate more than the maximum temperature, after which serious damage is likely to occur, and the approximate times at which changes take place. Each factory must find its own correct periods. No general rule can be laid down.

As previously stated, cold rolling eliminates fermentation during the rolling stages, or reduces it as required to produce tea with a greater reserve of pungency, briskness, etc., but the final fermenting stage must be carefully guarded to prevent loss of pungency, etc.

It is stated by some people that excess of air combined with thin spreading of leaf may extend the changes from the production of tannin red to undesirable tannin browns. It is practically noticed that tiers of super-imposed racks with wet thin cloth hung round them produce good bright infused tea. Such conditions should

reduce the oxygen supply from the air to the leaf juices and slow down the fermenting reactions. This method of handling leaf must be judged from its adaptability to local conditions, and possibly may be more favourable in cool climates.

The remarks previously made on the atmosphere of rolling room are equally applicable to the fermenting room, and on the subject of lighting it is doubtful whether light, dark, green or red light affects a ferment. Sun should, of course, be excluded, but beyond this the matter is a very open question. A cool, fresh and fairly humid atmosphere is certainly more important.

Space, on which to spread the normal quantity of fermenting leaf at about $1\frac{1}{2}$ inches for finer and $2\frac{1}{2}$ inches for the coarse bulk, should be available, at any rate for the greater part of the normal year. Whether it is worth the capital outlay to provide sufficient space to cope with the remaining rush period is doubtful and can only be determined by circumstances. If it is so considered withering, rolling and drying capacity must all be on the same scale, or the money is wasted; this is of considerable importance.

The floor is undoubtedly the best place for the final fermentation to take place, with a free air space to the ceiling. Racks may have to be used, but fermenting leaf generates heat, and with racks this is difficult to dissipate. With leaf on the floor, and a free air space above it, a very slow movement of the air is all that is required.

No rules can be laid down for the time fermentation should be allowed to go on before the leaf goes to the dryer. It may vary from 2 hours for fine leaf, when it is desired to preserve any flavour there may be, to 5 hours

for the coarse bulk. What suits one type of leaf may not suit another, and every district will vary.

It is only by keeping other processes as constant as possible, varying the times of ferment and tasting tea made from them constantly, that the best period can be discovered: also, this will not remain constant through the year as both leaf and air temperatures have seasonal and daily variations.

There is no doubt that the smell of leaf is the best guide but here again, anyone coming in from the fresh air may well detect a difference that would not be noticed very easily if one was constantly in the factory atmosphere. A general time-limit would appear to be best for practical purposes, checked occasionally by smell.

It can be said that much of the care frequently lavished on the fermenting room, its temperatures, its humidity, its red or green windows, and so on, is very often wasted by a quarter of an hour's carelessness and overheating of leaf in the rolling room. The rolling room, therefore, often requires very much more attention than does the fermenting room.

Cold Temperature Fermentation.

The study of fermentation of leaf at temperatures in the region of 50 to 60°F requires further study. The changes in this case may not be quite similar to that usually visualised in fermenting reactions at around 80°F and may come more under a maturing or ripening action similar to that which takes place in the maturing of meat hung in a cool room.

Very little is known on this subject except that good quality tea can be produced from leaf fermented for 12 or more hours in temperatures varying between 50 and 60°F. It is doubtful if artificial cool conditions for this purpose will withstand the capital cost of the necessary machinery and equipment.

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CHAPTER VI.

DRYING OF TEA.

It is interesting to note in past experience of tea drying, at a period before special care was taken to register inlet air temperatures to dryers, that the Planter usually judged the necessary inlet air temperature by the feel of the leaf discharged from the dryer. Thus, with a single firing process, the inlet air temperature might be at a maximum of around 220°F, while in the first firing stage of a double firing process the inlet air temperature might be at around a maximum of 240°F and varied in each case to suit the average condition of leaf fed to the dryer.

In recent years, it has been illustrated, in the drying of well withered and fermented leaf, that a good average tea product can be produced in single, or double firing processes, with an inlet air temperature of 180°F. This inlet air temperature gradually became fairly general in Ceylon and although it produced good tea from well withered leaf, considerable trouble has been experienced from the production of undesirable tea in the treatment of under-withered leaf and especially with small cut or C.T.C. treated leaf or other type of small cut leaf having increased water content.

These troubles led to a careful study of existing drying conditions and it has been shown that fermenting reactions if carried to the desired stage, and latterly under the correct temperature control in the dryer, will produce made tea with good pungency, etc., but if the reactions are carried too far, or fired at too low a temperature, the

made tea may lose all pungency, etc., and become more or less a dead material.

It was previously stated that fermenting reactions could be eliminated by reducing the leaf to a temperature under 50°F, at which point the ferments will not react to any extent, in contact with oxygen.

Fermenting Reactions.

In drying leaf with existing methods, it is desired to eliminate fermenting reactions as far as possible. It is, however, necessary to extract water from the fermented leaf by means of heat application and, in this connection, it is known that fermenting reactions can be reduced to practically nil by exposing the leaf in thin layers to the percolation of natural air heated to 150°F or 160°F.

The passing of fermented leaf from exposure to natural air conditions to that at 150°F air temperature should have a very close study, due to the fact that it is required to cover a temperature between a period when the leaf passes from say 80°F to 110°F. During this period, the fermenting reactions are accelerated to a very great extent and the loss of pungency, etc., will depend upon the time taken for the leaf to pass from 80°F to 150°F, without a care-hardening effect, especially during the period of exposure when the leaf passes from 80°F to 110°F, after which the reactions decrease progressively in activity to the 150°F, point, when they will be practically nil.

If fermented leaf be brewed, the liquors will be found to have a very strong pungent and rasping taste, but if the fermented leaf be dried under good conditions,

the liquors will be found to have become less pungent and more mellow, illustrating that reactions possible of a digesting type (fermentation) take place even under good drying conditions. If the drying conditions are poor, stewing or uncontrolled fermenting reactions will take place, and can cause almost a complete loss of pungency, etc., and in warm climates produce a tea termed flat, soft, etc.

A careful investigation carried out in the existing methods of drying tea illustrates that the pungency, etc., in made tea liquors is dependent upon the reduction of fermenting reactions to a minimum during the drying period by means of a good percolation of air having a temperature control of 150°F to 160°F at a point under the second top tray in an eight-tray dryer. An extension of the investigation to tea districts in India and Ceylon indicates that the temperature can be raised to 160°F under the top tray of a six-tray dryer or in the Venetian Type dryer.

Control Temperatures.

It is found in all cases, in the first stage of a double firing process, or in the single firing process, there is a limit of 170°F under the second top tray, beyond which there is a tendency to case-harden leaf with resultant reactions in packed and stored tea, resembling that of under-fired tea. On the other hand, a reduction below 150°F under the second top tray of an eight-tray dryer prolongs the time for the leaf to reach 150°F at a lower point in the dryer, with a consequent increase in stewing reactions and a direct reduction in pungency, etc.

It will now be realised that leaf fed to the dryer represents a product containing large and small leaves and also with a water content which may vary from 48 to 68% or more by weight of leaf fed to the dryer.

Under these conditions, it is absurd under existing conditions to try and retain regular inlet air temperatures to dry a variable leaf product; therefore, the only practical method resolves itself into the control of a vital air temperature at a fixed desirable point within the dryer drying zone and this, by practical experimentation, is found to be best placed under the top tray of a six-tray dryer or under second top tray of an eight-tray dryer.

The critical or vital control temperature is found to be around 150 to 160°F; therefore, standardised tea of best quality can be produced with this control, provided the inlet air temperature is allowed to adjust itself to suit the water and other variation in the leaf fed to the dryer, within maximum air inlet temperatures decided upon. It must now be remembered that such maximum temperatures correspond to maximum outputs from the dryer and the dryer output will be greater or smaller dependent upon the maximum allowable inlet air temperature necessary to maintain the vital control temperature point within the dryer as previously stated.

For instance, with a comparative air circulation, a similar output of tea from a dryer could not be expected with an air inlet temperature of 180°F as compared with that to be obtained from an air inlet temperature of 220 to 240°F.

The resultant storage properties of leaf dried with air circulation at under the necessary vital control temperature may increase quality production but, at the same

time, reduce the length of period during which that quality can be retained under storage.

Effect of Temperature Control.

With correct percolation of air, and a thin spread of leaf, combined with an air temperature control under the second top tray of an eight-tray dryer at 150°F, the exhaust temperature will be around 130 to 134°F, say an average of 132°F, giving a mean temperature on the two top trays between 150 and 132°F, of 141°F. Should air or leaf conditions, or a combination of both, reduce the vital control air temperature under the second top tray; it may be found that the 150°F point is not reached, under extreme cases, until the leaf reaches a point under the 5th or 6th top tray.

The exhaust temperature will then be reduced to around 110°F and the mean temperature for the two top trays average around 120°F, or a mean temperature of 130°F for the five top trays.

In the first operation of a double drying process in an eight-tray dryer, and with the driving belt on the middle tray speed, the leaf will under normal conditions take 4.1 minutes to pass from the point of entry to the drying chamber, to the end of the second top tray, and enter within the vital temperature control zone of 150°F.

Should excess leaf or its increased water content decrease the air temperatures too quickly, it may be found that a stewing reactions occur, and reduce the vital control temperature under the second top tray. The leaf has then to travel farther downwards, possibly to a position under the fifth top tray before it reaches an air temperature of 150°F. The period of passage of leaf

in the dryer to the 150°F point will then be increased from 4.1 to 10.2 minutes. The decreased quality effect in made tea may be approximated by the index reaction figures of 578-1326.

The index reaction figure is obtained by multiplying 141°F, average temperature of two top trays by 4.1 mins. equals 578; and by multiplying 130°F average temperature of the five top trays by 10.2 mins. equals 1326.

In a single firing process, and the driving belt on the slow speed, the corresponding periods of leaf passage in the dryer will be 7.5 and 18.5 minutes, and will naturally increase the loss of pungency, etc., the approximate corresponding index reaction figures will be 1057 to 2400. The loss of pungency will vary and be less in cool climates where a slow rate of ordinary fermentation may be balanced by accelerated fermentation in the dryer.

Experience points to the fact that an efficient single firing process is only possible if the fermented leaf fed to the dryer has a maximum of 60% water content and preferably around 50 to 58%.

Leaf exceeding 60% water content requires a double firing process; otherwise it is not possible to maintain a vital control temperature of 150°F in conjunction with reasonable inlet air temperatures or reasonable outputs of tea from the dryer. This statement can be referred to all types of fermented leaf.

It is true that cut or C.T.C. leaf may dry more quickly than rolled leaf, but it is also true that small leaf with increased water content may reduce the temperature of circulating air too much, and bring the vital control temperature of 150°F below the desired point in the drying zone; and thus increase the loss of pungency, etc.

In the drying of C.T.C. treated, or cut tea leaf, it is better to increase the vital air control temperature under the second top tray of an eight-tray dryer from 150°F to some point within a maximum of 170°F (dependent upon local conditions) necessary to produce a tea which will retain quality under storage. The first firing operation should cover 25 to 30 minutes and tea should be discharged at 13½ to 14 anna dryness. Output of a 6'-0" eight-tray dryer may require to be reduced from 480 lbs./hr. to 300 lbs./hr. to obtain this object.

A careful survey of conditions in relation to the suction type dryer, with decreased air capacity, in comparison with the more modern pressure air dryer having larger air circulation may show a very considerable loss of pungency in made tea produced from the suction dryer. This remark refers to Estates situated below 5,000 ft. elevation.

The loss of pungency may vary in relation to an index figure of 580 to 1060 in the drying process in the pressure air dryer as compared to the suction air dryer and illustrates the recent tendency to change suction air dryers to pressure air circulation. The object being to obtain the vital air control temperature of 150°F at the correct position in the drying zone. The following data is interesting in relation to this subject.

Reaction Figures—6' - 0" Eight-Tray Dryer.

Tray Speed Ft. / min.	Total Time in Dryer.	Time to 150° F. 2nd tray.	Index	Time to 150° F. 5th tray.	Index.
3.3	29.7 mins	7.5 mins.	1057	18.5 mins.	2360
4.5	21.6 ..	5.4 ..	781	13.5 ..	1755
6.0	16.3 ..	4.1 ..	578	10.2 ..	1326
7.9	12.3 ..	3.1 ..	437	7.7 ..	1001
10.3	9.4 ..	2.4 ..	338	5.8 ..	754

Drying Conditions.

The art of drying tea under existing methods is to expose the rolled and fermented leaf to currents of air which will, without loss of quality in made tea, stop fermentation and fix the fermented juice in a dried state within the leaf fabric in a condition most suited to the average human taste.

As previously stated, it is possible to develop properties of quality in leaf by accelerating fermenting reactions within definite control points in withering or rolling. Such leaf is then more sensitive to rapid reactions which may cause loss of quality during the initial period in drying when the leaf passes from 80 to 120°F. With such leaf, this danger period must be as short as possible and the vital control temperature raised from around 150°F to around 170°F.

The killing of fermentation in the drying process might be reasonably termed a heat sterilisation process and depends upon its success on evaporation of water and raising the tea leaf itself to a maximum of 170–180°F, preferably around 170–175°F, near to the point of discharge from the dryer.

Very great care is required to prevent case-hardening of the outer surface of the leaf. Should the leaf become case-hardened, the evaporation of water proceeds at a decreased rate, with the result that internal heat will accumulate in the leaf, and cause loss of quality in a manner somewhat similar to case-hardening of leaf, during the withering stages.

A further trouble with case-hardening of leaf is the retention of water in apparently dry tea, the water may

be retained until the storage period and then gradually work outwards to the leaf surface. In a short period of time, the leaf may become mouldy, or lose quality, become flat, or lose all characteristics of the original tea, and become a more or less dead material.

Fortunately, leaf with accelerated fermentation is more porous and allows the easy percolation of oxygen, or the easy evaporation of water; therefore, there is less risk of case-hardening such leaf at higher vital air control temperatures around 170°F than there is with normally rolled leaf which requires the vital control temperature retained between 150 to 160°F.

A careful study of existing tea drying methods illustrates that each individual piece of leaf must be surrounded with a moving current of air.

As the leaf progresses through the dryer, it gradually becomes heated and loses water by evaporation. As this progresses the leaf should gradually come in contact with warmer and more dry air until just before discharge from the dryer, the leaf should be in a fairly dry state and in contact with air having a minimum temperature of 180°F and be around 1-2% humidity, that is almost dry air.

Dryer Air Circulation.

A study of air circulation illustrates that under normal conditions, a 6'-0" Dryer reducing leaf from 66% water to around 15% water content in the first firing stage followed by a Venetian Type Dryer in a final firing stage reduces the leaf from 15% to 3% water content and will produce around 480 lbs. made tea per hour. The first firing stage will require 12,000 to 15,000 cub. ft. or

air circulation per minute followed by 8,000–9,000 cub. ft. or air per minute in the final dryer, representing 1,500 to 1,880 cub. ft. of air per 1-lb. of made tea in the first dryer and 1,008 to 1,128 cub. ft. of air per 1 lb. of made tea in the final dryer making a total of 2,508 to 3,008 cub. ft. of air per 1 lb. of double fired tea.

If the tea is dried in one single firing stage the air circulation will require 12,000 to 15,000 cub. ft. of air per minute for a discharge of 350 lbs. dry tea per hour representing 2,058 to 2,568 cub. ft. of air per 1 lb. of made tea.

The most efficient method of drying could be obtained by regulating the air circulation volume to the water evaporation, but it is very obscure, as yet how far this economy can be obtained, at the expense of the toasting or sterilising temperatures required for the retention of quality in made tea, and any development work in this direction would require to be carried out with great care.

Water Evaporation.

A study of the 6'-0" eight-tray dryer as applied to N. E. Indian Tea Trade illustrates that 100 lbs. of green leaf containing 25 lbs. of made tea may be withered down to 75 lbs. before being placed in the dryer.

1 lb. of made tea will, therefore, be equivalent to 3 lbs. of fermented leaf placed in the dryer and will require the evaporation of 2 lbs. water.

With this type of fermented leaf, it is better to divide the drying operation into two stages and evaporate 1.6 lbs. water in the first stage leaving 0.4 lbs. water to be evaporated in the final stage per 1 lb. of made tea pro-

duced. This is scientifically not quite correct as the made tea is not dry but contains 2.5 to 3.0% water when discharged from the final dryer; however, it is sufficiently correct for all practical purposes.

In calculating an output of 480 lbs. made tea per hour from the two drying stages it will be found that 768 lbs. of water is evaporated in the first firing stage with the use of around 15,000 cub. ft. of air per minute or around 1,170 cub. ft. of air per 1 lb. of water evaporation.

In the final stage of firing, 192 lbs. of water requires to be evaporated with the aid of around 8,000 cub. ft. of air per minute or around 2,480 cub. ft. of air per 1 lb. water evaporation. The final drying stage is more of a toasting process than an actual water evaporating one.

In the first firing operation, during wet weather conditions, and with an air supply of 15,000 cub. ft. at 90°F and full saturation (approximately 1,000 lbs. air per minute), the exhaust air will have a temperature of around 130°F, provided the vital air control temperature of 150°F is maintained correctly in the drying zone. Under such conditions, the exhaust air, after absorbing the water of evaporation, will have a humidity of 39.5% which may increase to 95% under poor working conditions; caused by over-feeding leaf to the dryer, or decreased air circulation, when 150°F may be found under the 5th top tray and the exhaust temperature, reduced to around 105°F.

Retention of Quality.

The poor working conditions can be rectified by either of the following means found suitable to meet local conditions:

1. By reducing the quantity of leaf fed to the dryer.
2. By reducing the dryer tray speed, the fan revolutions per minute remaining as before.
3. By increasing the fan revolutions per minute in relation to tray speed.
4. By increasing the maximum allowable air temperature necessary to restore the vital air control temperature under the second top tray to 150°F.

Full pungency and quality in made tea is only retained at a maximum if the exhaust and inlet air temperatures are allowed to vary to suit the maintainance of a vital air control temperature of 150–160°F at the correct point in the drying zone. Loss of pungency and quality will vary in relation to the position of the vital air control temperature in the drying zone, and explains, in great measure, the variable tea product produced by regulating the inlet air temperature and allowing the vital air control temperature point to vary from under the second to under the fifth top tray in an eight-tray dryer in relation to any variation in weight of leaf or, water content in leaf, fed to the dryer.

Inlet Air Temperature.

In order to calculate the inlet air temperature necessary to produce good working conditions in a dryer drawing 15,000 cub. ft. per minute of natural air at 90°F. and around 100% saturation into the air heater, it is necessary to calculate the heat units (B. Th. Us.) The undernoted figures give an approximate idea of the values. An allow-

ance has been made to cover average losses of radiation, etc. It should be noted that one B. Th. U. represents the heat required to raise 1 lb. water 1.0°F.

Inlet Air.	Exhaust Air.	Tem. Dif.	B. Th. Us. used in Dryer.	B. Th. Us. Lost to exhaust.	Useful Total B. Th. Us. received by air.
180°F.	130°F.	50°F.	11,850	9,500	21,350
190	130	60	14,120	9,500	23,620
200	130	70	16,590	9,500	26,090
210	130	80	18,960	9,500	28,460
220	130	90	21,330	9,500	30,830
230	130	100	23,700	9,500	33,200

Calculations based on dry air, see page 98.

In order to make a profitable use of the previous table, an example of calculation is given relative to the previously mentioned evaporation of 12.8 lbs. water per minute, or 768 lbs. water per hour.

1-lb. water evaporation requires approximately 1,010 B. Th. Us. under the dryer working conditions.

Heat required for evaporation will be 12.8 multiplied by 1,010 B. Th. Us. or a total of 12,928 B. Th. Us. per minute.

Heat lost to exhaust is, approximately, exhaust air temperature 130°F minus air temperature 90°F equals 40°F multiplied by 1,000 lbs. air per minute multiplied by constant 0.237 equals 9,500 B. Th. Us. per minute. The constant 0.237 is used because 0.237 B. Th. Us. is required to raise 1-lb. dry air 1°F in temperature.

Heat required to warm tea to 170°F plus heat lost to radiation can be approximately estimated as 80% of

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the heat lost to exhaust or 9,500 multiplied by 0.8 equals 7,600 B. Th. Us.

Heat to evaporation of water	..	12928	B.Th.Us.
Heat lost to exhaust	.. ..	9500	„
Heat to warm tea, radiation, etc.		7600	„

Approx. Total heat requirement .. 30028 B.Th.Us.

If we now turn to previous table, it is found that an inlet air temperature of 220°F will be required. It should be a simple matter for anyone to make a similar rough calculation sufficiently accurate to act as a practical guide without the intricate calculations required for a more scientific calculation.

It will now be realised that, in the case just mentioned, a reduction of inlet air temperature from 220°F to say 180°F would not provide sufficient heat in the circulating air to give correct drying conditions and explains, in great measure, the troubles experienced in India during 1931 to 1932 with low inlet air temperatures, especially during poor weather conditions. The quantity of leaf to be dried is at a maximum during poor weather, and by overloading dryers in relation to maximum inlet air temperatures, the characteristic monsoon stewed tea is produced.

It should be understood that during good weather conditions in Assam or, with the use of controlled withering houses, it is possible to obtain a fermented leaf with considerably reduced water content and it is then possible either to reduce the volume of air passed through the dryer or decrease the maximum inlet air temperature necessary to maintain the vital air control at 150°F under the second top tray of an eight-tray dryer or under the

top tray of a six-tray dryer, *see* calculations on pages 89 to 91, under heading 'Inlet Air Temperatures to Dryers.'

Type of Dryer.

The choice of drying machinery is now greatly extended from past years but to a great extent the existing machines follow three distinctive types, each of an efficient type.

1. The Endless Chain Type in which the internal travelling tray surfaces are provided by three or four sets of double endless tray surfaces moved by chains and arranged so that leaf can pass backwards and forwards six or eight times the length of the dryer before being discharged in a fully or partially dried condition. Both types produce well fired tea dependent upon the local conditions of leaf supply, and its water content; also upon the air circulation and its control temperature conditions.

The main difference in old and new type machines is represented by the design of air heaters, each of which provides a large heating surface area for transmission of heat from the fuel combustion gases to the circulated air. Working costs and repairs will be increased, and discharge of leaf decreased, from a dryer fitted with small and inefficient heating surfaces. The endless chain type of dryer is usually best suited to mass production of fairly large quantities of made tea ranging from 350 to 480 lbs. made tea per hour; they are suitable for the full retention of quality and pungency in made tea.

Many people prefer the latest type of endless chain dryer fitted with a separate leaf feeding arrangement as against the type which provides an extended arrangement of the top double tray sections. The reason being that

the separate feeding arrangement allows the tray surfaces to remain cool, as compared with heated tray surfaces in the extended tray type.

2. The Venetian or tilting tray type of dryer in which leaf is spread on an exposed top tray surface, made of separate trays each of which can be tilted at will, and thus deposit the leaf on a lower and similar tray surface. Usually six superimposed tray surfaces are used, each capable of being tilted.

These dryers are usually used for the final firing of tea leaf, or for the full firing of fine and small tea grades of good quality, which are best dried by hand regulation of the speed at which the leaf is passed through the dryer, and thus ensure the discharge of a well toasted leaf, with full retention of quality in the made tea.

The outputs of made tea are usually about half that of the endless chain ones and they can easily follow in the final firing of partially dried tea discharged from the endless chain dryers.

3. Down draft dryers represent a type of dryer in which the circulating air passes downwards through the tray surfaces; fresh non-tilting trays are fed to the dryer, and by a special arrangement of levers, they are moved upwards as desired and extracted from a position near to the top of the dryer.

In all types of existing dryers, it has been usual to heat natural atmospheric air and circulate it through the dryer. Some attempts have been made to partially or fully condition the air before heating it, *i.e.*, to extract water from the atmospheric air and produce a standard fairly dry air supply. The success of such systems has so far been defeated by the cost of an air conditioning

plant and the necessary requirements of a comparatively high air temperature application to give a heat sterilisation to ensure the provision of the best storage properties in made tea.

Fuel Consumption in Dryers.

The efficient working of tea dryers is often mistakenly calculated in terms of made tea in relation to fuel consumed. The highest fuel economy is then considered to be the smallest expenditure of fuel to produce 1-lb. made tea, and is mostly obtained under drying conditions which produce stewed or underfired tea.

It is important to remember that the cost of fuel is small compared with the value of the tea product; therefore, the cost of extra fuel necessary to produce good drying conditions will be recovered many times over from increased market prices obtained from made tea.

The cost of fuel varies in different districts and may be approximated from the fuel consumption table. On page 97 are shown the average costs of fuel per 1,000 lbs. made tea at minimum and maximum fuel consumption. It must, however, be remembered that maximum fuel consumptions may be increased, if only a comparatively small quantity of tea is made in the dryer.

The quantity of fuel required per 1 lb. made tea can be reduced if the vital air control temperature is not correctly maintained in the drying zone or if bye-passed air, as explained later, is used to an excessive extent, and results in a false vital air temperature control.

On the other hand, the necessary fuel consumption can be decreased to the practical minimum by careful

practical supervision on the following points, always provided a correct vital air control temperature is maintained within the drying zone.

The dryer should be kept as constantly full of leaf as possible; otherwise, heated air escapes and produces a wastage of fuel without any relation to tea production.

During the preliminary heating up period, the dryer fan should be worked, but the air circulating valve should be practically closed allowing only a small quantity of air to pass through the air heater and dryer chamber until the desired working temperature is reached, and thus save fuel during the heating up period.

After the drying work is completed, any small remaining fire should not be removed, but allowed to die down gradually by closing the chimney damper, closing the fire door and its ventilating grid, closing the ashpit opening either by means of the ventilating grid, or by placing a special sheet iron plate tightly over the ashpit opening. By these means, all accumulated furnace heat can be retained, as far as possible, until next morning.

Considerable fuel consumption can be saved by the use of some type of bell or other instrument of sound by means of which the dryer attendant can draw the fireman's attention to any change in leaf about to be fed to the dryer and thus allow the fireman to regulate the furnace fire to suit the condition or quantity of leaf fed to the dryer. Such co-operation between the dryer attendant and fireman will reduce fuel consumption and increase the quality of tea production.

Fuel consumption may be increased by reason of increased air humidity, either naturally in cases when the

furnace is placed outside the factory, or artificially when the furnace is placed inside a badly ventilated firing room.

Owing to the smallness of Assam coal, it is found beneficial to wet it slightly before stoking. All unburnt particles which fall through the firebars can be usefully raked up and mixed with fresh unburnt coal, or a special turbine design of fire grate can be used.

A common mistake, especially with the use of small coal, is to add excessive quantities of fuel at long intervals of half hour or so. This causes overheated fire-bars, incomplete combustion, and spasmodic expansion of furnace parts, leading to increased furnace replacements.

Fuel economy is produced by a bright burning fire from fuel spread evenly over the grate area; any excessively thin fuel spots on the fire-bars allows larger quantities of air to be drawn to such parts, with the result that sufficient air does not pass through the thicker fuel layers to keep the fire-bars cool. The fire-bars may thus be burnt out wholly or partially while the combustion efficiency decreases and fuel consumption increases.

A slow fire with a dull burning upper surface is caused by insufficient air draught and is not economical. Sufficient air does not pass to keep the fire-bars cool and they become burnt out or twisted; the following reasons may cause this trouble:—

Length of chimney may not be sufficient to overcome resistance to the passage of air through the fire and smoke ducts, chimneys range from 30 to 40 ft. high.

Smoke ducts may be too long or have too many bends, badly designed ducts may add 10 feet or more to the chimney height. Damp ducts reduce chimney draught.

Furnace fire door or its ventilating grid may allow too much air to pass over the top of the burning fuel and not enough air drawn through the burning fuel; this will cause fire-bar troubles.

If the chimney is damaged or the damper be uncontrolled, the draught may be destroyed and produce a slow burning fire with consequent fire-bar troubles.

If too much hot ash or small burning coal accumulates in the ash pit, the fire-bars may be overheated and damaged.

Coal fires may be too thick and cause too much resistance to passage of air through the burning fuel and cause fire-bar trouble.

Wood fires may be made by placing logs closely side by side and built up to some considerable height, especially if the logs be damp or unseasoned. In such cases, wood logs usually allow open spaces at front or back of fire-bar area, with the result that the air draught passes freely through the open spaces with greatly reduced draught through the compact mass of burning logs. The resultant effect is a poor fire accompanied by a tendency for flame to be drawn along the underside of the fire-bars from the burning logs to the open fire-bar spaces. Such conditions overheat the fire-bars and may destroy them within a period of one to two weeks.

Good firewood burning conditions are best obtained by cutting wood logs into lengths of 12 to 18 inches long and spreading them evenly over the grate area. This method produces good burning conditions, eliminates fire-bar troubles, and makes a saving of 25 to 30% in the wood fuel bill.

Withering fans may reduce drying room air pressures and require to be balanced by 10 to 20 feet extra chimney height; this refers only to furnaces placed inside a closed factory or firing room. This is only correct if the air heater is situated within the drying room.

Storage of Fuel.

It is general practice on many Estates to store coal or wood fuels in the open, exposed to weather conditions of rain and sunshine.

Under such conditions, some types of coal will deteriorate and more or less quickly reduce the possibility of obtaining bright and efficient combustion.

Accumulation of water in coal can be very considerably reduced by arranging a convenient covered storage place to hold 2 to 3 days supply of coal.

With wood fuel, the wood logs should be seasoned for at least 3 months to partly remove the internal sap or water content. The best method of storage is to pile the logs with the lower layer slightly above the ground surface and the upper layers placed in such fashion as to allow air ventilation. The whole pile of wood should be covered with some cheap weather protection, such as thatched grass, etc.

Firewood may be considered to be in good condition when it contains around 20–25% water content and to be unsuitable or uneconomical when it contains around 40% water. In this latter case, 10 to 20% heat value of the fuel is wasted in evaporating water from the fuel itself and the fire is reduced to a slow burning and uneconomical one, requiring large quantities of wood on the fire-grate at one time, which condition may reduce the draught

through the fire-bars and allow them to be overheated or damaged.

Control of Air Circulation Tea Dryers.

Tea Dryers are designed to give an ample air circulation at normal fan speeds and elevations up to 1,000 feet above sea level.

Some Dryers are designed with double fan speeds, *i.e.*, normal slow fan speed for good weather or well withered leaf, and normal high fan speed for poor weather or under-withered leaf containing excess water content.

At elevations above 1,000 ft. special attention is required to regulate the correct fan speed. At higher elevations, the air becomes more rarified and therefore will absorb less water per cubic foot of air circulation than at lower elevations. It is usual, therefore, to increase fan speeds about 10 R. P. M. for every .01 decrease in relative density of the air. This is affected both by elevation and temperature of air, and is more fully described under the heading "Speed of Dryer Fans."

The volume of air passing to the air heater should have free access from the outside atmosphere to the air heaters, and the heated air exhausted from the dryers should pass easily, by good means of ventilation, from the firing room.

Should the air heater and dryer be both placed within a badly ventilated firing room, the firing room atmosphere will be used over and over again, and soon become overheated, and over-saturated with moisture beyond the condition possible to retain quality in tea, during the drying stage.

Air Bye-Passes are usually fitted to dryers for the purpose of conveying a portion of the heated air from the lower tray sections directly to the upper ones. This is sometimes a most dangerous procedure and may provide a false temperature at the vital control point of a dryer. By this means, fuel consumption can be reduced at the expense of a considerable reduction in quality in made tea.

Starting the Dryer.

During the warming up of air heater, the air fan should be worked with the air control valve about 1/8 full open, just sufficient to prevent damage to the air heater parts.

On starting up the dryer, either for the first time each day, or after a period of rest, the leaf should be fed to the dryer with the air control valve 1/4 full open. During the first leaf feeding period, the vital air control point, under the second top tray of an eight-tray dryer, will register a temperature near to the inlet air temperature, but as the leaf travels downwards to the third top tray, the air temperature at the vital control point will decrease. The main air control valve should then be gradually opened to maintain the necessary vital control temperature at a minimum of 150°F., the valve should be fully opened as the dryer becomes fully loaded with leaf.

Should the air temperature and volume not be carefully regulated, as suggested, there is a grave risk of overheating or case-hardening to the first 100 lbs. of leaf discharged from the dryer and possibly a decrease in the market value of bulk tea.

Control of Leaf Passing to the Dryer.

The latest types of Dryers are fitted with a separate leaf feeding arrangement which allows the feeding blank tray surfaces to keep cool and prevents loss of leaf sifted through the perforated trays of extended feeding tray arrangements.

On the extended tray arrangement fitted to older type dryers, the heated trays may in hot climates encourage the acceleration of fermenting reactions and allow small leaf to be sifted through the tray perforation at a point under the mechanical spreader. If the leaf is of a sticky nature it may partly adhere to the heated tray surfaces.

The sifted leaf may have its fermenting reactions considerably accelerated, with a resultant decrease of quality in made tea. It is, therefore, better to replace all extended feeding arrangements with the recent new type of separate feeding ones.

The Mechanical Spreader of either a separate or an extended feeding arrangement should not exceed a speed of 70 R. P. M. In some cases, the spreader is revolved at around 150 R. P. M. and upwards; there is then a risk of leaf being thrown upwards and exposed to the firing room atmosphere with consequent acceleration of fermenting reactions, or production of tannin browns.

The blade tips of the spreader should be periodically examined and if necessary reset so that the blades are parallel with the tray surfaces, and about 1/8" above the highest part of the tray surface, when the spreader is at its lowest position.

Control of Leaf Passing through Dryer.

Advantage is sometimes obtained by fitting an individual spreader on each sectional tray surface within the dryer so that the leaf, after it has dropped from one tray surface to the lower one, may be retained in an even spread.

Such rotating spreaders may have a tendency to sift fine leaf through the tray perforations; therefore, it may be better to utilise non-rotary individual spreaders.

In order to determine whether the leaf should be dried in a single or double firing process; it is necessary to know the approximate water content of leaf fed to the dryer.

With controlled withering houses, at elevations of 2,000 ft. and upwards, it is generally possible to provide fermented leaf at 50–60% water content. Under such circumstances it is possible to fire leaf in a single process.

On Estates situated under 2,000 ft. elevation and with controlled withering houses, it is more usual to provide fermented leaf between 58 and 64% water content. Under such circumstances and especially with leaf over 60% water content, considerable care is required in a single firing process.

On Estates with uncontrolled withering houses, where fermented leaf is provided with 60 to 70% water content, the firing of leaf should be carried out in two stages.

Should fermented leaf be passed too quickly through the dryer, it may have the fermenting reactions accelerated or if spread thin, the leaf may be case-hardened. In either case, the result will be loss of quality in made tea

either before or after storage. The following points are important:—

First Stage, Double Firing Process.

(1) Leaf should be fed to the spreader in small quantities, so that each charge of leaf does not stay in front of the spreader more than a maximum of two minutes. It has been found in some cases that a charge of leaf may lie for eight to ten minutes before passing under the spreader. The spreader should not revolve at more than around 70 R. P. M.

(2) Leaf should take at least 20 minutes to pass through the dryer.

(3) Leaf should be discharged with 18 to 25% water content, *i.e.*, 14 to 12 anna dry.

(4) Temperature of air under the second top tray of an eight-tray dryer should not be under 150°F and not above 160°F, unless specially treated leaf is being dried, when the temperature of air under the second top tray may increase to 170°F. It is often necessary during wet days, when withering is bad, to increase the maximum inlet air temperature in order to secure conditions enumerated in items 1, 2, 3 and 4.

(5) Inlet air temperature should not decrease below 180°F, and should not, in the ordinary course of events, increase above 240°F. Cases are known where the dryer has been so over-loaded that the inlet air temperature has had to be increased to 260°F, in order that 150°F be maintained under the second top tray of an eight-tray

dryer and the stewing reactions reduced to normal in made tea. Such high inlet air temperatures cannot be allowed if the water content in discharged leaf is reduced below 20%.

(6) Unrestricted flow of air to the air heater, unrestricted escape of air from the drying chamber, and a well ventilated firing room are necessary for the retention of quality in made tea.

Second Stage, Double Firing Process.

As per No. 1 in the first stage.

Leaf should be at least 20 to 30 minutes in the dryer.

Leaf should be discharged with 2.5 to 3.5% water content.

Inlet air temperature should be 180°F.

As per No. 6 in the first stage.

Single Firing Process.

As in No. 1, first stage, double firing process.

Leaf should be at least 30 to 40 minutes in the dryer.

Leaf should be discharged with 2.5 to 3.5% water content.

As per No. 4 in the first stage of the double firing process.

Inlet air should not decrease below 180°F and not increase above 220°F.

As per No. 6 in the first stage of the double firing process.

In all cases, it should be remembered that the possible discharge of leaf from the dryer is in relation to the inlet air temperature, always provided that the temperature under the second top tray does not fall below 150°F; thus 180°F inlet air temperature will give a minimum discharge of leaf. If the discharge of leaf from the dryer is forced, the temperature under the second top tray may fall below 150°F and excessive stewing reactions will result.

Atmospheric Air Conditions in Relation to Tea Drying.

To understand the theory of drying, it is necessary to realise that one cubic foot of air is not a fundamental or a comparative quantity as its value changes with temperature and elevation, decreasing in weight with increased temperature or elevation above sea level.

On the other hand 1.0 lb. weight of air represents a definite unchanging value in relation to the quantity of moisture which it can absorb and is independent of changes of temperature or elevation so long as its volume can expand or contract; therefore, as air alters in volume to suit temperature and elevation and water content it is always better to think in weight of air only, and not in volume.

As an illustration, 1 lb. of air at 90°F and in a saturated water condition (100% saturation) will occupy a volume of 14.55 cubic feet of free space and hold

0.031 lb. of water vapour in suspension; any variation of temperature will affect the volume and not the quantity of water which it carries within certain definable limits thus:—

If the temperature of 1 lb. of saturated air at 90°F and a volume of 14.55 cubic feet is reduced to 60°F, its water carrying capacity will be reduced from 0.031 to 0.011 lb. of water; therefore, the 1 lb. of air will be compelled to drop or deposit out 0.031 minus 0.011 or 0.02 lb. water during the drop in temperature. In decreasing from 90 to 60°F, the 1 lb. of air, which at 90°F contained 57.50 B. Th. Us., will decrease to 26.25 B. Th. Us., losing 31.25 B. Th. Us. At the same time the volume will decrease from 14.54 at 90°F to 13.32 cubic feet at 60°F. It will, therefore, be realised that the loss of water is best referred to the weight of air which does not change, and not to the volume of air which has altered.

If the temperature of 1 lb. of saturated air at 90°F is increased to 150°F, its capacity for carrying water will be increased from 0.031 to 0.212 lb., therefore, the air at the higher temperature will be able to absorb 0.212 minus 0.031 or 0.181 lb. water from any wet material in contact with the air. If the 1 lb. of air has not absorbed water from any wet substance during the heating period, it will still contain 0.031 divided by 0.212 or 14.6% of its full or saturated water content. The volume of 1 lb. of saturated air at 90°F is 14.55 cubic feet, but it is increased to 15.0 cubic feet at 150°F and 14.6% saturation; therefore, the water content of the air is best referred to the unchanging weight and not to the changing volume.

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CHAPTER VII.

CALCULATIONS FOR TEA DRYING.

Water and Heat Value of Circulating Air.

In raising the temperature of saturated air from 90°F to 150°F without addition of water, the 1 lb. of air is not only increased in volume but it absorbs 14.5 B. Th. Us, and increases its natural heat value from 57.5 to 72.0 B. Th. Us. This heat can be utilised to evaporate water from any wet substance and represents its natural drying capacity.

If the 1 lb. of air, heated as above, be brought into contact with wet material it will absorb water and in so doing it will give up its heat value from 72 to 57.5 B. Th. Us. It decreases in temperature, and increases in saturation from 14.6% saturation to full water capacity at 100% saturation in the following manner.

150°F and 14.6%—140°F and 20%—120°F and 40%—100°F and 84%—90°F and 100%.

It is usual to calculate the exhaust air temperature from a dryer at around 130°F as necessary to maintain 150°F under second top tray of an eight tray dryer, and it is found desirable that the exhaust air temperature at 130°F should not exceed 40% saturation.

On reference to the Air Table, it is found that 1.0 lb. air at 130°F carries 0.112 lbs. water at saturation point; therefore at 40% saturation, the air at 130°F will carry 0.0448 lbs. water.

Effect of Badly Ventilated Firing Room.

If we consider the effect of a badly ventilated firing room and visualise the original natural atmosphere at 90°F and 100% saturation, heated air and water vapour is continually being added from the dryer exhaust to the drying room atmosphere and soon it may increase to 110°F and 90% saturation.

At this point the drying room atmosphere will carry 0.053 lbs. water per 1 lb. air compared with 0.0448 lbs. water in an exhaust air from the dryer of 130°F and 40% saturation.

If further water of evaporation is added to the air equal to 0.0138 lbs. water per 1 lb. air as previously explained, the total water content in the exhaust air will increase to 0.053 plus 0.0138 or a total of 0.0698 lbs. water per 1 lb. air.

As previously explained, the full water capacity of saturated air at 130°F is 0.112 lbs. water per 1 lb. air. The exhaust air will have reached a saturation of 0.0698 lbs. water divided by 0.112 lbs. water or 70% saturation.

The increased exhaust air saturation from 40% to 70% will thoroughly upset the drying conditions and seriously reduce quality in made tea.

Effect of Weather Conditions.

If we consider bad weather conditions, with air at 90°F and 100% saturation drawn into the heater, it is

found that 1 lb. of such air carries 0.031 lbs. water in the form of vapour.

The circulating air absorbs water evaporation from the drying leaf and is exhausted at 130°F and 40% saturation. In this condition it will carry, as previously explained, 0.0448 lbs. water.

If we consider good weather conditions with air at 90°F and 50% saturation drawn into the heater, it is found that 1 lb. air carries 0.031 multiplied by 50% or 0.0155 lbs. water.

The evaporating capacity of the 1 lb. air can now be calculated as follows:—

Bad Weather Conditions.

One lb. circulating air absorbs 0.0448 minus 0.031 or 0.0138 lbs. water in the form of vapour; therefore, a dryer with 1,000 lbs. air circulation per minute will evaporate 0.0138 multiplied by 1,000 or 13.8 lbs. water per minute as a maximum.

Good Weather Conditions.

One lb. circulating air absorbs 0.0448 minus 0.0155 or 0.0293 lb. water in the form of vapour; therefore a dryer with 1,000 lbs. air circulation per minute will evaporate 0.0293 multiplied by 1,000 or 29.3 lbs. water per minute as a maximum. This illustrates the enormous difference between good and bad weather conditions.

AIR TABLE.

Values of 1 lb. Weight of Air.

Air Temp.	Original Water Content.	Full Water Capacity.	Humidity. %	B. Th. U. Content.	B. Th. U. Full Saturation Content.	B. Th. U. Content Dry Air with no Water Content.
60° F.	0.011 Lb.	0.011 Lb.	100 %	26.25	26.25	14.46
70	0.015	0.015	100	33.80	33.80	16.87
80	0.022	0.022	100	44.00	44.00	19.28
90	0.031	0.031	100	57.5	57.5	21.6
100	"	0.043	72	59.0	73.5	24.1
110	"	0.059	53	61.0	96.0	26.51
120	"	0.081	38	63.0	123.0	28.92
130	"	0.112	28	66.0	160.0	31.33
140	"	0.153	20	69.0	210.0	33.74
150	"	0.212	14.6	72.0	281.0	36.15
160	"	0.299	10.4	74.0	382.0	38.57
170	"	0.434	7.2	77.0	639.0	40.97
180	"	0.657	4.8	82.5	810.0	43.38
190	"	1.098	2.9	86.5	1336.0	45.79
200	"	2.295	2.0	95.5	2730.0	48.20

Inlet Air Temperature to Dryers.

It should be noted that the water content of air makes a considerable difference in its heat value. As any instance, air at 90°F and full saturation contains 57.5 B. Th. Us., but dry air at 90°F without any water content has only 21.6 B. Th. Us. or a difference of 35.9 B. Th. Us.

Thus air at 90°F and 50% saturation would contain 21.6 plus 50% of 35.9 B. Th. Us. or 21.6 plus 17.95, or 39.55 B. Th. Us.

If natural air at 90°F and 50% saturation containing 39.55 B. Th. Us. be fully saturated to 100%, it will still contain 39.55 B. Th. Us. and will, therefore, reduce its temperature to that of saturated air corresponding to

39.55 B. Th. Us. or 76°F. The true temperature is dependent upon the spray water temperature used for saturation. The true result requires further intricate calculation, but the illustration is of approximate practical value so long as it is remembered that the saturated air temperature will be approximately near to that of the spray water temperature. Therefore, if the spray water temperature in this instance be 72°F the saturated air temperature would be nearer to 72°F than 76°F. This information is of interest in the cooling of rolling and fermenting rooms by passing natural air through spray water chambers.

It will also be noted that air of 90°F and 100% saturation heated to 200°F is reduced to 2% saturation, but it must be remembered that the same air without water addition, if reduced to 90°F will again contain 100% water saturation. The water is not lost in heating the air, but the air volume expands and increases the volume of air to its original water content and thus we arrive at 2% saturation at 200°F.

Capacity of Air for Evaporation of Water.

Previous calculations illustrated the inlet air temperature required for an evaporation of 12.8 lbs. water per minute. Further calculations can now be made to show the approximate possible maximum evaporation from 15,000 cub. ft. of air at 90°F and 100% saturation, drawn into the dryer air heater and representing approximately 1,000 lbs. air per minute.

It is assumed that the vital control temperature of 150°F will be maintained under the second top tray of an eight-tray dryer and that the exhaust air will average 130°F with 40% water saturation.

1 lb. air at 90°F and 100% saturation contains 0.031 lbs. water per 1 lb. air multiplied by 1,000 lbs. air gives a water content of 31.0 lbs.

1 lb. exhaust air at 130°F and 40% saturation contains 0.112 lbs. x 40% per 1 lb. air or 0.0448 lbs. multiplied by 1,000 lbs. air gives a water content of 44.8 lbs.

The capacity of 1,000 lbs. weight of circulating air per minute for water absorption is, therefore, 44.8 minus 31.0 or 13.8 lbs. water evaporation or 828 lbs. water evaporation per hour.

Inlet Air Temperature to Dryer, Wet Weather Conditions.

Having now obtained the maximum capacity of circulating air for water absorption it is required to find the necessary inlet air temperature to dryer (first firing).

1 lb. water evaporated into vapour and exhausted at 130°F requires approximately 1,010 B. Th. Us.

13.8 lbs. water evaporated requires
 $13.8 \times 1,010 = 13,818$ B. Th. Us.

1000 lbs. air exhausted
 at 130°F into an
 atmosphere of 90°F
 gives a loss of $(130 - 90) = 40^\circ\text{F} \times 1,000$
 lbs. x constant 0.237 = 9,500 ,,

Heat to warm tea and
 radiation loss, etc.,
 equals approximately
 80% of 9,500 = 7,600 ,,

Total approximate heat
 required by circulating air = 30,918 ,,

Note.—Air at 130°F. and 40% humidity will be calculated as dry air. See pages 66 & 96.

The inlet air temperature to dryer is obtained by first finding the difference (T) between the inlet air temperature and the natural air which in this case is 90°F.

$$T = 30,918 \text{ B. Th. Us.}$$

$$\frac{1,000 \text{ lbs. air} \times \text{constant } 0.237}{1} = 130.5^\circ\text{F.}$$

Inlet air temperature equals 130.5 plus 90 = 220.5°F

The above calculation is a rough but sufficiently correct guide to the minimum inlet air temperature required in this case. The maximum range of inlet air temperature would safely be set at 220 to 230°F. The leaf should be dried in two firing stages.

The calculations just made relate to the working of a dryer during poor weather conditions in India; it is essential that the capacity should be sufficiently large to efficiently deal with such rush periods. Should the maximum inlet air temperature be reduced to 180°F during the rush period, the maximum water evaporation would be reduced from around 13.8 to around 8 lbs. water per minute and thus explains the tendency during 1932 for Planters in N.-E. India to increase fan speeds and air circulation with the use of low inlet air temperatures.

Inlet Air Temperature to Dryer, Good Weather Conditions.

In good weather conditions or in factories where leaf is withered to around 58%, the leaf to be dried contains less water content and can be dried in one firing stage.

An eight-tray endless chain dryer discharge can be calculated at 350 lbs. made tea per hour. 58 lbs. fer-

mented leaf will produce 24 lbs. made tea; therefore, the water evaporation will be 58 lbs. fermented leaf minus 24 lbs. dry tea or 34 lbs. water which gives a water evaporation rate of 1.41 lbs. water per 1 lb. made tea, *i.e.*, $34/24 = 1.41$.

350 lbs. made tea per hour will require 350×1.41 or 493 lbs. water evaporation or at the rate of 8.2 lbs. per minute.

During such conditions it is usual to reduce the dryer air circulation from 15,000 cub. ft. of air per minute to 10,000 cub. ft. and also reduce the temperature of inlet air; the following calculations will serve as illustration.

The withering house is supposed to be air conditioned and the outside atmosphere 90°F with 100% saturation representing the worst drying condition.

10,000 cub. ft. of the above air per minute weighs around 690 lbs.

8.2 lbs. water per minute
requires $8.2 \times 1,010 = 2,282$ B. Th. Us.

690 lbs. air exhausted
per minute from 130°F
to $90^{\circ}\text{F} = 40^{\circ}\text{F} \times 690$
 $\times 0.237 = 6,541$ „

Heat to warm tea and
radiation loss, etc.,
equals approximately
80% of 6,541 = 5,233 „

Total heat in air 20,056 „

Inlet air temperature as per previous calculation.

$T = \frac{20,056 \text{ B. Th. Us.}}{690 \text{ lbs. air} \times 0.237} = 123^{\circ}\text{F.}$

690 lbs. air \times 0.237.

123°F plus 90°F natural air gives 213°F as the maximum inlet air temperature which can be reduced towards 180°F during good weather conditions.

The previous calculations are not intended to give scientifically correct results, for which intricate calculations are required, but to give a type of easy calculation which is capable of giving an approximate result sufficiently correct to check up practical results.

The only saving which could be made in the calculated losses would be a reduction of 30 to 40% in the radiation losses by cladding the outer surfaces of circulating fan, air ducts between dryer and air heater, and as much of the outer surface of the dryer chamber as is practical.

When dealing with reduced quantities of circulating air, it is necessary to remember that the evaporation of water and discharge of fired tea is also reduced. Should the dryer be fed with an excess quantity of leaf, poor drying conditions will be produced with a consequent loss of quality in made tea, for example.

The previous calculations are all based on certain volumes or preferably weights of air circulated through the dryer per minute. As previously explained the dryer fan speed to maintain a constant weight of circulated air through the dryer alters at varying elevations and temperatures. This is more thoroughly explained in the following examples which may be used either in connection with withering or drying.

The Speed of Dryer Fans

increases approximately 10 R. P. M. for every 1,000 ft. altitude above sea level but it will be found more correct

to obtain a constant which includes the effects of both altitude and temperature as follows:—

For Altitude Air Density

at 60°F and sea level will decrease approximately 0.00003 per one foot elevation above sea level; that is, if density of air is 1.0, the comparative density at 5,000 ft. will be 1.0 minus (0.00003 multiplied by 5,000) or 1.0 minus 0.15 or 0.85 which represents the constant.

A fan revolving at 450 R. P. M. at sea level and circulating 1,000 lbs. of air per minute will circulate 1,000 lbs. of air per minute at 5,000 ft. by revolving the fan at 450 divided by 0.85 or at 530 R. P. M. It must be remembered that the weight of air remains the same but its volume increases in proportion of 0.85 to 1.0.

For Temperature Air Density.

If we take air at a fixed elevation, say at sea level, and increase its temperature, from 60°F, the air density will vary approximately 0.002 per 1°F difference in temperature.

The difference in density between 60°F and 90°F will, therefore, be 30 multiplied by 0.002 or 0.06.

As the density of air at sea level and 60°F is 1.0, the density at the same level and 90°F will be 1.0 minus 0.06 or 0.94.

To maintain the same weight of air circulation at 90°F as at 60°F the fan speed will be required to be increased from, say, 450 to 450 divided by 0.94 or to 479

R. P. M., and the volume of air would be increased in proportion of 0.94 : 1.0.

If the initial temperature had been 90°F and it was required to maintain the same weight of air circulation at 60°F then a fan running at 450 would require to be slowed down to 450 multiplied by 0.94 or to 423 R. P. M., and the volume of air would be decreased in proportion of 1.0 : 0.94.

Combined Altitude and Temperature Air Density.

If we take a practical illustration of a dryer in the tropics at sea level and drawing natural air into the heater at 90°F and at the rate of 1,000 lbs. air per minute and we wish to find the fan speed which will give the same weight of air at an altitude of 5,000 ft. and 60°F.

In calculation for temperature it was shown that the fan speed requires to be raised from 450 divided by 0.84 or to 530 R. P. M.

In calculation for altitude it was shown that the fan speed requires to be decreased from 450 multiplied by 0.94 or to 423 R. P. M.

The combined altitude and temperature calculation will now be shown by taking 530 R. P. M. and correcting it for drop of 30°F by multiplying 530 R. P. M. by 0.94 which gives a corrected speed of 498 R. P. M. In this case, the air volume to maintain 1,000 lbs. weight of air per minute will increase with the increase of altitude and decrease with the decrease in temperature.

The previous calculations assume that equal quantities of water are to be evaporated from the leaf, but if the leaf at higher elevations has a reduced water content in comparison with that at lower elevations, a further correction in fan speed reduction may be made to suit the leaf to be dried.

Dryer Air Temperatures.

The following particulars have been prepared and illustrate the approximate range of air temperatures and air saturation starting from the inlet air position under the bottom tray of an eight-tray dryer, to exhaust air position immediately above the top tray.

It will be noticed that the vital control temperature of 150°F is maintained under the second top tray (above the third top tray) with good conditions, and is found under the fifth top tray with poor conditions representing an overloaded dryer producing reduced quality in made tea.

Tray No From Top.	Good Conditions.		Poor Conditions.		Good Conditions.	
	Air Temp-e.	Air Hum-y.	Air Temp-e.	Air Hum-y.	Air Temp-e.	Air Hum-y.
	F.	%	F.	%	F.	%
Under 8	205	1'6	205	1'6	180	6'6
Above 8	200	1'9	183	5'0	176	7'3
.. 7	193	3'1	163	12'3	173	8'5
.. 6	184	5'0	148	20'4	168	10'0
.. 5	175	8'1	140	28'4	164	12'3
.. 4	165	12'3	132	36'0	158	14'5
.. 3	155	17'4	125	44'0	152	19'0
.. 2	142	32'1	120	53'5	140	28'4
.. 1	125	44'0	110	73'5	125	44'0

Heat Calculations for Dryer.

A table has been prepared showing the necessary heat values of 1 lb. of air to allow any one to approximate the total heat value transmitted to air drawn into an air heater for circulation through a dryer. The heat values are correct but the method of calculation is not scientifically correct; however, the method of calculation suggested gives a practical heat value within a small percentage of error and will be found satisfactory for all practical purposes in calculating the quantity of fuel required to heat the circulating air.

HEAT VALUE OF 1-LB. AIR.

NATURAL AIR.			AIR HEATED TO 180°F. WITHOUT ADDITION OF WATER.	
Temp.	Dry Air.	Sat. Air.	Dry Air.	Sat. Air.
1. 60°F.	14'46	26'25	43'38	58'25
2. 70°F.	16'87	33'80	43'38	65'80
3. 80°F.	19'28	44'00	43'38	76'00
4. 90°F.	21'60	57'50	43'38	89'50
			AIR HEATED TO 200°F. WITHOUT ADDITION OF WATER.	
1. 60°F.	14'46	26'25	48'20	62'20
2. 70°F.	16'87	33'80	48'20	69'80
3. 80°F.	19'28	44'00	48'20	80'00
4. 90°F.	21'60	57'50	48'20	93'50
			AIR HEATED TO 220°F. WITHOUT ADDITION OF WATER.	
1. 60°F.	14'46	26'25	53'0	69'0
2. 70°F.	16'87	33'80	53'0	80'0
3. 80°F.	19'28	44'00	53'0	91'0
4. 90°F.	21'60	57'50	53'0	103'0

A calculation, not strictly correct, but near enough for ordinary practical working conditions without intricate calculations can be made as follows:—

If saturation of natural air is above 60% water content, use the saturated air columns and if below 60% use the dry air columns.

HEAT CALCULATIONS FOR DRYER

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Thus 1-lb. of natural air at 70°F and 80% saturation heated to 180°F without addition to the original

Cost.	Type of Fuel	Fuel Cost Per Ton.	Fuel Per 1,000 lbs. Made Tea.	Fuel Cost Per 1,000 lbs. Made Tea.	District.
Min.	Coal.	Rs. 17.5	500 lbs.	Rs. 3.91	N. E. & C. India.
"	"	" 17.5	1,200 "	" 9.38	N. E. & C. India.
"	"	" 28.0	500 "	" 6.25	Max. N. E. & C. India.
"	"	" 28.0	1000 "	" 12.50	{ Max. N. E. & C. India. Min. S. & S. W. India.
Max.	"	" 40.0	500 "	" 8.91	S. & S. W. India.
"	"	" 40.0	1,000 "	" 17.82	S. & S. W. India.
Min.	Liquid Fuel	" 60.0	230 "	" 6.12	N. E. & C. India.
"	"	" 60.0	400 "	" 10.7	N. E. & C. India.
"	"	" 85.0	230 "	" 8.71	Max. N. E. & C. India.
"	"	" 85.0	350 "	" 13.30	{ Max. N. E. & C. India. Min. S. & S. W. India.
Max.	"	" 120.0	230 "	" 12.24	S. & S. W. India.
"	"	" 120.0	350 "	" 18.65	S. & S. W. India.
Min.	Firewood.	" 4.5	1,200 "	" 2.41	S. & S. W. India.
"	"	" 4.5	3,000 "	" 6.05	S. & S. W. India.
Max.	"	" 12.0	1,200 "	" 6.43	S. & S. W. India.
"	"	" 12.0	3,000 "	" 16.0	S. & S. W. India.
"	"	" 12.0	1,500 "	" 8.0	N. E. & C. India.
"	"	" 12.0	4,000 "	" 21.8	N. E. & C. India.
Min.	Electricity	Per Units	units.		
"	"	Rs. .021	700	Rs. 14.7	S. W. India.
"	"	" .021	900	" 18.9	S. W. India.
Max.	"	" .031	700	" 21.7	S. W. India.
"	"	" .031	900	" 27.9	S. W. India.

Note:—1 Ton of liquid fuel averages 220 gallons.

Note:—1 Cub. yard firewood is calculated at 700 lbs. weight.

Note:—1 Ton coal 2,240 lbs.

water content of the natural air (as in passing through a heater) will require 65.80 minus 33.80 or 32 B.Th.U.s. per 1 lb. air, or at the rate of 32,000 B. Th. Us. per 1,000 lbs. of air circulated per minute.

1 lb. of natural air at 70°F and 50% saturation heated to 180°F as above will require 43.38 minus 16.87 or 26.41 B.Th.U.s. per 1-lb. air or at the rate of 26,410 B.Th.U.s. per 1,000 lbs. of air circulated per minute.

We have thus an explanation for the necessity to burn more coal during damp weather.

The Cost of Drying Tea

varies in different parts of India in comparison with the available fuel supply and its cost. The undernoted costs are given for approximate figures of average conditions and should be corrected in detail for each individual Estate. See page 97.

In calculating fuel requirements, the total B.Th.U.s. to be added to natural air should be calculated from dry or saturated air columns in table page 96. The B.Th.U.s. of fuel can be calculated per 1 lb. fuel as 3,500 for wood, 10,000 for coal, and 18,000 for liquid fuel.

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CHAPTER VIII.

CONTROL OF WATER EVAPORATION DURING TEA MANUFACTURE.

The control of water transference or evaporation from tea leaf during the period of growth and subsequent manufacturing stages is of considerable importance and the following information is well worthy of some study.

Growth of Leaf.

The concentration of juices within the growing leaf depends on the evaporation of water from the leaf surface. The production of crude properties which lead to quality in leaf is, therefore, dependent upon sunlight and preferably a cool atmosphere, encouraging slow growth of the leaf fabric, and a good evaporation of water; which encourages the flow of sap in the bush. The efficient retention of the properties in leaf responsible for quality production is thus conserved to best advantage.

Plucking of Leaf.

As soon as the leaf is plucked from the bush evaporation of water is considerably reduced; therefore, it is necessary to protect leaf from the sun; otherwise, it will accumulate more heat than can be balanced by evaporation of water. Accumulated heat will encourage changes which partly destroy the properties responsible for quality production in made tea.

Transportation of Leaf

from field to withering house requires that the leaf be loosely packed so that sufficient air is in contact with the leaf to absorb the evaporation of water. Should the leaf be too tightly packed, and thus exclude the contact of air with the leaf surface, the evaporation of water will not take place, and reactional heat will accumulate within the leaf. Quality production in made tea will thus be partly destroyed.

Withering of Leaf.

Heat produced by reactions during the withering process is partly removed by radiation to the circulating air, but mainly by heat lost to evaporation of water, always provided, the evaporated water can be absorbed by the circulating air.

If the circulating air is so saturated that it cannot absorb water, evaporation of water from the leaf will be so reduced as to allow heat from reactions, which must go on inside the leaf so long as oxygen can percolate through the leaf fabric, to accumulate, and produce internal combustion, or other results, which partly destroy the properties of quality in made tea, by heat accumulation.

If circulating air is too dry and greedy* for the absorption of water, the outer surface of the leaf may become too dry (case-hardened), after which evaporation of water from the leaf and percolation of oxygen into the leaf becomes difficult. This results in a leathery type of leaf not capable of producing full quality in made tea.

Nature requires the circulation of cool air and not too greedy in the absorption of water from leaf, say air at 60 to 70°F with around 75-80% saturation.

Rolling of Leaf.

After the leaf becomes bruised and oxygen has more ready access to the juice content, the reactions are accelerated and heat is produced at greater rates.

It is most important that this heat be liberated freely from the leaf without excessive evaporation of water, which may cause an excess production of tannin browns, or otherwise reduce quality production in made tea.

Advantage is, therefore, taken of the possibility to radiate away heat by artificially cooling the roller surfaces in contact with the leaf.

Very great benefit is obtained by utilising this method to artificially cool leaf, during the rolling process, and retain its temperature in hot atmosphere to within the range of 65 to 70°F best suited to control leaf reactions during rolling, and in a manner independent to a great extent of evaporation of water from the leaf.

These remarks are of special interest when rolling C.T.C. or cut leaf which accumulates in a dense mass favourable to heat retention within the leaf.

Sifting of Green Leaf.

If excessive evaporation of water takes place during the sifting process, a rapid cooling action will take place in the leaf. This points to rapid evaporation of water and may require regulation in relation to the production

of tannin browns. Humidification of the air reduces the rate of evaporation of water from the leaf.

Fermentation of Leaf.

Evaporation of water from leaf requires to be controlled by contact of humidified air in relation to the air temperature, so that the bulk of leaf spread on the fermenting surfaces can accumulate heat to some point around 80 to 83°F, dependent upon local conditions.

The air saturation or humidity is best regulated to 90 to 95% at 80°F or slightly above that temperature, and at 80 to 85% if under 80°F.

Drying of Leaf.

As the atmosphere in the drying room is usually hot, the leaf must not be stored in basins or in heaps in front of the dryer feeding tray spreader; otherwise heat will accumulate rapidly within the leaf and destroy quality in made tea. It must always be remembered that once fermentation is complete, the leaf must reach a heat sterilising temperature of a minimum of 150°F in a minimum time without case-hardening, after which evaporation will continue freely without loss of properties responsible for the production of quality in made tea.

Grading and Sorting of Leaf.

When leaf is discharged from a dryer it has only 2.5 to 3.5% of water in its fabric, therefore, it is very greedy to absorb water from the air. It must be remembered the reabsorption of water should not exceed a total of 5% water content in the leaf; otherwise, post-fermen-

tation will be encouraged and partly destroy the properties of quality in made tea during storage periods.

If water absorption takes place from the air to too great an extent during grading and sorting processes, it is necessary to pass the leaf quickly through a dryer and extract the excess water content.

Should this be necessary during a damp day with air at 90°F and 95% saturation, considerable care must be exercised to reduce the air circulated in the dryer to around 25 to 30% saturation as a minimum.

As an instance, take air at 90°F and 100% saturation carrying .031 lbs. water per 1 lb. of air. To find the temperature to which the air should be raised to reduce its water content to 25%, multiply 0.031 by 95 and divide by 25 which gives 0.118 lbs. water per 1-lb. air. On reference to an air table we find the necessary minimum temperature is 130°F. *See* page 87.

If the dryer circulating air is only slightly warmed, say to 110°F, the tea on passing through the dryer may not be dried as expected, and post-fermentation may take place in the packing cases during transport and storage.

General.

It may be of considerable interest to study the variation of water content recorded in some Estates during the whole manufacturing process.

The method of obtaining the results is to obtain double checked leaf samples from the growing bush and at each stage of leaf manufacture and carefully estimate the water content in the product at each stage; in this

manner, the water content in material necessary to produce 1,000 lbs. dry tea can be obtained. To obtain the weight of material at any stage of manufacture add 1,000 lbs. to the weights of water given in the table.

Each example is interesting for some defect in the process and can be compared with item No. 6 representing normal conditions for a double drying process, and with No. 7 for a single drying process.

1. is defective in long transport, and an overloaded first drying machine.
2. is defective in an under wither, combined with excessive loss of juice in hard rolling and fermentation.
3. is defective in under wither, loss of juice in rolling and fermentation, but very good first drying arrangements.
4. is defective in under wither, loss of juice in rolling and fermentation, but good first drying arrangements.
5. is defective in under wither, loss of juice in rolling and fermentation but good first drying arrangements.
6. is normally good throughout for elevations below 2,000 ft.
7. is normally good for elevations above 2,000 ft. showing a hard wither, small rolling and fermentation loss, and good single drying process.

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CHAPTER IX.

BACTERIA.

The study of life in all its stages indicates that both human and plant life contain two main sections of activity which operate for healthy progress on the one side, and for putrefaction or destruction on the other side.

To the average man it is sufficient to understand that freshness in life or quality production in tea manufacture is aided by the section including the activity towards healthy progress and may include bacteria enzymes, etc. The activity in this case operates within a certain range of alkalinity or O. H. concentration indicated by healthy progress.

Tea leaf, like any other substance, contains crude essential elements which, with the aid of oxygen, disintegrate or produce various types of digestion, such as fermentation, all of which come under the term of slow combustion, and will proceed until all the energy represented by the crude essential elements is used up and only a dead material remains.

In tea manufacture, the progress of slow combustion with its production of heat can only be allowed to go a certain limit, which retains sufficient energy for further action to take place, after the tea is brewed, to give a pleasing taste in the mouth.

Should the process of slow combustion (fermentation) be accelerated, with consequent loss of energy during any stage of manufacture, it is usually indicated by the production of excess heat, and at the end of manu-

facture, the process of slow combustion may have proceeded so far as to leave a more or less dead material termed, stewed, unattractive, or other names associated with poor quality tea.

Before the period of drying, over-fermented leaf in the above case would have lost too much O.H. concentration, and have reached a stage favourable to the growth of bacteria, etc., which are associated with putrefaction.

We can thus say that a certain type of bacteria, enzymes, etc., work in a helpful manner so long as freshness remains in the product. The destructive bacteria remaining dormant until the freshness or O.H. concentration decreases to such a stage as to encourage their activity. At this stage, the helpful bacteria, enzymes, etc., become dormant, and freshness or quality in tea gradually decreases.

The great danger in tea manufacture is caused by an accumulation of juice or other material in which the helpful bacteria, enzymes, etc., have become dormant and the destructive bacteria is rapidly increasing on material leading to putrefaction.

This may occur at all parts of surfaces in contact with wet leaf, if they are not continually washed free, every 4-5 hours, of any material verging on the putrefaction stage. If present, the putrefaction bacteria can do untold harm in reducing the freshness or quality in the tea-product.

A further source of trouble is broken floor surfaces in rolling or fermenting room, or drains, or uneven

floor surfaces where juice or material may collect for periods of over 5 hours.

To the average man, it is, therefore, enough to know that cleanness and freshness of all parts capable of coming in contact with leaf is the greatest enemy to the putrefaction bacteria, and if thoroughly carried out, will prevent any undue loss of quality from this cause, during manufacture.

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During the storage period, with 4-5% water content (similar to black tea), a very strong scent is produced after 2-3 months' good storing conditions. The scent is very strong for about one month and during this period, the green tea under storage rises 4-5°F showing that a type of fermentation or digestion has taken place.

It is important to note that fermentation in green tea manufacture is reduced to a minimum, all through the manufacturing process, and Nature does not indicate the completed rotation of changes until within a definite period after storage. The large percentage of the essential oils are condensed within the product and retained for further use dependent upon the efficiency of the storage facilities.

A very important point to notice is that the essential oils may not be produced, if the water content of the green tea is too high, or if other storage facilities are not efficiently supplied.

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CHAPTER XI.

GRADING AND SORTING OF DRIED TEA

is important in that it consists of processes which separate out the leaf into even grades of tea, each containing pieces of tea approximately similar in size and formation. Each grade usually denotes a separate market appearance and different quality of colour, strength and flavour in made tea liquor.

The dried tea product, to be sorted, is composed of original twigs of new growth from the bush consisting of a bud and two or three fine leaves, each increasing in growth and, as far as is known, decreasing in the properties of tannin content.

After withering, it is one object of the initial rolling periods to separate out the bud and fine leaf of best quality from the remaining coarser bulk, and twist the individual leaves into an attractive appearance. After drying, the fine and the coarse grades are delivered to the sifting and sorting room for final individual separation into their grades.

Loss of Dried Juice.

As already suggested, juice from the leaf cells is released and coated over the surface of the rolled leaf, as well as saturated throughout the leaf fabric. The dried juice is the real market product and the leaf fabric the absorbent material in, and on which, the juice is retained. After the juice is dried, it forms a fine powder,

which adheres to the outer surface of the leaf, and is also distributed throughout its fabric.

It will, therefore, be understood that dried juice adhering to the outer surface of the leaf will not withstand severe rubbing or scraping of the leaf surface, or breaking of the leaf fabric. If these actions occur in excess, part of the dried juice, treated with considerable care and expense in the earlier processes will be lost. The loss is difficult to visualise; otherwise, much more care would be exercised to prevent the direct loss of a manufactured product.

Conservation of Dried Juice.

As already explained, the valuable dried juice adhering to the surface of dried tea can be lost by scratching or rubbing of the leaf surface or by the breaking of the leaf fabric. The practical solution appears in the preparation of leaf grades while the leaf is still wet, either during the rolling or other special processes, or in sifting of the rolled leaf immediately afterwards.

The tea trade is now appreciating this important point but in many cases, it is found that existing drying equipment is more suited to the drying of leaf in bulk rather than in assorted grades. Any alteration to provide extra small dryers, with trays suitable for the drying of fine grades of leaf, represents considerable capital outlay, and requires consideration to determine if the particular factory has sufficient fine grades to warrant the expenses; if so, the altered drying methods are well worthy of consideration.

Regular Grades.

It cannot be said that the tea trade is one which can be fully standardised, as methods of manufacture and grades of tea produced depend upon local soil conditions, climate, and type of available leaf. This possibly explains the present position in which each Planter has continually to investigate in order to find selections of tea grades to meet a narrow margin suitable to his individual buyer. The main object being to maintain a regular line of certain tea grades within as narrow a margin as possible and upon which his buyer can depend. Any extensive experimentation such as took place during 1932 upsets the buyer, the Planter may then find much trouble, accompanied with considerable financial loss, before he finds another regular buyer.

Regular Quality.

It is usually found that tea quality is good and the tea well fired when it arrives on the London Market at different and regular periods. Unsuitable tea is largely due to climatic conditions, but also, to a very considerable extent, due to lack of facilities to dry the tea properly during poor weather, also, lack of facilities for the rapid sorting and packing of tea, the lack of which allows the tea to reabsorb too much water, in which state loss of quality is produced during the storage period.

All these troubles can be overcome, to a great extent, with proper control of air temperatures during the drying periods, and, or good re-firing facilities before packing, always provided the tea is not left in open heaps or

badly designed tea bins for too long periods before packing, dependent upon local conditions.

A small electric heater with a consumption of 1/4 unit or less would help to maintain a warm dry air in the bins at a very low cost.

Existing Sifting Methods

to a great extent cover the use of vibrating or rotating machines which separate out the various grades. These are more or less harmful dependent upon the amount of scraping and scratching actions set up on the leaf surfaces. In this manner, the leaf more or less loses the dried juice originally adhering to its outer surfaces. It is then termed more or less grey, which means that the lack of dried juice coating allows more light to be reflected from the outer surfaces of the leaf, and the leaf becomes, in appearance, a grey black in place of a dull black colour.

Loss of Tip.

As previously explained, the attractive appearance of tip is produced by a hairy material on underside of fine leaf, which, with the saturation of juice, reflects a golden type of light. To the value of an attractive appearance some people add the property of extra properties of quality and caffeine.

During the sorting and grading of tea, any tendency to scrape or scratch the leaf surface removes part of the hairy substance, and thus reduces, to a considerable extent, the valuable market property of tip, and takes the 'bloom' off the tea.

Loss by Case-Hardening of Leaf in Drying.

Leaf, which has been case-hardened in the drying, is usually found to have minute or larger blisters on the leaf surface; these are delicate surfaces and can easily be removed by scraping or scratching actions and cause greying of tea, with consequent loss of dried juice.

Loss from Cutters.

It is most important that all cutters should have sharp cutting edges; otherwise, long leaf is broken and minute showers of dried juice are thrown from the leaf. This indicates that all cutting of leaf is best performed in the wet state, either in cold rollers, C. T. C. Machines or tobacco cutters, etc.

Production of Dust.

It is possibly better to grind the longest and poorest quality dried leaf rather than cut it, as the great percentage of the dried juice is recovered amongst the tea dust.

Packing of Leaf.

It is of the utmost importance that leaf be packed in even grades and with the minimum of dust production. It is also important that tea leaf should be packed in a dense mass with as little air space as possible between the particles of tea.

It is further most important that the tea itself should not contain more than a maximum of 5% water content, which should not be increased during storage to more than 6% water content. During storage, post-ferment-

ation takes place and increases the proportion of essential oil or aroma which is produced as a bye-product from post-fermentation and distilled and re-absorbed by the leaf. If the correct water content is not carefully provided for, the essential oil and aroma will not be produced, or the correct toasted flavour retained in the tea. This is specially the case if the water content is increased beyond the specified limits.

CHAPTER XII.

STANDARDISATION OF TEA MANUFACTURE.

Experience up to date shows that it is a fatal mistake to standardise successful manufacturing methods in one factory and try to apply the results to one or several other factories in the same or different districts. Two instances may illustrate this statement.

Rolling of Leaf.

So far as one can gather, it is not wise to apply cold rolling of leaf to manufacturing methods unless the leaf temperature exceeds 75°F otherwise, colour of liquors may be decreased below the market requirement. The exception is in cases where retention of quality and pungency is of more importance than colour of liquors.

The number of rolling periods and pressure on leaf is governed by the rate of fermenting reactions which may actually alter in any one factory from day to day and requires careful judgment.

The cutting of green leaf preparatory to rolling is also dependent upon the rate of fermenting reactions, and cannot be applied to all types of leaf.

Drying of Leaf.

The rate and amount of fermenting reactions which can be allowed in an existing drying method is dependent

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upon the type of leaf and climatic conditions. Thus in cool climates, where fermenting reactions are naturally greatly retarded, specially with tough leaf, it may be of advantage to encourage fermenting reactions within limits in the first firing period at low temperatures and check the fermentation in the second firing period. This may be successful under certain conditions in cool climates but would be absolutely disastrous in a warmer climate.

It will thus be realised that manufacturing conditions must receive continual study in any factory throughout the year and can only be duplicated in another factory after a very careful study of leaf, soil and climatic conditions, including the manufacturing facilities offered in each factory.

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CHAPTER XIII.

POWER FOR TEA FACTORIES.

Steam Engines

are not affected by high elevation and are really the most reliable. A boiler with large water capacity such as the Cornish or Lancashire type is most suitable for the type of water usually found near to tea factories.

A high speed Steam Engine of a good make combined with an Electric Dynamo is possibly the most reliable power plant and allows all machinery to be electrically driven without a mass of belting in the factory.

The slow running Horizontal Steam Engine represents a very reliable power unit, but it is usually associated with belt-driven machinery.

The economical use of a Steam Engine depends to a great extent on regularly blowing out the boiler and the use of boiler compounds to keep the internal surfaces of the boiler clean. It is also most essential to use a good type of steam cylinder oil; otherwise, both steam pistons and valves will wear quickly and increase fuel consumption.

The cost of fuel is usually represented by 0.8 to 1.0 lbs. coal, or 2 to 2.5 lbs. fire-wood per 1 lb. made tea. The repair costs are low.

Suction Gas Engines.

The power of Suction Gas Engines are both affected by density and temperature of air as described in relation to dryer fans; for example:—

A Suction Gas Engine which develops 100 H.P. at an air temperature of 60°F. at sea level will develop 100 multiplied by 0.94 or 94 H.P. at sea level and a temperature of 90°F.

A similar engine which develops 100 H.P. at sea level and 90°F, as is usual in the tropics, will, at an elevation of 5,000 ft. and 60°F temperature, be reduced to 100 multiplied by 0.85 or 85 H.P. due to elevation alone and corrected to 85 divided by 0.94 or 90 H.P. due to decrease in temperature from 90 to 60°F.

The calculations are exactly similar to those described for combined altitude and temperature air density in connection with fan speeds; therefore, further examples are unnecessary. *See* pages 93-94.

Suction Gas Engines work at a low cylinder pressure and therefore have a low cost of repair, but very considerable care is required to extract all tar or similar substances from the gas, otherwise trouble will be found at valves and piston rings. The cost of fuel is usually 0.5 to 0.7 lbs. Charcoal or 1.4 to 2 lbs. wood per 1 lb. made tea.

Oil Engines

are affected by elevation in a manner described for Suction Gas Engines. The most modern power unit is represented by a vertical high speed enclosed engine of the Diesel Cold Starting Type combined with an electric Dynamo. Modern engines of a good type are very reliable, provided a good type of liquid fuel is used and nothing but the best lubricating oils supplied to the piston and bearings. The cost of fuel is usually represented by

0.4 to 0.6 lbs. liquid fuel (0.044 to 0.064 gallon) per 1 lb. made tea.

Electric Power from Public Supply.

Is not affected by elevation and is usually supplied to a factory at 10,000 to 110,000 volt pressure and transformed to 400-440 volts for supply to the factory-machinery. Electric power to tea machinery is clean and gives an increased working space by reason of the lack of belting.

Considerable care requires to be taken to determine that the factory electric system is guarded as well as possible against over voltage pressure caused by thunderstorms. All information can be obtained from the electric supply company and it is well to take their advice on this matter.

The power costs usually are 1 unit of electricity per 8 lbs. made tea, or 1 unit of electricity per 6 lbs. made tea, including power for controlled withering systems.

Electric Drives to Tea Machinery.

During recent years, much progress has been made towards the introduction of electric power for driving tea machinery, especially to groups of Estates that can be supplied from a private Hydro-Electric Power Scheme.

Very considerable progress is also being made, in some countries, by providing Hydro-Electric Power over large Industrial areas with extension power lines to Tea Estate Areas, and may indicate much future progress provided the capital cost of long power lines will withstand the economical charge on comparatively small power supplies scattered over a fairly wide area. Greatest eco-

nomy will naturally be obtained by groups of Estates situated within a fairly close range of each other.

The use of Electric Power, especially with individual electric drive incorporated in the design of each machine is very desirable and worthy of careful consideration even if the power costs are slightly more than that which could be provided from local fuel supplies such as wood, coal, or oil.

The introduction of individual drives to Tea Machinery eliminate a great waste of space, especially in the rolling room, occupied by belts in ordinary power drives, and also allows the rolling room to be kept thoroughly clean, which, in this section of manufacture, is a very great asset towards the production of better quality tea.

The type and size of Electric Motor requires careful consideration in relation to Tea Rollers and may generally be divided into two types suitable for light and heavy rolling. Thus, it is possible to utilise a smaller Motor for light than for heavy rolling, but it would then be fatal to the motor to utilise a light roller for heavy rolling as the power required would destroy the motor originally selected for light rolling.

On the other hand, an electric motor will work more efficiently within a close range of its full power, therefore, considerable economy will be obtained by carefully selecting the motors suitable for each machine. This refers to rollers, dryers, withering fans, etc.

In calculating the average tea factory electric power (K.W. load), it is usual to estimate that one month contains 720 hours in which the full working power will range from 15 to 18% or at the rate of 108 to 130 full working hours per month.

In many cases, an electric motor with an electric power factor of less than 0.8 may be cut off or charged at a special rate. This eliminates all motors except those fitted with slip rings or those fitted with dual purpose armatures, such as the Kosfi Type of Motor, which provides a power factor of 0.9 and converts magnetising losses to a useful purpose. In some cases it may be necessary to include one or two Kosfi type motors to increase a general low average power factor, but all information on this subject can easily be obtained from Electric Power suppliers or Agents for Electric Motors.

In Tea Factory work it is usual to provide current from the main supply at 10,000 to 100,000 volt pressure to transformers which reduce the pressure to 220 or 440 volts for general supply to the machinery motors.

It will well repay Planters considering the supply of Electric power to carefully consider all information which can be obtained from the Electric Power Suppliers on the subject of safeguarding the factory electric system against thunderstorms, also on the subject of general safeguards connected with control gear for working the motors. It must be remembered that inefficient materials caused by the cutting down of contract prices below the safe limit is dangerous and may produce financial loss from accident or fire.

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CHAPTER XIV.

RELATIVE AIR HUMIDITY.

Degree Fah. Difference between Dry & Wet Bulbs.

Air Dry Bulb of	Percentage Humidity.																		
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	40	50	60
50	100	87	74	61	49	38	27	16	5	0									
55	100	88	76	65	54	43	33	23	14	5	0								
50	100	89	78	68	58	48	39	30	21	13	5	0							
65	109	99	80	70	61	52	44	35	27	20	12	5	1	0					
70	100	90	81	72	64	55	48	40	33	25	19	12	6	1	0				
75	100	91	82	74	66	58	51	44	37	30	24	18	12	7	1	0			
80	100	91	83	75	68	61	54	47	41	35	29	23	18	12	7	1	0		
85	100	92	84	77	70	63	56	49	44	38	33	27	22	17	13	8	0		
90	100	92	85	78	71	65	58	52	47	41	36	31	26	22	17	13	3	0	
95	190	93	85	79	72	66	60	54	49	43	39	34	30	25	21	17	3	0	
100	100	93	86	80	73	68	62	56	51	46	41	37	33	28	24	21	4	0	
110	109	93	87	81	75	70	65	60	55	50	46	42	38	34	30	26	11	3	0
120	100	94	88	82	77	72	67	62	58	53	49	45	41	38	34	31	17	5	1
130	100	96	89	86	82	75	69	66	61	57	50	47	44	42	40	37	23	10	3
140	100	97	89	88	83	75	71	69	64	61	54	51	48	46	44	42	28	15	7
150	100	97	89	88	83	75	73	71	66	63	57	54	50	49	47	46	32	19	10

Example: Dry bulb 90°F, wet bulb 80°F, humidity=65%

BRITISH STANDARD WEIGHT AND MEASURE.

Avoirdupois Weight

16 drachms, or 437.5 grains	...	1 ounce.
16 ounces, or 7,000 grains...	...	1 pound.
14 pounds	... ..	1 stone.
28 pounds, or 2 stones	... ..	1 quarter.
4 quarters, or 8 stones, or 112 pounds.	... ..	1 hundredweight.
20 hundred weights	... ..	1 ton.

Liquid Measure

4 gills (34.659 cubic inches)	...	1 pint.
2 pints (69.318 " ")	...	1 quart.
4 quarts (227.274 " ")	...	1 gallon.
56,800 drops	...	1 gallon.

Lineal Measure

12 lines	...	1 inch.
12 inches	...	1 foot.
3 feet	...	1 yard.
2 yards	...	1 fathom.
5½ yards, or 16½ feet	...	1 rod, pole, or perch
40 poles, or 220 yards	...	1 furlong.
8 furlongs, or 1,760 yards	...	1 mile.

Land Measure

7.92 inches	...	1 link.
100 links, or 66 feet	...	1 chain.
10 chains	...	1 furlong.
8 furlongs	...	1 mile.

Superficial Measure

144 square inches	...	1 square foot.
9 square feet	...	1 square yard.
30½ square yards, or 272½ square feet.	...	1 rod.

Land Measure

9 square feet	...	1 square yard.
30½ square yards	...	1 square rod, pole or perch.
40 square poles, or 1,210 square yards.	...	1 rood.
4 roods, or 4,840 square yards	...	1 acre.
640 acres, or 3,097,600 square yards	...	1 square mile.

Cubic Measure

1,728 cubic inches	...	1 cubic foot,
27 cubic feet	...	1 cubic yard.

ITEMS OF INTEREST.

Water weighs	...	...	62·3 lb. per 1 cub. ft.
Earth weighs	...	...	76-90 lb.
River sand weighs	...	...	120 lb.
Cabook weighs	...	...	108 lb.
Concrete weighs	...	...	150 lb.
Loose sand weighs	...	...	110 lb.
Masonry weighs	...	...	150-160 lb.
Cement weighs	...	...	90 lb.
Clay weighs	...	...	63 lb.
Slaked lime weighs	...	...	25-37 lb.
Quick lime weighs	...	...	53-75 lb.
Iron weighs	...	...	450-470 lb.
1 Cub. rod metal equals	...	...	60 bushels.
1 Bushel sand equals	...	...	146 lb.
1 Barrel cement equals	...	...	390 lb.
1 Bushel cement equals	...	...	112 lb.
1 Gallon water equals	...	...	10 lb.
1 „ liquid fuel equals...	...	...	9·5 lb.
1 Cub. yard firewood equals	...	...	450-750 lb.
1 Gallon oil gives	56,800 drops.		
1 Oil lubricator requires	18-25 drops per minute.		
1-B. Th. U. equals heat required to raise	1 lb. water 1°F.		
1-B. Th. U. equals	778 foot lb. work.		
1 Horse power equals	33,000 ft. lb. per minute.		
1 Electrical commercial unit equals	1·34 horse-power.		
1 Electrical commercial unit equals	1000 watts for 1 hour.		
1 lb. water vapour contains	970 B. Th. Us. plus difference between temperature of original water and that of the water vapour in degrees Fah.		

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CHAPTER XV.

HISTORICAL IN MEMORY OF MR. WILLIAM JACKSON.

(Extract from "Home and Colonial Mail", 7th January, 1910, reprinted in memory of Mr. William Jackson who may well be termed the Father of Tea Machinery.)

[BY AN EX-PLANTER-CUM-ENGINEER]

As a rule, people are not very keen about being troubled with matters long since consigned to the more or less oblivion of ancient history. When, however, efforts are made to review undeniable strides in the march of progress it may be pardonable, and certainly not uninteresting, to delve a little deeper into the past in order to fully appreciate the contrast, which in the matter of tea drying machinery and appliances is to say the least of it, strongly marked. The reasons of so taking the subject of "Tea Drying" from a retrospective point of view lend themselves perhaps somewhat readily to explanation, for although there are a goodly number in the United Kingdom who are able to call to mind the primitive methods adopted, there are very few planters left in the gorgeous East who are familiar with any other than the more modern tea-drying machinery. The system of tea manufacture generally in Assam was without any sort of doubt learned from the Chinese about the year 1839, and the heating or drying agent employed—live charcoal—a commodity readily obtainable. Of the appliances utilised in the operation, the basket-work dhool and circular tray

or sieve (common to Assam) were the first, but it will readily be seen that this method could only be practicable when manufacturing a very small quantity of tea, so that other means had to be devised for expediting the work, and it was not at all improbable that occasionally, if not frequently, the rolled leaf was spread on zinc sheets and placed in the sun's rays to dry; indeed, there were unmistakable signs that this was in some parts the practice, at any rate as late as the 'seventies. An improvement of the original dhool was effected by converting the zinc sheets into cylinders and building them into "Kutchra" (sun-dried) brickwork, arranged usually in sets of two rows of six each, so that the "tekla," or Batti-wallahs, stood facing each other, the live charcoal being fed in through the top of the dhools and the ashes removed by means of suitable openings left in the brickwork, inverted U-shaped pieces having previously been cut from the zinc sheets. Upon this method an improvement was made in the shape of "Pakha" (kiln-dried brick) Chulas arranged in rows as with the dhools, the openings at the top being, of course, square in place of circular, while on the walls rested square trays composed of wire wove in wooden frames, on which the leaf was spread and dried. This in turn led to the construction of frames to hold two or more trays resting on slides, so that they might be drawn in and out with ease. The modified Chula was, perhaps, more generally in vogue in Cachar and Darjeeling, and probably paved the way for some of the earlier types of drying machines.

Familiar as the name of Mr. William Jackson is now to all and sundry connected with the vast tea-growing industry, and be it not omitted in respect of a great number of entirely novel and unquestionably clever in-

ventions relating to machinery for the manufacture of tea from start to finish, it will be noticed that his earlier published inventions were for the most part restricted to rolling, and in this connection may be mentioned a motion, or collection of motions, embodied in the "Excelsior" roller for which Letters Patent were granted in the year 1881, the action having been described by more than one competent authority as an entirely new mechanical movement. With regard to rolling machinery, there can be little doubt left in the mind of anyone who is at all acquainted with tea machinery that Mr. Jackson secured the entire confidence of planters in all districts from the very first, due perhaps partly, if not mainly, to the fact that his first machine was to a very large extent as nearly as possible an exact replica, by mechanical means, of the methods adopted by human hands and sometimes feet, as evidenced in the earlier types of the single-action roller. This, of course, pleased the Assam men, who were by far the numerically stronger, and, by the way, the most conservative. It was through this tenacious clinging to rooted ideas that tended so largely to contribute to the hindrance of progress in respect of tea-drying appliances, for it was by common assent agreed, and to all intents and purposes insisted upon, that live charcoal was the only agent over which tea could be satisfactorily fired or dried. In the meantime, drying the tea by means of hot air had gained favour in other parts of India; that pure hot air might be substituted, and with advantage, for the fumes of live charcoal was by no means foreign to Mr. Jackson's thoughts, but, for one thing, it would seem that he was anxious to meet the wishes of the planters with whom he was best acquainted, indeed, this spirit has pervaded his whole course of action right up to the present time, even

to the extent of a slavish determination on his part. For the next, Mr. Jackson had in mind the heating of air by steam as likely to be efficacious and cleanly; but what was perhaps the greatest drawback, he was dreadfully hampered in getting his inventions and experiments put into practical form. There is a very amusing little incident which has often been humorously related by Mr. Jackson himself in respect of one firm who undertook the manufacture of some of his earlier ideas, the exact details need not be mentioned in these notes, but the net results were that Mr. Jackson found himself in the hands of Messrs. Marshall, Sons, and Co., of Gainsborough, an alliance which has since proved a happy one, not only for Mr. Jackson and the Gainsborough family, but for all parties concerned.

Retracing our steps ever so little, we may revert to the "Excelsior" roller, the movement of which really meant to the inventor finality so far as rolling action was concerned, for subsequent improvements were for the most part modifications simplifying mechanism and increasing capacity as exigence demanded, gradually leading up to the last "Metallic Rapid," for any improvement upon which there seems likely to be a very long wait and no hurry. There is, however, little doubt that the "Excelsior" machine might have been very badly spoiled in the making, and, beautiful as it was turned out, it frequently got very harshly treated in the using. The latter, however, had nothing whatever to do with either inventor or manufacturer, but what did concern them more nearly was the scrupulous care and attention paid by the one to the designs and wishes of the other, which must have inspired Mr. Jackson with a still larger measure of confidence in his Gainsborough friends, for it was

about the same period, early in the year 1880, that Mr. Jackson was granted Letters Patent No. 758 in connection with the mechanical portion of his now so familiarly known and deservedly popular "Venetian" Dryer. His stove or air-heating appliance difficulty had, after the expenditure of much time and money in experiments, been solved, and although the present-day arrangements are manifestly improvements on the original, the idea of drawing air through a number of tubes externally heated constituted the theory and practice of his system, which had evidently been carefully preserved for some years prior to launching the "Venetian" as a complete machine.

A very grateful tribute is paid by Sir James Buckingham, *Kt.*, *C.I.E.*, to his old Assam friend in a compact and most interesting and entertaining little volume entitled "A few facts about Indian Tea." When dealing with the subject of firing or drying tea, Sir James says, "Then Mr. Jackson came to our aid with the Venetian Dryer and afterwards with the Victoria, Britannia, Paragon, etc., etc." The "Venetian," it may be said, started well and has maintained its position; although in its original conception it was perhaps designed more particularly as a dryer at the close of the manufacture it got into very general use, especially in small and medium-sized factories, for checking fermentation, and firing twelve annas, or 75 per cent., for which purpose it undoubtedly served remarkably well. The general arrangement of the machine did not, however, by any means confine its sphere of usefulness to narrow limits, for when occasion required it served equally well for finishing off ten, twelve, or fourteen anna dried tea. For completely

drying at one operation the capacity of the 42 in. machine was claimed to be about 50 to 60 lb. per hour, which under normal conditions was easily accomplished. The system, however, of drying tea off on one machine never really found great favour, while the balance of opinion was, and is, that more work could be get out of any two machines by the two operations system than by firing right off. Anyway, in the case of a rush if the rolled and fermented leaf can be got on to the dryers at the proper time there is the opportunity of maintaining a regularity in the manufacture which is what the buyer in Calcutta or London wants, for indeed it may be said "there is no such thing as bad tea, only some's better than others," and if fellows would make up their minds at the commencement of a season to manufacture right through under a system calculated to suit local conditions instead of chopping and changing about there would be very much more uniformity in prices obtained. These alterations in system are often the result of design, but whether by design or accident they should be most strenuously avoided, as many successful men can abundantly prove. Little need be said regarding the mechanical side of the "Venetian" Dryer; its name is indicative of its action, while everyone throughout the length and breadth of the tea-growing districts is familiar with it.

In the pursuance of the compilation of these notes, modifications and improvements as they were introduced will reveal themselves. These alterations were, however, mainly in the direction of reducing wear and tear and the frequent necessity for renewal parts. It will be very well remembered that the early and middle '80's witnessed tremendous extensions to the tea area in Cachar and

Sylhet especially, while it was also about this period that the Ceylon planters, in view of the failure of coffee, decided to convert their estates into tea gardens, with the result that many thousands of acres were added to the area under tea. The Bheels in Cachar and Sylhet, which from the first had been looked upon as hopeless swamps, suddenly became amenable to the level and theodolite, and the vast expanses of hitherto waste lands were soon growing tea in the most luxuriant manner. In Assam as well extensions were put out, but on a rather less gigantic scale, still the advantages of a proper system of drainage began to be recognised, and this with a plentiful allowance of "Tincture of Steel," a now familiar term used to signify high cultivation, alone added on an average of 50 to 60 per cent. to the yield, without taking into consideration the yearly increases to the area of the old gardens, with the result that the crop of Indian tea between 1880-1 and 1886-7 had gone up in leaps and bounds. Then, too, had to be considered the gradual popularity of centralising the manufacture. Each of these no insignificant items, therefore, put together made a very important whole indeed, and one which the engineer alone was in a position to tackle. The rolling question, of course, had been solved, but in spite of the fact that Mr. Jackson had his "Venetian" and other inventors had also dryers of merit, the utility and value of which William Jackson is far too noble-minded to disallow, it was apparent to him that in the matter of capacity of tea-dryers there was plenty of scope for improvement. That the great achievement was not made known earlier was, we are inclined to think, due to the idea that in tea manufacture each operation should be under control and in sight the whole time, and this prevalent and prejudicial

notion withal tended to hamper progress, but Mr. Jackson knew perfectly well that nothing short of a continual feed and discharge dryer must sooner or later be accepted by the planters, but to couple perpetuity of action with complete access during the entire process was a mechanical impossibility. It was, therefore, long after he had thoroughly satisfied himself in his own mind of the efficiency of the "Victoria" Dryer that he presented it to the industry—in fact, it was not until 1888 that the first of this class of machine was sent out. The main features of the "Victoria" dryer were a very much enlarged arrangement of the stove as employed in the "Venetian," through the tubes of which air was drawn by means of suitable exhaust fans, the whole of the heating system being under a very close control in the matter of the quantity of air that should be heated in its passage through the tubes as well as fine adjustment by way of regulating the temperature in the drying chamber proper.

It is interesting to recall that about the period 1886-7 the sudden awakening of the Assam planters to the value of the Kodallie as a stimulant for the tea bush and its almost spontaneous effect provided a rush of leaf as unexpected as it was very nearly unmanageable, the net results of this was that one of the efforts put forth to cope with the increased yield was to dry off quicker by means of higher temperature, and it was probably about this same time that the practice of 10, 12, and 14 anna drying became not only recognised but imperative, with the result that the effort to check fermentation as speedily as possible really and truly, if not burnt, certainly scorched a large quantity and those samples submitted for valuation which just escaped being burnt, but were manifestly high-fired, got reported on as "malty" and

were exceedingly well received by British buyers. This doubtless contributed in a measure to the success of the "Victoria." Mr. Jackson's own description of his machine reproduced in tea machinery catalogues of the period published by Messrs. Marshall, Sons, and Co., served to provide a faithful and eminently intelligible account of the invention and its advantages.

All work to be successful depends upon healthy criticism. We will welcome this from our Readers.

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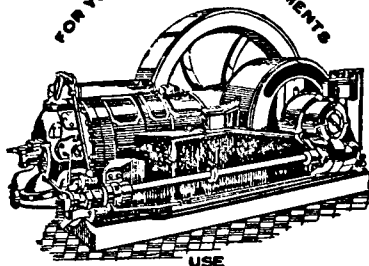
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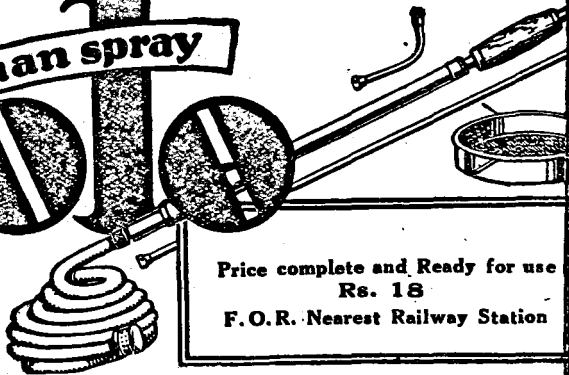
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