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GOVERNMENT OF INDIA

# PLANNING & DEVELOPMENT DEPARTMENT

(OFFICE OF THE INDUSTRIAL ADVISER)



## Report of Heavy Chemicals and Electro-Chemical Industries Panels

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## INTRODUCTORY

The Heavy Chemicals and the Electro-chemical Industries Panels were constituted by the Planning and Development Department (Government of India) in their letters No. P-1(11)44 and P-1(21)44 dated the 8th March 1945, respectively, the members being as follows:—

*H. C. Panel.—*

*Chairman.—*

Sir Shri Ranx

*Members.—*

Mr. Kapilram Vakil.

Dr. M. S. Patel.

Mr. V. Seshasayee.

Mr. S. G. Sastry.

Mr. P. R. Crerar.

*E. C. Panel.—*

*Chairman.—*

Sir J. C. Ghosh.

*Member.—*

Dr. B. K. Ram Prasad.

Mr. Kenneth Hall.

Dr. M. S. Patel.

Mr. Kapilram Vakil.

Mr. T. Parker.

2. The General Directive to Industrial Panels called for recommendations of the Panels on the following points:—

3(1) The scope and extent of development, including the type of products recommended.

(1-A) The estimated requirements of capital goods together with such details of those requirements as may be available in India and how much should be imported from abroad.

(2) Whether the industry should be under Government ownership either on grounds of national interest or because private capital is unlikely to take it up, and if so, whether it should be wholly or partly managed by Government.

(3) In the case of Industries to be developed other than under State ownership, the capital required for such development, whether the whole of it is likely to be available by public investment and, if not, the extent to which Government assistance may be required.

(4) The extent to which technical advice from abroad may be necessary.

(4-A) The availability and the future requirements of technical personnel so as to obtain a clearer indication of the present short-comings and future needs.

(5) The manner and the degree of co-operation with foreign firms considered necessary and desirable, both as regards capital and management.

(6) The location of the industry.

(7) The nature of the assistance required from Government in the form of protective duties, bounties, research grant, expert advice, etc.

(7-A) The relative incidence of the import duty on the finished goods in comparison with the duty on the raw materials from which they can be manufactured.

(8) If the industry is to be under private ownership and management, what controls, if any, should be exercised by Government.

(9) What should be the organisation of the different units of the industry, e.g., should there be an industrial association? Would a cartel be desirable?

(10) The stages by which the industry should be developed.

(11) Should the industry cater for the export market?

(12) Should the industry be developed, as in Japan, on the cottage industry basis and if so, to what extent?

3. Since many of the subjects to be dealt with by the two Panels were common, the Chairman and the members of these Panels agreed to have joint meetings and discuss all the subjects together. This was found to be more satisfactory for expeditious work and unnecessary duplication of work was thus avoided. We have also submitted only one report, Part I dealing with Heavy Chemicals and Part II with Electro-chemical Industries. Four meetings in all including the meeting with the Provincial Government and State representatives were held. The Electro-chemical Industries Panel also held a joint meeting with the Non-ferrous Metals Panel at which subjects of common interest, such as copper, zinc, aluminium, magnesium and ferro-alloys were discussed.

4. Mr. Kapilram Vakil who was a member of both the Panels attended only the first meeting. He passed away on the 29th January 1946 and the Panels were deprived of the benefit of his valuable views on the different chemical industries, of which he was a pioneer in India.

Two members, Messrs. P. R. Crerar and T. Parker resigned before the completion of the work of the Panels, as they relinquished their appointments and left India. Mr. Crerar attended one meeting and Mr. Parker, two and they were in agreement with the views expressed in the report, although their signatures do not appear herein.

5. At the meeting of the Panels with the Provincial and State representatives on the 31st May 1946, Sir Shri Ram, the Chairman of the Heavy Chemicals Panel announced that he had just been informed of the decision of the Government of India that they did not think it necessary to fix any targets or location for Heavy Chemical and Electro-chemical Industries. This was certainly unexpected. The value of all planning lies in a proper and organized control of the development of industries in different areas having regard to the availability of raw materials in the different areas and proximity to markets. Targets and location form the core of any intelligent planning and no rational planning is possible without them. If the Panels, after thorough consideration during a period of nearly a year, are not to make any recommendations on these points, we feel that all our work may be considered to have been wasted. There was also unanimity of opinion in that meeting of Provincial and State Government representatives that this decision of the Government would lead to chaos as it would enable persons to start industries wherever they liked. We have retained the contents of the report as they were before we were informed of this decision of the Government, as we feel strongly that Government control as regards targets and location is essential. We hope the Government of India will reconsider their decision in the light of our views and also of those expressed by all the representatives of the Provincial and State Governments.

(iii)

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## HEAVY CHEMICALS.

**Importance of Heavy Chemical Industries.**—The absolute dependence of a country on a sound Heavy Chemical Industry for success whether in war or peace has been so thoroughly demonstrated since the first World War, that it is superfluous to argue for the establishment and development of such an industry in this country. Great strides have been made in India in a number of industries, such as iron and steel, textiles, sugar, cement and jute during the last war, but the advance in chemical industries has been much less, as can be seen from a comparison of the capital invested in those industries and in Heavy Chemicals respectively (Appendix I). We are, therefore, of the opinion that in any future planning which aims at the industrial advancement of India, the establishment of a sound Heavy Chemical Industry is essential.

### Heavy Chemicals.

2. The term "Heavy Chemicals" is generally understood to refer to those chemicals that are produced in large quantities—usually at low cost, and serve as raw materials or treating agents for other process industries. The importance of heavy chemicals, therefore, lies in the fact of their being essential for other industries like textiles, soap, rayon, fertilisers, glass, leather, paper, etc., and their consumption depends on the activity of those industries. Consequently, while the price of basic chemicals will undoubtedly influence the development of other industries, there must be an all-round development of consumer industries to enable a sound Heavy Chemical Industry to be established. The main Heavy Chemicals are, as generally understood, sulphuric and other mineral acids and related compounds, soda ash, caustic soda and fertilisers; but taking into account the new chemicals that have come into industrial use during recent years, as a result of newly developed processes, the list would include a much larger number. A comprehensive list of Heavy Chemicals is given in Appendix II. Consumption of Heavy Chemicals per head of population is an index of the industrial development of a country and India's very unfavourable position can be readily seen from the following figures in respect of three important Heavy Chemicals,—sulphuric acid, soda ash and caustic soda.

TABLE I.

*Annual consumption per head of population.*

	Sulphuric acid.	Soda ash.	Caustic soda
India . . . . .	0.33lb	0.6lb	0.30lb
U.K. . . . .	44.8lb		
U.S.A. . . . .	113.0lb	56.0lb	19.4lb

## I. SULPHUR AND ITS COMPOUNDS.

### (a) Sulphuric Acid.

3. There is scarcely an important industry which is not directly or indirectly dependant to some extent on sulphuric acid, one of its salts or derivatives. The manufacture of the acid involves by far the greatest consumption of elemental and combined sulphur. From an analysis of

the main lines of consumption in the U.S.A. and in India (Table II), it is seen that some of the industries which consume sulphuric acid in large quantities in other countries have not been developed in India to any appreciable extent. In considering the future expansion of the industry, we have therefore been guided by the possibility of establishing new consumer lines or expanding those already existing.

TABLE II.

	U.S.A. (1940) Qty. (tons).	%age.	India (1944). Qty. (tons).	%age.
Fertilisers . . . . .	1,406,600	24.7	20,000	35.9
Petroleum refining . . . . .	790,000	13.9	1,611	2.9
Chemicals . . . . .	677,900	11.9	21,000	7.7
Coal products. . . . .	559,800	9.8		
Iron and steel . . . . .	746,400	13.1		
Other metallurgical. . . . .	398,100	7.0	3,995	7.1
Paints and pigments . . . . .	354,600	6.2		
Explosives . . . . .	108,800	1.9		
Rayon and cellulose film. . . . .	292,300	5.2		
Textiles . . . . .	77,750	1.4	3,286	5.9
Miscellaneous . . . . .	279,900	4.9	5,868	10.5
	5,691,550	100.0	55,760	100.0

(Figures relating to the U.S.A. are from Rogers' Industrial Chemistry)

4. From an analysis of consumption of sulphuric acid in India (Table III), it is seen that although chemicals and fertilisers take up the largest proportion of the acid produced, the quantities consumed are very small as compared with those used for these purposes in other countries. The figures for fertilisers are particularly significant, bearing in mind the area and population of India.

TABLE III.

*Analysis of consumption of sulphuric acid in India (in tons).*

	Present consumption		Five-year target.
	Percentage.	Qty.	
1. Chemicals . . . . .	37.7	21,000	35,000
2. Fertilisers . . . . .	35.9	20,000	63,000
3. Metals . . . . .	7.1	3,995	7,000
4. Cotton Textile . . . . .	5.9	3,286	5,100
5. C.C.P. (S) . . . . .	4.0	2,236	1,000
6. Mineral Oil . . . . .	2.9	1,611	2,000
7. Leather . . . . .	1.4	790	1,000
8. Battery acid . . . . .	0.7	410	1,000
9. Distillery . . . . .	0.6	318	1,000
10. Miscellaneous . . . . .	3.8	2,114	2,500
11. Rayon Industry . . . . .			34,000
		55,760	152,600

5. We are aware that many industries formerly using sulphuric acid are now becoming independent of this chemical in other countries, typical cases being those of ammonium sulphate, hydrochloric acid, nitric acid and superphosphate. Ammonium sulphate is now made at some places from gypsum, hydrochloric acid directly from hydrogen and chlorine, and nitric acid from atmospheric nitrogen. Although enormous quantities of superphosphate are still made by the use of sulphuric acid, there are indications that it may also be made sooner or later by the use of electrical energy, eliminating the use of the acid altogether. In the U.S.A. this process has already been developed and plants have been erected and are working in the Tennessee Valley, but it may take some time before we are able to develop this technically difficult process in India. We understand, however, that one firm in South India is considering the installation of a plant.

6. On the other hand, the use of chemicals like sulphate of alumina, alum, copper sulphate and Epsom salt would increase in the post-war period. Superphosphate production will, at least for some time to come, consume a large quantity of the acid. Expansion in the textile, metallurgical and paint industries would take up more acid. Rayon and dyestuff industries when started would be large consumers. All these factors have to be taken into account in considering the question of establishing this industry on a sound footing.

TABLE IV

Year.	Production:	Capacity.
	Tons.	Tons.
1937-38 . . . . .	26,755	57,000
1938-39 . . . . .	25,585	57,000
1939-40 . . . . .	30,730	57,000
1940-41 . . . . .		
1941-42 . . . . .	42,909	57,000
1942-43 . . . . .	40,646	57,000
1943-44 . . . . .	59,000	57,000
1944 . . . . .	59,000	About 65,000*
1946 . . . . .		About 77,000

7. From the figures of production of sulphuric acid in India as also those of capacity during a number of years (Table IV), it is seen that including the four new contact plants which have been recently erected, the total production capacity is 77,000 tons per annum. One unsatisfactory feature of the sulphuric acid industry in India in the past has been that although capacity was as high as 57,000 tons, actual production was only about 26,000 tons, because the high price of the acid prevented

\*Capacity is probably more, if all the small plants installed during war are taken into account.



the consumer industries from thriving on account of foreign competition. On account of the high freight and insurance charges, the acid itself could not ordinarily be imported and marketed in India at competitive prices, but its salts and other solid products derived from it enjoyed favourable sea freight rates and having been manufactured from cheap acid in other countries, competition was intense in these. The result was that Indian factories could work only for short periods and the cost of production became still higher on that account. Therefore, in any expansion planned, we consider that capacity should be increased cautiously and new plants allowed to be installed only after a profitable outlet for the acid is assured.

8. Whatever may be the development of new processes involving the elimination of the use of sulphuric acid, it may be stated, with a fair amount of certainty that the low cost of the acid made under favourable conditions tends to prevent any sudden or radical change in the economic status of this important chemical. It is true that India's present capacity is sufficient for her immediate needs. New plants are also likely to be installed by some firms. On the other hand, developments should be expected along new lines. About 410,000 tons of ammonium sulphate are proposed to be manufactured in Sindhri, Alwaye and Belagula; corresponding to this, at least 100,000 tons of superphosphates would be necessary. Although there is difference of opinion among some agricultural experts as to the utility of superphosphates in certain parts of India, we consider that the five-year target for superphosphates should be 100,000 tons per year. Provision for the acid required for this quantity of superphosphate has been made under "Fertilisers" in Table III.

Rayon Industry will also require large quantities of acid. We understand that the Rayon Panel has fixed a five-year target of 60 tons of viscose rayon per day. This will require about 99 tons of 60° Be sulphuric acid equivalent to 77 tons of 100% acid per day or about 28,105 tons per year. Auxiliary chemicals for the rayon industry would require about 6,000 tons of acid per year, making up a total of about 34,000 tons for this industry. Sulphuric acid will also be required for the manufacture of ammonium sulphate from ammonia obtained during the distillation of coal. We anticipate that there will be increased distillation of coal hereafter, since larger quantities of coke for metallurgical purposes and of organic chemicals for the dyestuffs industry will be required. Provision for the extra acid required has been made under "Fertilisers" in Table III. The acid will also be required in the electrolytic alkali plants for drying chlorine, but it is not used up and can be utilised for the manufacture of salts. Taking into account the expansion visualised in the different acid-consuming industries detailed in Table III, we consider that the five-year target for sulphuric acid should be 152,600 tons per year. It is estimated that the Dyestuffs Industry may require about 20,000 tons of acid of different strengths, which is not included in the above target.

9. We understand that the Government of India have granted import licenses for one 35-ton-per-day plant for the manufacture of acid from gypsum to be erected in Madras Presidency and one 10-ton-per-day contact plant for Bihar. We also understand that the Travancore Fer-

tilisers & Chemicals propose to instal a 75-ton-per-day plant for their ammonium sulphate manufacture. The Travancore firm, would however, consume most of the acid in their own works, only about 3,000 tons being available for sale. When the other two plants with a total annual capacity of 13,500 tons are installed, the total productive capacity inclusive of the quantity available in the Travancore plant will be 93,500 tons. The balance required to make up the target figure will be 59,100 tons.

10. Appendix III gives the production of sulphuric acid in India in 1944-area-wise, from which it is seen that the greatest production was in Bihar and Bengal (many of the plants produced the acid for their own consumption). There was no production in the C.P.

11. Before suggesting location of new plants, we wish to make certain observations:—

(i) One important feature of sulphuric acid production is that it must be manufactured at or very near the place of consumption. The cost of transport even in steel drums or tank cars is high in proportion to the value of the product.

(ii) Out of about 41 plants in India including the four new ones, only 9 are contract plants, the rest being chamber plants, many of them old and inefficient. Further, there are about 10-12 plants, each with a capacity of less than 500 tons which, although working at a profit now, will not be able to withstand competition in normal times, except in those rare cases where they are situated in inaccessible places. They will have to be scrapped sooner or later, thus reducing the productive capacity in the country by about 3,000 tons. Further, most of the old chamber plants will have to be replaced and in many instances, we understand the owners are already taking steps in this direction.

(iii) Since there are no known deposits of element sulphur in India—the small quantity available at Koh-i-Sultan has not proved economical—we consider that immediate steps should be taken by Government to utilise the enormous quantities of gypsum available in the country, for the manufacture of sulphuric acid and for conversion into sulphur. We would specially lay stress on the latter, because gypsum deposits occur mostly in the Punjab and Rajputana, where sulphuric acid is not required in any large quantity. Transport of gypsum to different parts of India would involve carriage of five times the weight of sulphur contained in the mineral. In view of the intricate nature of the chemical process and the financial risk involved, it is possible that private capital will not be forthcoming to start this industry. Therefore, we recommend that Government should immediately instal a plant of proved efficiency and sound design for the manufacture of 35 tons of sulphuric acid and of 12 tons of sulphur per day from gypsum, cement being obtained as a by-product. Large deposits of gypsum occur in the Punjab and Rajputana and we are of the opinion that the Government experimental factory should be located in one of these two areas in the North. This Government experimental plant will be mainly for purposes of training technical personnel and investigation of the economics of the process. It will also be found useful in time of war when India will be cut off from sulphur sources. Since manufacture of sulphuric acid and sulphur from gypsum is not yet a well-standardised process,

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we recommend that the Government of India should depute Indian technologists of experience in sulphuric acid manufacture and industrialists associated with this industry to foreign countries to study the economics and the technical aspects of the processes in practice in different countries and on their recommendation, orders should be placed for the most efficient plant. If it is found that sulphur can be manufactured by this process at a competitive price in comparison with the imported material, more factories can be put up and the country made independent of imported sulphur. In this connection, we would refer to the South India plant for the manufacture of 35 tons of sulphuric acid per day from gypsum (vide para 9) and suggest that the *entrepreneurs* may be advised to take up the manufacture of sulphur in addition to the acid; their results would give us valuable data. We also recommend that the possibility of importing Spanish pyrites from which copper and sulphuric acid can be manufactured should be examined. This, if found economical, will prove to be of great benefit as the Indian resources of copper are slender. We understand that the Government of Bihar have under consideration a scheme for starting a spelter industry from imported zinc concentrates. We support this scheme which would enable both zinc and sulphuric acid to be manufactured.

12. Taking into consideration the small consumption of chemicals in different parts of India and the small rayon units proposed to be installed, we are of the opinion that plants of large capacity as in the U.S.A., U.K. or Germany are not suitable for Indian conditions. Although small units may prove less economical on account of large overhead charges and comparatively large initial cost, we consider that the saving in transport and distribution would more than outweigh these advantages.

13. We are of the opinion that 20 to 25-ton-per-day sulphuric acid plants are suitable economic units, but taking into consideration the special conditions in India, we recommend that 10-ton-per-day units would be the most suitable except in special cases where larger units would be justified. On this basis, for the extra production of 59,100 tons required, fifteen units will be necessary in addition to the Government gypsum-sulphuric acid experimental plant of 10,500 tons capacity. We suggest that of these, plants with a total capacity of 30,000 tons may be located as follows:—

(i) *Sind*: There is at present only a very small plant which may not survive competition in the post-war period. This province is isolated from other parts of India and inaccessible and has also large tracts of land brought under the plough as a result of the Sukkur Barrage. Therefore, largely to provide acid for the manufacture of badly needed phosphate fertilisers, it seems desirable that a plant of at least 3,000 tons capacity should be established there.

(ii) *Bombay* : In view of the large developments contemplated in other industries, it is likely that consumption of acid in this area will go up. Therefore, installation in that area of one or two plants producing 6,000 tons in the aggregate would be desirable.

(iii) *Bihar* : For the extra production of ammonium sulphate in coal distillation plants in Bihar, about 13,000 tons of acid will be required. Therefore, installation in that area of two or three plants of 13,000 tons

total capacity is necessary. We also understand that the Government of Bihar has approved of a scheme for the manufacture of 15,000 tons of superphosphate which would require 15,000 tons of sulphuric acid. For this purpose, a plant of 15 tons capacity per day would be necessary.

(iv) *C. P.* : There is no manufacture of sulphuric acid in this Province, but large developments are contemplated by the Provincial Post-war Planning Committee. A 3,000-ton plant may therefore be installed there. This will be exclusive of any demand that might arise due to the installation of steel plant in this province.

When the Government experimental plant of capacity 10,500 tons per year recommended in para 11(iii) and the plants mentioned above are all installed, capacity will be increased by 40,500 tons per year. The balance of 18,600 tons will have to be allocated after the location of rayon plants by the Rayon Panel is decided.

14. With reference to the General Directive, we wish to make the following remarks:—

3(1-A) Including freight and insurance charges, the cost of each of the 10-ton plants with equipment for producing oleum also, imported recently from the U.S.A. was \$75,000. Therefore, the capital goods (to be imported) requirements for the 15 plants are estimated at about \$11,25,000 or 37.5 lakhs of rupees. The cost of the Government experimental plant is not included in this figure, as we are not able to estimate it. Appendix IV gives the list of sulphuric acid plant equipment that can be manufactured in India. This has not been taken into account in the above estimate, as it is not possible at this stage to work out the cost of manufacture in India.

3(2) All the plants except the Government gypsum-sulphur and sulphuric acid plant should be permitted to be installed by private industrialists.

3(3) Vide replies to 3(1-A) and 3(2)

3(4) Foreign technical experts would be necessary only for the Governmental experimental plant.

3(4-A) Some scholars proceeding to U.K. and U.S.A. may be directed to specialise in this work. In our opinion, the Government experimental plant will require three chemists and three engineers and each of the other plants one chemist and one engineer.

3(5) None.

3(6) Vide para 13.

3(7) Government should have a staff of experts who should pay occasional visits to the different factories on request, at a fee if necessary. This would conduce to a general increase of efficiency in the industry.

Since large quantities of sulphur are purchased annually both for the acid plants and sugar factories, we consider it desirable that the whole quantity should be purchased by a single corporation—Government-aided or otherwise—deliveries being arranged at such intervals as will enable minimum tonnages entitled to special freight rates to be imported.

We understand that at present, most of the sulphur is imported packed in gunny bags which raises its cost appreciably. Arrangements should be made to import sulphur loose; facilities should be provided for unloading it in Indian ports and for transporting it in railways.

These would result in cheaper sulphur.

We consider that the present tariff rates on the acid are sufficient.

3(7-A) There is no import duty on sulphur which is not available in India and there is a revenue duty of 30 per cent. *ad valorem* on sulphuric acid. Therefore, until the manufacture of sulphur in India is established, consideration of (7-A) does not arise.

3(8) We understand that even at present chamber plants of small capacity are being erected in different parts of the country without any control. We consider this harmful to a healthy growth of this industry and are of the opinion that chamber plants should not ordinarily be allowed to be installed unless the acid manufactured is for consumption in the plant itself and not for sale.

As far as possible, chamber acid should be used without further concentration for the manufacture of fertilisers, contact acid being reserved for special uses; exception may be made only in very special cases.

Wherever waste acid is available, its use for the manufacture of fertilisers and sulphates should be encouraged.

Ceiling prices should be fixed by the Government periodically on the basis of a fair margin of profit over the cost of manufacture. This is necessary, since cheap acid is essential for development of consumer industries. Although on account of its corrosive nature and high cost of transport, the acid enjoys virtual protection, solid products such as salts and dichromates prepared from sulphuric acid do not possess these advantages and cannot be developed if they are not assured of a supply of cheap acid.

3(9) To safeguard the interests of the industry, an association of Sulphuric Acid Manufacturers should be formed. We are not in favour of cartels.

3(10) Vide para 7

3(11) In the present stage of development of the industry, we do not think there is any prospect of export. When the industry is well established, this question will have to be taken up.

3(12) There is no possibility of a cottage industry.

*Note.*—All the figures given in this section refer to 100 per cent. Sulphuric Acid

## SULPHATES.

### I (b) (i) Sulphate of Alumina. Alums.

15 Alumino-ferric, i.e., sulphate of alumina with a small quantity of iron present as an impurity is largely used for purification of water

supplies and sizing in paper industry. For use as a mordant in dyeing and printing of cotton textiles, sulphate of alumina free from iron is required. Alums (double salts with sulphate of alumina) are also used

in dyeing, paper-making, tanning and textile industries. The raw materials required of alumina are bauxite which is available in large quantities in India and sulphuric acid. The process of manufacture is quite simple, no elaborate plant being required. The salt has been prepared by the sulphuric acid manufacturers for some years.

16. Present production is 16,000—17,000 tons per year, total requirements being about 20,000—21,000 tons. Taking into account the expansion planned in the paper and other industries, and the expected increased consumption of the chemical in water purification, we consider that a five-year-target of 38,000 tons as shown in Table V would be suitable.

TABLE V.

	Present consumption	Five-year target
	Tons.	Tons.
Paper industry . . . . .	10,000	20,000
Water purification . . . . .	3,500	14,000
Others . . . . .	2,000	4,000
	20,500	38,000

17. Since the quantity manufactured at present is all consumed locally, there is no immediate likelihood of export. When, however, there is increased manufacture, the question of export will have to be re-examined. This is one of those industries for which the raw materials are available in India and on this account it deserves special encouragement. We recommend that such protection as will enable it to develop successfully should be given to this industry.

(ii) **Magnesium Sulphate (Epsom Salt).**

18. This salt is used extensively in medicine, in the finishing of cotton fabrics, for weighting silk, paper and leather and for textile dyeing. In medicine, it is used in the form of Epsom salt. Before the war, imports of this salt were about 600 tons per annum mostly from Germany where it is obtained from the well-known potash deposits at Stassfurt. In India, it was made mostly by treating magnesite with sulphuric acid, but now it is also being recovered from bitterns. The total Indian production is estimated at about 3,500—4,000 tons and can be increased, if required, without any special difficulty. We do not consider any special efforts necessary.

(iii) **Iron Sulphate (Green copperas)**

19. Green copperas is hydrated ferrous sulphate used largely for the manufacture of ink and in the paint industry. It is obtained by dissolving scrap iron in sulphuric acid. As a matter of fact, large quantities are obtained as a by-product in the pickling industry in the steel plants. The present production of about 2,000 tons per annum is more than sufficient and can be increased, if necessary. No action is required in this case.

**(iv) Copper Sulphate.**

20. Copper sulphate is used principally as a fungicide, the chief purchasers being coffee, tea and rubber estates and the Department of Agriculture. It is made from scrap copper and sulphuric acid, imports into India have been about 1,800—1,900 tons per annum, agriculture taking up 80 per cent. of the material. Defence requirements were 2,000 tons for rot-proofing of bags, but this demand is fast disappearing. Estimated Indian production per annum is about 900 tons. Although copper sulphate is an important chemical required in agriculture for destruction of pests, we consider that the slender copper resources of India should not be used for the manufacture of copper sulphate, but should be utilised for more important purposes. The possibility of manufacturing copper sulphate from imported copper pyrites may be examined. Large quantities of copper sulphate would, however, be necessary for use in agriculture and this demand is expected to increase with greater applicability of scientific methods of control. Since this will be for the benefit of the ryot, we recommend that the copper sulphate imported for agricultural purposes should be free of duty.

**(v) Sodium Sulphate.**

21. Sodium sulphate is employed in the manufacture of wood pulp and glass, and in the textile industry as an auxiliary in the dyeing of cotton and wool. Purified and crystallised, it is known as Glauber's salt,  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$  and is used in medicine in large quantities. Pre-war consumption of sodium sulphate which is obtained as a by-product (salt-cake) in the manufacture of hydrochloric acid was about 3,000—4,000 tons. Production used to be about 2,000 tons and imports about 1,700 tons. Recently, large deposits of the salt have been discovered in the Didwana Salt Range in Jodhpur. We do not therefore consider that any special efforts for manufacture are necessary and do not suggest any target.

**OTHER SULPHUR COMPOUNDS.****(c) (i) Sodium Sulphide.**

22. Sodium sulphide is used as a depilatory in the tanning industry for dehairing hides, in textiles as a developer of sulphur dyes, as a causticising agent in paper industry and to a small extent in photography. Pre-war imports were about 2,000—3,000 tons, there being no manufacture in India. We understand small quantities are now being manufactured. Textiles, leather, paper and other industries consume about 3,700 tons of this chemical. Taking into consideration the expansion planned for in these industries during the next five years, we expect a larger consumption of sodium sulphide as detailed in Table VI and therefore recommend a five-year-target of 7,000 tons per year.

TABLE VI.

	Present consumption.	Five-year target of production.
	Tons.	Tons.
Textiles . . . . .	2,500	4,500
Leather . . . . .	500	1,000
Soda ash plants . . . . .	600	1,250
Paper . . . . .	100	250
About . . . . .	3,700	7,000

23. We understand that the Jodhpur State has undertaken the manufacture of this chemical. We have no doubt that the State authorities are fully alive to the importance of making arrangements for the production of all the sodium sulphide required in India, within a reasonable time and making it available to the consumers at reasonable prices. If, however, this scheme does not become successful within a period of one year, the Government of India should make other arrangements. We also recommend that at the same time alternative sources should be developed. Sodium sulphate is obtained as a by-product in dichromate and hydrochloric acid plants and the management of these factories should be encouraged to manufacture sodium sulphide by the grant of special concessions.

**(c) (ii) Sodium Sulphite.**

24. Sodium sulphite is employed in India mainly in photography and to a small extent in some industries. Pre-war imports were 100 tons per year. Present production is adequate and we do not consider any special steps necessary.

**(iii) Sodium Thiosulphate. (Hypo).**

25. The pre-war requirements of sodium thiosulphate which is used chiefly in photography (80 per cent.) and to a small extent for leather (20 per cent.), were of the order of 500 tons. There was no manufacture in India before the war. But now, production has been started by a number of firms, plants of 300—500 tons capacity having been put up recently. It is expected that local manufacture will cover the requirements; we, however, consider that this infant industry should be protected.

**(iv) Sodium Hydrosulphite (Hydros).**

26. Sodium hydrosulphite is an important chemical used in the textile and sugar industries. Pre-war requirements were about 1,600 tons per annum, 80 per cent. of which was used in dyeing, 15 per cent. for sugar manufacture and 5 per cent. for miscellaneous purposes. We suggest a five-year-target of 2,500—3,000 tons. We understand that the



manufacture of this salt has not been taken up in India, cheap zinc and sulphure dioxide being necessary for its economical production. We recommend that investigations which are being carried out by the Council of Scientific and Industrial Research on the possibility of developing alternative processes utilising Indian raw materials should be continued.

## II. ALKALI INDUSTRIES.

27. One of the most important operations in Chemical Industry is the manufacture of alkali, which is essential for the manufacture of many of the goods in everyday use. Glass, soap, paper and textiles are all alkali products, while vegetable ghee, leather, disinfectants, dyes and numerous other industries require alkali for their manufacture; Chlorine, one of the products of the caustic alkali industry is essential for water purification, in the paper and textile industries and for manufacture of chlorinated solvents, medicinal preparations and dyes.

### (a) Common Salt.

28. Common salt is the most important raw material of the alkali industry, finding use directly as such in LeBlanc, ammonia-soda, electrolytic caustic, glass, leather, soap, textile, paper, ceramic, enamel and other industries. It is also a preservative and is used in fish-curing, meat-packing, dairying and other industries. It is the preponderant mineral constituent of sea water and also of the deposits which have resulted from the desiccation of ancient lakes and seas. Salt is chiefly used in India for edible purposes, its use in industries being very small compared with that in other industrial countries. But hereafter, when industrial development takes place, the consumption of salt will naturally go up enormously and it will be necessary to provide for this increase. The total consumption of salt in India is about 2.25 million tons of which Heavy Chemical Industries recently established are estimated to consume about 225,000 tons; but with the development of new industries this may be expected to increase to half-a-million tons easily.

29. Complaints have been received that salt is abnormally expensive, especially in Bengal, resulting thereby in higher cost of alkali, which, in turn, affects the cost of manufacture of other products. As regards purity, although the salt available at present is suitable for most purposes, its purity is not sufficiently high for use in the alkali industry, as can be seen from the analysis of the different types of salt manufactured in India and of that used in the U.S.A. for alkali industries (Appendix V). We are, therefore, of the opinion that in order to establish a successful alkali industry in India, pure salt must be supplied at cost price. Because of the necessity of transport over long distances between the factories and the centres of salt manufacture, special railway freight concessions are also necessary. In view of the importance of this subject, the Central Board of Revenue arranged, at our request, for Mr. H. A. C. Gill, Collector of Central Excise and Dr. S. S. Aiyar, Chief Chemist, Central Board of Revenue, to meet the Panel in order to clarify some points about the manufacture and supply of common salt

to chemical industries. We give below the points clarified as a result of discussion:—

(i) It was suggested that the C.B.R. should permit manufacturers of common salt to use such methods of purification as would make the salt suitable for use directly in their industries. The officers did not anticipate any trouble in permitting this to be done.

(ii) The Panel wanted that the C.B.R. should supply pure salt to all industries. The representatives said that conditions varied in different places, the source being rock salt in some places and brine in the others. It would be, therefore, difficult to lay down a uniform policy for all places.

(iii) A request was made that owners of salt pans who manufactured salt for industries should be permitted to remove small quantities of brine for purposes of experiment after paying duty if necessary. Mr. Gill said there was no objection to it.

(iv) The Panel was of the opinion that by-products of bitterns should be permitted to be recovered. The reply was that this was permitted and even encouraged.

(v) The Panel desired that the use of brine for recovery of salt should be permitted all the year round. It was stated in reply that in a few places, climatic conditions were against working of salt pans all the year round; otherwise, no objection could be seen.

(vi) The Panel was keen that the price of salt should be reduced by improved methods of manufacture. It was stated in reply that although just at present, due to increased cost of manufacture, the price of salt was a little higher than usual, normal price was as low as cost of manufacture permitted. At the salt sources controlled by the Government of India, salt was sold at cost price and all possible methods were being applied to produce the salt at the lowest possible cost. (We understand, however, from Messrs. Imperial Chemical Industries that while salt was being supplied to their Rishra plant at Rs. 75 per 100 mds. in 1940, the present price is Rs. 400 for many of the consignments. This would seem to require examination in view of the statement made by the Collector of Central Excise). The question of introducing improved methods in privately owned salt works was outside the scope of the Central Excise Department; but if individual manufacturers could reduce the price still further by improved methods, there would, of course, be no objection from the point of view of the Government Salt Works.

(vii) It was suggested that salt dust should be given free of charge or at least at the same uniform rate to all industries. Salt dust, it was stated, was being issued at the same uniform rate to all industries, except that under the terms of a contract entered into with the Alkali & Chemical Corporation of India, the waste salt of Khewra Mine, which includes salt dust and marl, to which they were entitled under their agreement, was being issued to their Khewra factory at a special fixed rate. Limited quantities of dust salt from Warcha mine and of crushed salt from Khewra mine were being issued, it was stated, to other industrial concerns to the extent available.

**(b) Lime.**

30 Slacked lime is used in enormous quantities for preparation of mortar and to a small extent in the sugar industry and in a large variety of chemical operations, being the cheapest form of alkali. It is an essential raw material for causticising soda ash and for liberating ammonia from ammonium salts as in the soda ash industry. Estimated consumption in chemical industries in India is about half-a-million tons. Large quantities of limestone sufficiently pure for use in industry are stated to be available at a number of centres, but the information available (Appendix VI) seems to be insufficient, since chemical analysis of limestone will not itself give an indication of its easy convertibility to lime by burning in the kiln. We consider this information essential for the location and successful working of important chemical industries depending on lime and recommend that the C.S.I.R. should investigate the burning qualities of the different samples of limestone available in India, in collaboration with the Geological Survey of India. We are also of the opinion that complete information about the quantities of limestone available, uniformity of grade and analysis should be collected and made available to the industrialists. It is essential that chemical industries should be able to obtain lime of guaranteed quality for their use. Although lime of good quality is produced in soda ash plants, it is consumed in the plants themselves. At present there is no plant in India manufacturing lime by modern processes, for supply to chemical industries, especially to the sugar factories, where it is essential. We are, therefore, of the opinion that Provincial Governments should encourage the installation of modern lime kilns suitable for burning the limestone available in the province to supply high grade lime to the sugar and other chemical industries.

**(c) Soda Ash.**

31 Soda ash is one of the most extensively used chemicals in the world, glass industry alone consuming a fourth of the production. World production in 1941 by the chemical process was about 6 million tons. Large deposits of this chemical also occur in different parts of the world, in Mexico, Persia, Southern Russia, California and the Magadi lake in British East Africa. An analysis of consumption of soda ash in the U.S.A. in 1940 is as follows:—

TABLE VII.

	Tons.
Glass . . . . .	807,000
Soap . . . . .	163,000
Caustic and bicarbonate . . . . .	700,000
Other chemicals . . . . .	634,000
Cleaners and modified sodas . . . . .	121,000
Pulp and paper . . . . .	99,000
Water softeners . . . . .	29,000
Petroleum refining . . . . .	11,000
Textiles . . . . .	40,000
Exports . . . . .	54,000
Miscellaneous . . . . .	165,000
	2,823,000

(Roger's Industrial Chemistry).

In India, about 107,500 tons of soda ash were consumed in 1944, as detailed below:—

TABLE VIII.

	Present consumption.	Five year target.
	Tons.	Tons.
Glass . . . . .	25,000	50,000
Papers . . . . .	12,000	24,000
Textiles . . . . .	9,000	12,500
Dichromates . . . . .	5,000	5,000
Sodium Silicate . . . . .	3,500	3,500
Ordnance factories . . . . .	3,000	3,000
Misc. Chemical industries . . . . .	2,000	4,000
Washing and cleaning . . . . .	48,000	70,000
For manufacture of 57,000 tons of caustic soda . . . . .		95,000
	107,500	267,000
		(or about 270,000 tons)

32. There are three soda ash plants in India at present, but although their capacity has been of the order of 74,000 tons per annum (Table IX), actual production has been only about a half of it.

TABLE IX.

	Tons.
Dhrangadhra Chemical Works . . . . .	18,000
Tata Chemicals, Mithapur . . . . .	36,000
I.C.I. Plant at Khewra . . . . .	20,000
	74,000

As we have stated before soda ash is essential for glass, paper and other industries, which have all been established in India and are expected to expand in the post-war period. As detailed in Table VIII, taking into account the expansion of these and other soda-ash-consuming industries during the next five years planned by the respective panels, we are of the opinion that a five-year-target of 270,000 tons should be aimed at. This target includes the soda ash required for manufacturing 57,000 tons of caustic soda by the causticising process (para 50). If we assume that the present capacity will be translated into production soon, the balance of productive capacity to achieve the target will be 196,000 tons.

33. We understand that one of the present plants is planning expansion from a production of 18,000 tons to 24,000-30,000 tons per year and that the Government of India have granted an import licence to a firm in Madras Presidency for one plant of capacity 15,000 tons per year in the first instance, to be later raised to 30,000 tons. Extra production to be arranged for would, therefore, be about 160,000 tons. This is an industry which has been established in other countries on the basis of plants of large capacity—about 70,000—100,000 tons per annum. For Indian conditions this scale of operation may not be

practicable. We consider, however, that plants of fairly large capacity are necessary and recommend that four units, two of 50,000 tons each and two of 30,000 tons each be installed.

*Location.*—Without a detailed examination of all the conditions necessary for the proper location of a soda ash plant, it is difficult to suggest exact locations for the four plants mentioned above. Each ton of soda ash requires for its manufacture 1.7—1.8 tons of salt, 1.3—1.5 tons of limestone, 0.1—0.11 ton of coke and 0.7—1.05 tons of coal in addition to small quantities of ammonia. Further plenty of water is required—2,000—2,500 Cft. i.e., about 12,250—15,500 gallons per ton of soda ash. Punjab is the only Province where almost all the raw materials are available, but there is already a plant working there. Sind has both salt and limestone; coal and coke will have to be transported. Bihar has limestone, coal and coke; salt will have to be transported. South India near one of the sea coast towns has both limestone and salt; coal and coke will have to be transported. The Central Provinces have both limestone and coal; salt and coke will have to be transported. Therefore, it is seen that all the raw materials are not available in any part of India except in the Punjab. Taking all the factors into consideration, we recommend that the four soda ash plants be located as follows:—

(i) One 50,000-ton plant.—In Sind, as near to Karachi as possible, where both limestone and salt are available. Coal and coke will have to be taken by sea from Bihar via Calcutta.

(ii) One 50,000-ton plant.—In Bihar, near Shahabad where limestone of good quality is available. Salt will have to be taken from the Punjab salt mines or from Sambhar lake. Attempts should also be made to manufacture the necessary amount of salt—about 85,000 tons per year from sea water at the nearest coastal town. Coal and coke are available and ammonia also will be available in the new Sindhri plant.

(iii) One 30,000-ton plant.—In South India, near one of the sea coast towns. Lime will have to be made from shells. Coal and coke can be transported from Bihar via Calcutta.

(iv) One 30,000-ton plant.—In the Central Provinces.

The availability of water and raw materials near the selected site has to be examined in consultation with the Provincial Governments.

It may be mentioned that the consumption of soda ash in the different parts of India is as follows:—

	1939-40	1943-44
	Tons.	Tons.
Calcutta Zone (Bengal, Assam, Bihar, U.P. including Delhi, Orissa and a part of C.P.)	46,579	30,031
Bombay Zone (Bombay—Central India, part of C.P. and Rajputana)	16,895	30,627
Madras Zone (Madras, Mysore and other South Indian States and a part of Hyderabad)	7,830	6,57
Karachi Zone (Sind, Baluchistan, Punjab and N.W.F.P.)	14,039	8,89
Total	85,343	76,128

34. Small quantities of the chemical now being collected from the Reh deposits in Cutch, Sind, the U.P., Bihar and the C.P., have not been included in the production figure given in Table IX. But this work has not been organised properly and an important source of soda ash is thus not being utilised. We recommend that the Governments of the above-mentioned provinces should organise this collection properly on a cottage industry basis and thus utilise the resources of the country. Soda ash collected in this manner may not be sufficiently pure for chemical industries, but it will be useful for domestic purposes.

35. With regard to the soda ash industry we make the following recommendations with reference to the points in the General Directive to Industrial Panels :—

3(1-A) Taking into consideration the present abnormal conditions as regards price and availability of plants, we are not in a position to give the estimated requirements of capital goods in this case with any accuracy. The late Mr. Kapilram Vakil was of the opinion that the pre-war cost of a soda ash plant worked out to Rs. 1,10,000 per ton per day, and on this basis the pre-war price for plants of total production capacity, 1,60,000 tons per year or about 530 tons per day would be nearly Rs. 6 crores. The present cost would probably be more.

3(2 & 3) We consider this industry, essential by itself and for the manufacture of products in daily use. The manufacture of extra production required to achieve the target should be arranged for by Government ownership entirely or partly in association with private capital

3(4 & 4A) For this industry, we consider that technical advice from abroad is necessary. Indian chemists and chemical engineers should however, be trained as early as possible to take up positions of responsibility. We would suggest, in this connection, that some Government scholars who are being sent abroad for training may be asked to specialise in this industry. We consider 12 chemical engineers in all would be sufficient.

3(7) This industry requires protection, either higher duty or subsidy, but only to such an extent as will not penalise the consuming industries.

3(7-A) Does not apply.

3(8) The chemical should be made available to the consumer at a reasonable price.

3(9) No association or cartel is necessary.

3(10) We consider that the plants should be installed as soon as a survey of the proposed sites is completed.

3(11) We do not consider that there is any likelihood of export, at least for the present.

3(12) There is no possibility of a cottage industry, except the collection from alkaline earth deposits referred to in para 34.

**(d) (i) Sodium Bicarbonate.**

36. The use of sodium bicarbonate is chiefly in medicinal preparations, food materials and fire-extinguishers. It also serves as a source of carbon dioxide in baking powders and in artificial mineral waters. India consumes about 6,000—6,500 tons per annum, present production being only about 1,500 tons. As this chemical depends on soda-ash for its manufacture, it would be comparatively easy to develop it when soda-ash production is increased. We do not consider it necessary to make any special recommendation.

**(ii) Sodium Silicate.**

37. Sodium silicate is employed in the lining of casks, weighting of silk and in the manufacture of soaps of cheaper quality. It is also employed as an adhesive either alone or with cement materials in the making of concrete surfaces. The manufacture is fairly simple, the chemical being produced when soda-ash and clean sand are heated in a special furnace. It is difficult to estimate the production of sodium silicate in India, as manufacture is carried on by small firms, all over the country. The only indicator is the quantity of soda-ash issued for the purpose which, in 1943 was 3,500 tons. The preparation is comparatively easy and a number of manufacturers have taken it up; but modern methods are not used and the quality of the product is not good. We consider that improvements must be effected in both these respects. Success of this industry would, however, depend on the price of soda-ash.

**(iii) Cyanides and Ferro-Cyanides.**

38. Sodium cyanide in the presence of oxygen dissolves almost all metals except lead and platinum and this property is made use of in the extraction of gold and silver from their ores. It is also used in case-hardening of steel and in electro-planting. Calcium cyanide is used in fumigation since it is easily hydrolysed by water evolving hydrogen cyanide possessing lethal properties. Ferro-cyanides are used in admixture with other products like starch etc. for the manufacture of commercial blues. In India, sodium cyanide is used chiefly in Kolar Gold Fields, Mysore State, for the extraction of gold, average consumption per year being about 200 tons valued at Rs. 2.5 lakhs. Since the quantity required is not very large and there is only one large consumer, we do not consider it necessary to recommend any steps to manufacture this product immediately.

**(e) Caustic Soda, Caustic Potash and Chlorine.**

39. Caustic soda is one the most important heavy chemicals, its principal uses being in the rayon, soap, paper, mercerized cotton, explosives, dyestuffs, vegetable oils, chemical and other industries. From

published data, we find that a quantity of nearly a million tons was produced in 1940 in the United States and disposed of as shown below :—

TABLE X.

	Tons.
Soap . . . . .	85,000
Chemicals . . . . .	196,000
Petroleum refining . . . . .	79,000
Rayon and cellulose film . . . . .	205,000
Lye . . . . .	42,500
Textiles . . . . .	42,500
Rubber reclaiming . . . . .	18,000
Vegetable oils . . . . .	14,000
Pulp and paper . . . . .	47,000
Exports . . . . .	93,000
Miscellaneous uses . . . . .	155,000
	977,000

40. In India, manufacture has been developed only to a small extent but consumption is appreciable and is likely to increase hereafter. On the basis of unrestricted off-take of the existing consumer industries, about 54,000 tons of caustic soda are required annually.

TABLE XI.

	Present consumption.		Five-year target.
	% age.	Quantity.	
Soap . . . . .	43	Tons. 23,500	Tons. 52,000
Textiles . . . . .	38	15,400	21,000
Paper . . . . .	16	9,000	18,000
Miscellaneous including oil-refining, vegetable ghee etc.	6		
For the manufacture of 60 tons of viscose rayon per day . . . . .	11	6,000	12,000
	114	54,000	133,000

41. The present Indian capacity for manufacture is 12,600 tons per annum, and with the three electrolytic plants which are expected from the U.S.A., productive capacity will go up to 17,600 tons ; manufacture will still be largely short of consumption. No country can afford to depend on imports of this essential chemical. Consumer industries are well established in India and can be easily developed : we therefore, consider it essential that caustic soda production in India should be stepped up as early as possible.

42. Both the methods of manufacture, electrolysis of brine and causticising of soda ash are being used more or less to an equal extent



in other countries, although there is a general tendency to change over gradually to the electrolytic process as can be seen from the following table of production in the U.S.A.:-

TABLE XII.

	Lime-Soda.	Electrolytic.	Total.
	Tons	Tons	Tons
1921 . . . . .	148,000	67,400	213,400
1925 . . . . .	318,000	126,320	444,000
1929 . . . . .	469,000	217,000	686,000
1933 . . . . .	392,000	221,000	613,000
1937 . . . . .	436,000	429,000	865,000
1939 . . . . .	474,000	441,000	915,000
1940 . . . . .	446,000	531,000	977,000

(Roger's Industrial Chemistry)

### Electrolytic Alkali.

43. Capacity to utilise chlorine obtained in an almost equal quantity sets a limit to the adoption of the electrolytic process. In the U.S.A., new uses of chlorine have been developed because of the urgent need for finding fresh outlets for the large quantity of chlorine produced in the electrolytic caustic industry. These new uses have been developed to such an extent that now there is actually a move towards chlorine without alkali. The percentage consumption of the large quantities of chlorine produced in the U.S.A., is as follows :-

TABLE XIII.

Pulp bleaching . . . . .	%
Chlorination products . . . . .	21
Disinfectants and sanitation . . . . .	60
Textiles . . . . .	6
Miscellaneous uses . . . . .	5
	8

44. The prospect of our developing all these lines in India immediately does not look promising, although the need is there. To take one instance, 21 per cent. of chlorine produced in U.S.A. or about 90,000 tons were used for bleaching pulp, a substantial portion of which was used for paper manufacture. Population of India is three times that of the U.S.A. and when universal compulsory education is introduced, as has been visualised, the demand for paper will be enormous and we estimate that India will require more than 100,000 tons of chlorine for bleaching pulp. This will, however, form a long-term

programme, the question being bound up with the educational policy of the Government and expansion programme of the paper industry. For the present, we understand that the Paper Panel has fixed a five-year-target of double the present production of 62,000 tons of white paper per annum. To revert to Table XIII, chlorination products include a large variety of chemicals. Carbon tetrachloride, chlorinated, naphthalenes, chloroform, refrigerants and hypochlorites consume large quantities; extraction of bromine from sea water and chlorinated rubber are responsible for a good off-take. Treatment of drinking water, of sewage and effluents from industrial plants, and of water in swimming pools uses up 6 per cent. If electrolytic caustic industry is to be developed in India, proper disposal of chlorine is essential. This problem is important from two aspects—the higher cost of caustic due to non-utilisation of chlorine and what is equally serious, the disposal of the poisonous gas produced.

45. We consider that in addition to pulp manufacture, which will be the obvious large outlet for chlorine, the most promising lines are manufacture of DDT and hexachlorocyclohexane (benzene hexachloride; 666) the two most valuable insecticides. In a country where malaria takes its heavy annual toll and there is enormous damage to crops by insects pests, the importance of these two chemicals cannot be over-emphasized. In the absence of definite programmes of the Departments of Public Health and of Agriculture, it is difficult to estimate the possible annual requirements. We understand from the Public Health Commissioner to the Government of India that while he finds it difficult to forecast the probable requirements of DDT and 666 with any degree of accuracy for the next five years due to the results of large scale field controls not being ready, he does not consider that the average demand over the next five years is likely to exceed 5,000 tons per year for anti-malaria purpose only. This was clarified by the Deputy Public Health Commissioner in a discussion with the Panel. With the present grants and on the cost of DDT, which is, exclusive of the solvents and cost of preparation of the final spray, about Rs. 9,000 per ton, we understood that more than 5,000 tons could not possibly be used. We consider this price of DDT very high. While its published price in England is 4 shillings per lb., it is only 26 cents or about 15 annas to 1 rupee in the U.S.A. Therefore, if the material can be had at a lower price, it should be possible to use more of it. The army authorities seem to be of the opinion that the dosage to be aimed at should be 2.4 ounces of DDT per acre. About three applications per season would be necessary and this would have to be done over large areas. The estimate of the Public Health Commissioner does not seem to include the whole of India. Further, agricultural uses and other civilian uses such as spraying in homes to kill mosquitos, flies, etc., have to be taken into account. Taking all these into consideration, we are of the opinion that an eventual annual target of 30,000 tons in all of DDT and 666 should be aimed at.

(a) 30,000 tons of DDT would require about 75,000 tons of chlorine for its manufacture. The complicating factor, however, is the disposal of large quantities of hydrochloric acid obtained as

a by-product. In addition to the acid produced in the manufacture of chlorobenzene and chloral, the two components for the production of DDT, large quantities are also produced due to the formation of dichlorobenzene in appreciable quantities. Actually, about 40,000—45,000 tons of hydrochloric acid will be obtained as a by product.

(b) 666 is easily made by the addition of chlorine to benzene and the production of hydrochloric acid is small. There are four isomers produced, only one of which is 15 times as active as DDT for insecticidal purposes, the other three being inert. The active component is, however, produced only to the extent of 10—12 per cent., the remaining 88—90 per cent. being useless, according to the information available at present. Since, however, a mixture of all the four isomers is almost as active as DDT, it may be more practicable to use the crude product as such for most purposes. 30,000 tons of 666 require about 22,000 tons of chlorine.

In view of the established production of both these chemicals on a large scale in other countries and possibility of shortage of benzene in India due to manufacture of dyestuffs, we are of the opinion that this scheme should be taken up gradually after the programme of the Government is known. The manufacture of benzene hexachloride will obviously have to be done near the coal distillation plants in Bihar. Even for DDT, we recommend that in order to avoid the transport of benzene which is inflammable, to different parts of the country, chlorobenzene, should be prepared near the coal distillation plants and transported to the different parts of India. We are of the opinion, however, that in the first instance, a central alkali plant of 10,000 tons annual chlorine capacity (11,400 tons caustic) should be installed for this purpose in Bihar. The balance of 10,000 tons of chlorine would have to be distributed in different areas in close proximity to distilleries. It is therefore seen that for the present, only 20,000 tons of chlorine will be used per annum for the manufacture of these insecticides the production of which will be limited to that extent.

46. For all other uses, such as water purification, textiles, paper industry, etc., about 10,000 tons of chlorine in addition to the present consumption in different forms estimated at about 10,000 tons per year would be necessary. We, therefore, fix the five-year-target for chlorine at 40,000 tons per annum, the corresponding target for electrolytic alkali being 45,000 tons.

47. Present productive capacity is, as stated already, 12,600 tons of caustic soda per year and with the three new plants, it will be 17,600 tons. Therefore, the balance of production to be arranged for, to realise the five-year-target of 133,000 tons (Table XI) is 115,400 tons. Of the 17,600-ton-capacity, 11,400 is electrolytic and the balance of 6,200, lime-soda. Therefore, the provision to be made for extra production to bridge the gap between the present capacity and the five-year-target is about 33,600 tons of electrolytic alkali and about 82,000 tons of alkali by the lime-soda process for some time to come.

48. Before suggesting the location of plants, we should like to make the following remarks:—

(i) This important industry should be widely distributed as a most all Provincial Governments are taking up hydro-electric

schemes on hand;

(ii) In connection with the manufacture of DDT, for which chlorobenzene and chloral are required, sufficiency of Indian production of benzene has to be examined especially in view of the contemplated manufacture of dyestuffs for which large quantities of this chemical would be required. In order to avoid the transport of this inflammable liquid to the different centres for the manufacture of DDT, we are of the opinion that chlorobenzene, one of the ingredients for the manufacture of DDT, should be manufactured at the site of the production of benzene, that is, near the coal distillation plants in Bihar. The resulting chlorobenzene should be transported to the different parts of India. The chlorine required would be available in the central alkali plant to be established in Bihar, as suggested in para. 45. Chloral requiring for its manufacture absolute alcohol and chlorine should be made near the distilleries and DDT prepared on the spot by combining chloral with chlorobenzene obtained from the central factory.

(iii) Similarly, the benzene hexachloride also should be made at the site of production of benzene, i.e., in Bihar, where chlorine would be available in the Central alkali plant.

(iv) We understand that very pure caustic soda is required for the Viscose-rayon industry, the chemical made in the diaphragm cell not being sufficiently pure for the purpose. Since only a small quantity of chlorine is required in the viscose-rayon industry, disposal of chlorine obtained simultaneously with the caustic soda would present a problem. To solve this, we are of the opinion that the manufacture of caustic soda for the rayon industry should be linked up with the chlorine required for DDT and benzene hexachloride. In (ii) above, we have suggested that a central alkali plant producing about 10,000 tons of chlorine may be located near the coal fields. This plant will produce about 11,400 tons of caustic soda and we recommend that this plant may be of the mercury cell type, manufacturing caustic soda suitable for use in the rayon industry. Of the 30,000 tons of caustic soda required for the Viscose-rayon industry, the balance of 18,500 tons would have to be made by the lime-soda process or imported for the present.

(v) Common salt, cheap electric power and market for caustic soda and chlorine would decide the location of electrolytic caustic. We would lay special stress on cheap power, 3,500 KWH being required for each ton of caustic soda manufactured. One plant would anyhow have to be installed near Bihar and fields for the manufacture of chlorobenzene and benzene hexachloride.

49. We understand that the Government of India have granted import licences for 5-ton-per-day plants, two to be installed in Bombay and one at Porbandar, and a 10-ton plant for Mandi State. It is also understood that Mettur Chemicals are duplicating their plant. Government of Mysore have agreed to the installation of a plant of 8 tons capacity at Bhadravati, near the Mysore Paper Mills. Government of Hyderabad also propose to instal a plant of 5-ton-per-day capacity in Hyderabad. A well-established firm of manufacturers in South India is contemplating to put up a 8,000-ton plant on the East Coast of the Madras Presidency. All these total up to 21,000 tons. The total production capacity of electrolytic alkali from the existing plants, the three already ordered, the central plant in Bihar and the new plants referred to above would be about 44,000 tons. Since chlorine utilisation is the only limiting factor for the installation of more electrolytic alkali plants, we are of the opinion that these may be permitted to be installed if the applicants can demonstrate a definite scheme for the proper disposal of chlorine.

#### **Lime-Soda-Caustic.**

50. The present production capacity of lime-soda is about 6,200 tons and for the balance of about 82,000 tons, we are not suggesting any location immediately, as these plants will naturally be worked in conjunction with the soda ash plants and therefore their location will depend on the location of the latter. Provision for the soda ash required for causticising has been made in the soda-ash-target. It must be remembered, however, that with the increase in consumption of chlorine, production of lime-soda caustic will have to be reduced. Therefore, in the soda ash target, we have provided for sufficient soda ash to give only 57,000 tons of caustic soda, in the belief that after some time, about 25,000 tons more of electrolytic caustic and chlorine can be manufactured and consumed.

#### **Caustic Potash.**

51. There is no production of caustic potash in India now, but we understand that one firm in Bombay has been given permission to instal a plant. This is expected to be adequate for the present. Since caustic soda and caustic potash are produced by similar processes by the same equipment, there would be no difficulty in expanding production when there is need.

52. In connection with the General Directive to the Industrial Panels, we recommended as follows:—

3(1-A) A rough estimate would be 16 lakhs of rupees for each 5-ton plant.

3(2) We are of the opinion that this industry should be financed by private capital. Only the mercury cell alkali plant in Bihar may be installed by Government.

3(3) Vide replies to 3(1-A) and 3(2).

3(4) We consider that Government should have a staff of technical experts to visit the plants and give them technical advice when required.

3(4-A) There are very few technical men in India, who are familiar with this industry. If possible, we suggest that Government should direct some of the scholars who have been deputed to the U.S.A. and the U.K. to specialise in this work on the basis of one chemical engineer for each plant. Further, the technical personnel in the existing alkali plants should be given facilities for special training abroad.

3(5) We do not consider any help from foreign firms necessary.

3(6) Location has been given in paras. 49 and 50.

3(7) We are of the opinion that this industry should be protected but since caustic soda is an essential chemical for a large number of consuming industries, we recommend that such protection as will not penalise the consuming industries should be given. We leave it to the Government to decide which is preferable in the interest of Indian Industry—a higher duty or subsidy, or both.

3(7-A) Does not apply.

3(8) Vide 3(7)

3(9) To safeguard the interests of the industry, we recommend that caustic soda manufacturers should form an association, but no cartel should be permitted.

3(10) As regards the stages by which the electrolytic alkali industry should be developed, we are not able to make a recommendation at this stage since the demand will depend on the price of the insecticides. The industry should be developed in consultation with the Departments of Public Health and of Agriculture.

3(11) We do not think there is any possibility of export.

3(12) This industry does not lend itself for organisation on a cottage industry basis.

We are of the opinion that the Government should make available to the industry (i) cheap and pure common salt and (ii) electric power at not more than 0.15 anna per KWH

#### (f) Potassium Chlorate.

53. Potassium chlorate is used chiefly in the manufacture of matches, in pyrotechnics and blasting powders. The raw materials are potassium chloride, lime and chlorine, all of which are available in India. Cheap electric power is also necessary, power consumption being 6,800—7,000 KWH per ton of chlorate. We understand that pre-war imports were about 2,000 tons, there being no manufacture in India. After the beginning of the war, we understand that Wimcos have developed production to the extent of 1,800 tons per year and some small firms about 100—200 tons each. The present production which is not sufficient for the needs of the country, will have to be stepped up as the demand may be expected to increase still further. Small-scale manufacture independently is uneconomical and it would be desirable to instal chlorate plants as a part of alkali plants so that overhead charges may be reduced. There is only one firm now manufacturing chlorate on a large scale and this monopoly is not desirable especially as the firm is also a manufacturer of matches. We recommend, therefore, that a plant of 1,000—1,500 tons capacity should be installed in one of the alkali plants.

We understand that potassium chloride manufactured by Indian firms is only 70 per cent pure and not suitable, with the result that it has to be imported from Palestine. We are of the opinion that potassium chloride of suitable quality for this important industry should be prepared in India, the raw material bitterns being available in unlimited quantities.

### III (a) HYDROCHLORIC ACID.

54. Hydrochloric acid is an important mineral acid next only to sulphuric and nitric acids in importance. Manufacture of ammonium chloride, zinc and other metallic chlorides and cleaning of metals prior to rolling into sheets or coating with zinc, tin or lead,—all these require hydrochloric acid. We understand that pre-war imports were almost negligible, India producing all her requirements by the salt-cake process, i.e., by the action of sulphuric acid on common salt. Present production is about 2,500 tons. A more elegant process of manufacture of the pure acid is by direct combination of chlorine and hydrogen both of which are produced when brine is electrolysed. Only one or two firms in India are using this—what is quite a simple process now. In order to eliminate the use of sulphuric acid manufactured from imported sulphur and to provide a suitable outlet for some of the chlorine produced in the electrolytic alkali industry, we consider that all the hydrochloric acid required should be manufactured in this manner and suggest that in future only direct synthesis plants should be permitted to be installed. A quantity of about 1,000 tons of chlorine will be utilised for the manufacture of about 3,000 tons of acid, which we estimate as the probable quantity required per year. Any shortages can be supplemented by the acid obtained as a by-product in organic chlorinations, e.g., manufacture of DDT.

#### (b) (i) Zinc Chloride.

55. Zinc chloride is used in the textile industry to prevent growth of mildew, as a raw material for the manufacture of dry cells and in a few other industries. Small quantities are being made by the action of hydrochloric acid on zinc dross and skimmings, but to supply the demand, it has been necessary to import 1,800—2,000 tons annually. No special technical difficulty seems to be involved and we understand this manufacture can be developed when cheap zinc residues become available in sufficient quantities. No special action seems to be necessary at this stage.

#### (ii) Magnesium Chloride.

56. Magnesium chloride finds use in the manufacture of oxy-chloride cements, in the textile industry for sizing, in refrigeration, in the preparation of special floors and also in the manufacture of magnesium. Indian demand is about 7,000 tons. We understand that two firms in India manufacture it from bitterns; it is also being made by the action of acid on magnesite. Not only is the entire Indian demand met, but small quantities are also exported. No special action is called for.

**(iii) Calcium Chloride.**

57. The chief uses of calcium chloride are as a refrigerant and as a dust layer on roads. It is obtained as a by-product in the manufacture of potassium chlorate by the chemical process and can be prepared from distiller waste—a waste material available in Solvay soda-ash plants. Pre-war average annual imports used to be about 850 tons and consumption was about the same. Although the present Indian capacity is more than enough to meet the existing requirements, we feel that consumption will increase and future demand may be estimated at 1,500—2,000 tons per year. We understand that expensive chemical processes are being used for manufacturing this chemical. It would be desirable that it should be recovered only as a by-product.

**(iv) Potassium Chloride.**

58. Potassium chloride is a raw material for the manufacture of potassium chlorate, caustic potash and other important potassium salts like potassium carbonate and bicarbonate. It is also an important fertiliser. Imports into India of the fertiliser grade chemical have been about 3,000 tons per annum. One or two firms are manufacturing it now from bitterns, but the quality is not sufficiently good for the manufacture of potassium chlorate and has to be improved. Potassium chloride is also obtained as by-product in the preliminary refining of crude saltpetre. We are of the opinion that this manufacture should be organised properly and developed when there should be no need for imports.

**(v) Barium Chloride.**

59. Barium chloride is used in leather tanning and refining of common salt solution to remove sulphates and make it suitable for the manufacture of caustic soda. Small quantities are being made by the manufacturers of electrolytic caustic soda, but the cost of production is abnormally high. We consider that in the interest of Indian alkali industry, one firm should take up production of about 1,000—1,500 tons per year.

**IV (a) NITRIC ACID.**

60. Nitric acid is used chiefly for the manufacture of nitro-glycerine, nitro-cellulose, picric acid, T.N.T., dyestuffs, pickling of steel, gold refining, manufacture of chemicals, fertilisers, etc. Indian production has usually been from imported sodium nitrate except when indigenous potassium nitrate which is more costly had to be used during the war due to shortage of the imported product. In other parts of the world, the acid is manufactured by oxidation of ammonia, which, if adopted in India, will result in elimination of the use of sulphuric acid. Civil requirements in India are about 750 tons of 65 per cent. acid, War Department demands being met by Kirkee and Aruvankadu Ordnance factories, which are using ammonia-oxidation process. Local supply is equal to the demand, which was until recently about 1,300 tons in all.



61. Nitric acid is a very important chemical both for peace-time needs and for the manufacture of explosives and other chemicals used both in peace and in war. The demand is likely to go up in post-war years and we are of the opinion that a rough five-year-target of about 4,000 tons should be aimed at. In view of the reduction of the demand by the War Department, we understand that production has been reduced in Kirkee and Arvankadu factories and we recommend to Government that this capacity should be utilised for manufacture of peace-time explosives. An ammonia-oxidation plant may be installed later in one of the ammonia plants.

**(b) Potassium Nitrate.**

62. The important uses of potassium nitrate are as a fertiliser, for manufacture of gunpowder and for nitrepots in the lead chamber process for the manufacture of sulphuric acid and sometimes for the manufacture of nitric acid itself. We understand that large quantities are collected on a cottage industry basis in Bihar, the U.P., the Punjab, Patiala, Bikaner and Bharatpur, indigenous production being more than 15,000 tons per year: it is stated that during the first World War, a production of 25,000 tons was reached. Cost of the product seems to be high due to want of proper organisation and of employment of chemical methods, potassium chloride, a by-product not being recovered. We recommend that this industry should be organised properly by the Provincial and State Governments.

**V (a) AMMONIA.**

63. Ammonia is an important base essential for the manufacture of important ammonium salts,—the important fertiliser ammonium sulphate, and other salts like ammonium chloride, carbonate, bicarbonate and phosphate, for the manufacture of urea and nitric acid, and for use as a refrigerant. A certain quantity is always produced during distillation of coal but this has been developed in India only in a few centres. India produces about 1,500 tons of synthetic ammonia per year, the only existing plant being at Belagula in the Mysore State. We understand that this plant will be duplicated to increase the production of ammonium sulphate. A large plant is being installed at Sindhri in Bihar in connection with the scheme for the manufacture of sulphate of ammonia sponsored by the Government of India and another at Alwaye in Travancore. It is understood that the Government of Hyderabad has under consideration a scheme for the manufacture of 75 tons of ammonia per day which will be used for preparing ammonium sulphate, urea and ammonium nitrate.

64. Synthesis of ammonia is carried out by the direct union of the elements hydrogen and nitrogen. Hydrogen can be prepared either electrolytically or by the water-gas method; Mysore has been using the electrolytic process but the new Government of India and Travancore schemes contemplate manufacture by the water-gas method. Nitrogen is obtained from air by removing the other components. Including all the electrical energy used, 20,000 KWII are required per ton of ammonia produced by the utilisation of electrical power.

65. About 150 tons of ammonia were being imported per year into India before the war, 90 per cent. of which was for refrigeration. There was no manufacture of ammonium salts or other products. We are of the opinion that the manufacture of these products should now be taken up. For this purpose, about 12,000—15,000 tons of ammonia per annum will be a suitable target during the next five years, as shown below:—

	<i>Tons.</i>
For ammonium chloride (4,000 tons) and ammonium carbonate (600 tons) ..	1,500
For nitric acid (3,000—4,000 tons) ..	2,000—3,000
For urea (10,000 tons) .. .. .	6,000—7,000
For soda ash plants .. .. .	4,000—5,000
For refrigeration .. .. .	200— 300

The quantities produced at Mysore, Alwaye and Sindhri are proposed to be used up for the manufacture of ammonium sulphate; but since large quantities of ammonia will be produced at the latter two places, it is expected that the required quantity of ammonia will be made available from these sources for other purposes also, at least for some time to come. The cost of production of ammonia is very high in India and if industries requiring cheap ammonia have to thrive; we consider that it must be made available at a very low price. It is hoped that the ammonia plants will be able to supply cheap ammonia to other industries. At this stage, we do not think it necessary to recommend any new plants, until the proposed plants are installed and successfully worked.

**(b) (i) Ammonium Chloride.**

66. Ammonium chloride is used as a flux, as one of the ingredients in batteries, for tinning domestic utensils and for miscellaneous other purposes. It is prepared by the combination of hydrochloric acid and ammonia, from calcium chloride obtained from the distiller waste by means of ammonia and carbon dioxide, and also obtained as an intermediate product in the Solvay process. India used to import nearly 2,000 tons of this salt before the war. Present Indian production is negligible. When both ammonia and hydrochloric acid are manufactured in sufficient quantities—large quantities of hydrochloric acid will become available when electrolytic chlorine will be produced in excess of requirements for ordinary purposes—or when soda ash manufacture is further developed, there should be no problem in manufacturing the necessary quantity of ammonium chloride, which we expect will be about 4,000 tons per year in five years.

**(ii) & (iii) Ammonium Carbonate and Bicarbonate.**

67. The chief use of ammonium carbonate and bicarbonate is in medicine and baking powders. Pre-war imports were about 600 tons per annum. The salts are made by the direct combination of ammonia and carbon dioxide and the manufacture can be established at ammonia production centres,

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## VI. FERTILISERS.

68. Of the three essential elements necessary for plant food,—nitrogen phosphorus and potassium, nitrogen may be made available to the plant in the form of ammonium sulphate, ammonium nitrate, urea, calcium cyanamide, calcium nitrate or as ammonium phosphate, in addition to what can be supplied in the shape of farmyard manure; phosphorus in its salts, superphosphate and ammonium phosphate; and potassium in potassium nitrate and chloride.

### (a) NITROGENOUS FERTILISERS.

#### (i) Ammonium Sulphate.

69. We do not propose to consider ammonium sulphate as the Government of India have recently examined it carefully. About 6,000 tons are being made in Belagula, 20,000 tons from coke-ovens in Bihar and according to the new schemes, 50,000 tons in Travancore and 350,000 tons at Sindhri, Bihar, are going to be manufactured.

#### (ii) Urea.

70. Urea contains the largest percentage of nitrogen of all the nitrogenous fertilisers and is a very valuable plant food. It is also a raw material for the manufacture of the important class of urea—plastics, the manufacture of which is under consideration by the Plastics Panel. Urea is manufactured from ammonia and carbon dioxide and can be produced in sufficient quantity when the synthetic ammonia industry is established on a large scale. We recommend that to begin with, a plant of 10,000 tons capacity per year be installed at Sindhri by the Government of India along with the Sindhri ammonia plant.

#### (iii) Ammonium Nitrate.

71. Ammonium nitrate contains nitrogen both in its acid and alkaline portions and has a high nitrogen content. Although it is being used as a nitrogenous fertiliser in other countries, Indian Agricultural Authorities are not in agreement as regards its suitability for India. It would be necessary, however, for the manufacture of explosives. Its production would present no serious problems when both synthetic ammonia and synthetic nitric acid industries are established. We are not making any recommendation now in view of the fact that the question of its suitability for use as a fertiliser and of the establishment of explosives manufacture for civil use is still undecided.

#### (iv) Potassium and Calcium Nitrates.

72. Potassium nitrate has already been considered in para 62. Calcium nitrate is another fertiliser, manufacture of which can be taken up when cheap nitric acid becomes available.

(v) Calcium Cyanamide.—This is considered in Part II, para 11.

### (b) PHOSPHATE FERTILISERS.

73. In the U.S.A. large quantities of these fertilisers are added to the soil in higher proportions than other fertiliser constituents. The main sources of phosphorus are phosphatic rocks and bones, both of which are used extensively. The neutral calcium phosphate in either of

these has to be converted to soluble phosphate by the action of sulphuric acid or of phosphoric acid. Phosphate rocks or steamed bonemeal are also used as such for acidic soils or when a slow-acting fertiliser is required. At present in India, superphosphate is prepared by treating bones with sulphuric acid; this is a very wasteful method since the other constituents of bones like glue, gelatine, grease and fat are not utilised. Competition with foreign products will be difficult if the industry is worked in this wasteful manner. Therefore, to establish the bone-superphosphate industry on a sound footing, a large scale factory with facilities for recovery of glue and gelatine for which there is great demand in and outside India, before the bones are treated with sulphuric acid is necessary. At the same time, we recommend that the possibility of using bonemeal itself as a fertiliser to a greater extent than is being done at present, should be examined. This would save sulphuric acid. Another important raw material in India, viz., rock phosphate available in quantities as apatite in Singbhum area and as phosphatic nodules in the Trichinopoly District might well be utilised for the benefit of land. No sustained efforts have been made so far to work up these deposits. We consider, however, that it should be possible to utilise these for the manufacture of fertilisers of low concentration by the thermal process. As already stated (vide para 8) we recommend a five-year target of 100,000 tons per year for superphosphates.

We should like to refer in this connection to the use of ammonium phosphate as a fertiliser. This has the advantage of serving a double purpose since it contains both nitrogen and phosphorus.

74. To eliminate the use of sulphuric acid, it seems desirable to utilise electric power for the manufacture of highly concentrated soluble phosphates. Valuable work has been done in the U.S.A. by the T.V.A. and a new process has been developed. The process is technically difficult involving, as it does, manufacture of phosphorus from the ore, its conversion to phosphoric acid and combination with the phosphate to form soluble phosphate. Private enterprise may not be forthcoming to start this industry. We, therefore, recommend that Government of India should put up an experimental plant for manufacture of 10 tons of phosphorus per day and concentrated phosphates by the electro-thermal process. In order to conserve the phosphate resources of the country, we are of the opinion that it is necessary to prohibit the export of bones and bonemeal out of India.

### Phosphorus.

75. Phosphorus is used mostly in the match industry in the red or amorphous form, apart from its use for manufacture of war chemicals. Small quantities are used for the production of various metallurgical alloys such as phosphor-copper and phosphor-tin. Pre-war imports were about one hundred tons. War Department demand was about 700 tons per year during the war, but this has disappeared. When manufacture of concentrated phosphates by the use of electrical energy is taken up, the necessary quantity of phosphorus will become available easily. We do not, therefore, consider that by itself, manufacture of this small quantity of phosphorus justifies installing a plant.

**(c) POTASH FERTILISERS.**

76. Potassium may be used as a fertiliser in the form of chloride, sulphate, nitrate or carbonate or as organic potash. The raw material available in India in this respect is potassium nitrate, about 15,000 tons of which are, we understand, produced from large tracts of saline earth in Bihar, U.P., Punjab, Bikaner, Patiala and Bharatpur. Production can be increased, if necessary, without any difficulty. Cost of production is high, due probably to want of proper organisation and we recommend that this may be examined in consultation with the Provincial and State Governments.

**VII. OTHER INORGANIC CHEMICALS.**

**Calcium Carbide.**—This is considered in Part II, para 10.

**(a) Magnesia.**

77. The most important use of magnesia is in the preparation of magnesia cements and in the manufacture of refractories. Imports have been about 500—600 tons. Recently, one of the firms in India has started production and since it is expected that the requirements will be met by local manufacture, no action is necessary.

**(b) Arsenic Oxide.**

78. The important civilian use of arsenic oxide is as an insecticide. Pre-war average imports were about 250 tons. We understand that Chitral State has deposits of arsenic ores but no supply has been possible due to want of proper communications. We suggest to the Government of India that they may approach the Chitral State authorities to improve communications to enable the chemical to be brought into India cheaply.

**(c) Borax.**

79. Borax is used in the manufacture of glass and ceramics, imports having been of the order of 1,500 tons. There has been no production in India so far, but we understand that there are borax resources in some parts of India and recommend that they must be exploited.

**(d) Dichromates and Chromic Acid.**

80. Sodium and potassium dichromates are extremely important chemicals used for khaki dyeing, in chrome tanning of leather and to a smaller extent in the production of chrome yellow primrose chrome, lemon chrome, middle chrome and orange chrome, chrome green and chrome red pigments required by the paint industry and for chemical bleaching of some oils and fats. Potassium dichromate is also used in the match industry. Chromic acid required for chromium plating in the electro-plating industry and for anodising aluminium and its alloys is also prepared from the dichromates.

81. This industry started and developed in India purely as a war measure has been assured of protection against unfair competition from abroad after the war. In spite of the fact that the raw materials: chrome ore, soda ash, lime and sulphuric acid are available in India, cost of production is even now high compared to the imported product. The annual maximum capacity is about 5,000 tons but production has been

only about 3,500 tons. Annual imports before the war were only of the order of 1,000 tons, but the demand during the war increased to nearly 6,000 tons. If all the plants continue to work; we fear there will be over-production in the post-war period, unless there is a very large increase in the chrome tanning industry and manufacture of khaki textiles. The industry is now controlled by Government both as regards price and distribution; but when this control is removed and an open market established, the industry may not be able to survive competition in the post-war period. We consider that this industry should be given encouragement by grant of protection. A list of dichromate factories with their annual capacities is given in Appendix VII.

Some dichromate and other factories are manufacturing small quantities of chromic acid, but the use of the acid on an appreciable scale has yet to be developed. Present production is about 25-50 tons.

## VIII. OTHER ORGANIC SUBSTANCES & DERIVATIVES.

### (i) Alcohol.

82. Alcohol is required for the manufacture of ether, chloroform, acetic acid, pharmaceutical preparations, perfumery, spirit varnishes and a host of other products. Next to water, it is the most important solvent. It is also used on an extensive scale in spirit lamps and stoves and for motor engines. Its wide-spread use as a beverage is well-known. Therefore it is seen that it is a very important chemical for chemical industries in addition to its other uses.

A number of distilleries have been in existence in India during many years, but the alcohol produced in them was used mostly for the preparation of alcoholic beverages. It was far too costly to be used in industries. During recent years, however, large distilleries with equipment for manufacturing power alcohol have been installed and there are now five of them—two in the U.P. and one each in Bombay Presidency, Hyderabad and Mysore States. Their total maximum capacity is 2.5 million gallons of power alcohol per year, although their present production is only one million gallons. We understand that the Sugar Panel has fixed a target of 1.6 million tons of sugar per year and has come to the conclusion that when this production is reached 26 million gallons of alcohol can be produced from all the surplus molasses available. For chemical industries, only a fraction of this will be sufficient, but we have to emphasize that for the development of these industries it must be available at a very low price and free of duty, denatured with different denaturants suitable for use in the various chemical industries.

### (ii) Acetic Acid.

83. The chief commercial uses of acetic acid are in the manufacture of white lead and rubber, of acetates particularly cellulose acetate and solvents. Indian consumption is about 400 tons per annum. The acid can be manufactured in a number of ways—by wood distillation, from ethyl alcohol or synthetically from calcium carbide. There is only one wood distillation plant in India which has enough raw material to produce 300 tons of acetic acid per annum if conditions are favourable.



But, due to the high cost of wood it is unlikely that acetic acid produced by wood distillation can compete with the synthetic acid. Manufacture of power alcohol from molasses is likely to be taken up on a large scale all over the country and when the present abnormal conditions are over, the alcohol situation is likely to improve. We understand the Rayon Panel has recommended the manufacture of 10 tons of Acetate Rayon per day. This would require about 7,200 tons of acetic acid and of acetic anhydride each per year—equivalent in all to about 16,000 tons of acetic acid. We recommend that this manufacture be taken up starting from alcohol in distilleries. Without taking rayon into account, we estimate the demand to be about 600—700 tons per year. To meet this ordinary demand, no further steps are necessary as we understand that the Government of India have already granted an import licence for one plant of capacity 2 tons per day to one of the distilleries in the U.P.

**(iii) Lead Acetate.**

84. Imports of lead acetate have been about 80 tons per annum. We have not considered this subject as it more legitimately belongs to the Paints and Varnishes Panel and is being considered there.

**(iv) Sodium Acetate.**

85. Sodium acetate which is used in the textile industry is being manufactured in small quantities by a number of firms starting from acetate of lime obtained in the wood distillation industry. When manufacture of acetic acid is taken up, this salt could be more conveniently prepared from it. We do not consider any special steps necessary.

**Glycerine.**

86. The chief uses of glycerine are in pharmacy (70 per cent), explosives such as nitro-glycerine (18 per cent.) and in textiles, etc. (12 per cent.). Before the war, consumption in India was 850 tons; production in the soap industry was about 650—700 tons and nearly 100 tons used to be imported. The present annual production is 2,500 tons; although this is more than sufficient for India's requirement, it is understood that there has developed recently great demand from the U.S.A. for glycerine from India and this demand is likely to last for some time. Whether any increased manufacture has to be permitted in view of this demand, may be examined by Government. We understand that the Government of India have given import licences for two more glycerine recovery plants, one to be installed in Kathiawar and the other in Calcutta. Considering the large number of soap factories working successfully in India, we are of the opinion that manufacture of glycerine which is obtained as a by-product in the soap industry can be increased without any difficulty, when larger quantities will be required for the manufacture of nitro-glycerine explosives for use in connection with post-war schemes, such as construction of dams, highways, etc.

**(vi) Methyl Alcohol and Formaldehyde.**

87. Apart from the use of formaldehyde for the preservation of specimens and as an antiseptic, its industrial importance lies in its being one of the most important raw materials for the manufacture of plastics

and plastic glue necessary in plywood manufacture. The raw material is methyl alcohol from which it is produced in the Mysore Iron & Steel Works, to the extent of 60 tons per annum. We are of the opinion, however, that large scale manufacture of synthetic methyl alcohol should be taken up in the proposed ammonia plant at Sindhri, which will enable the required quantity of formaldehyde to be produced in India.

**(vii) Starch.**

88. Indian textile industry consumes about 20,000 tons of maize starch per annum. We understand that production in India now is sufficient, a number of firms having taken up manufacture. Starch is also the raw material for manufacture of glucose which, in addition to being an important medicinal product, will also be required in large quantities for the manufacture of confectionery and in the Viscose Rayon industry. Small quantities of glucose are manufactured at present. We understand that one complete plant for the manufacture of glucose (both liquid and solid) is likely to be installed in Calcutta and recommend that glucose manufacture from starch should be further developed to supply the requirements.

**(viii) Acetone.**

89. Acetone is an important solvent used for dissolving acetylene and varnishes and for the manufacture of cordite. The Indian Oxygen and Acetylene Company uses about 7,000 gallons of acetone for dissolved acetylene, but all this is not consumed, only evaporation losses being replenished. Government plant at Aruvankadu has a capacity of 1,000 tons per annum for manufacture from alcohol. We understand that an import licence for an acetone plant of 300 tons annual capacity starting from alcohol has been granted, the plant to be installed in the U.P. Civilian demand is at present very small, but with the development of the paint, lacquer and acetate rayon industries, much larger quantities would be required. For the manufacture of 10 tons of acetate rayon per day as recommended by the Rayon Panel, 12,000 tons of acetone will be required per year, but all of it will not be consumed and most of it can be recovered. We understand that demand from the War Department is reduced and production is considerably curtailed in the Government Ordnance Factories. We therefore, recommend that Government product on be released for civilian uses and for additional quantities, manufacture from alcohol be started. We also recommend that production of acetone by fermentation of molasses should be taken up, as it would give butanol, a useful solvent for the paint industry, as a by-product.

**IX. INDUSTRIAL GASES.**

**(i) Oxygen.**

90. Oxygen may be made either from liquid air or by the electrolysis of water, both processes being in use. It is obtained as a by-product in many of the hydrogenation factories where hydrogen is manufactured by electrolysis of water for hydrogenation of oils and also in the ammonia factory at Belagula and is collected in many of these factories.

It is usually compressed into cylinders and sold as such for oxy-acetylene welding. Production in 1937 was 22 million cft., which increased in 1942 to nearly 53 million cft. and is probably more now. In this connection, we recommend that transport charges for oxygen should be reduced, the weight of cylinders being more than that of the gas.

**(ii) Hydrogen.**

91. We have not considered hydrogen as its chief use now is for hydrogenation of oils and would be dealt with by the Food Department.

**(iii) Carbon Dioxide.**

92. Carbon dioxide is obtained as a by-product in the fermentation industry and is being collected in a few of the factories; it is largely used for the manufacture of aerated waters, in fire-extinguishers and also as a refrigerant in the form of dry ice, use of which unfortunately has not been developed in India, especially for preservation of food stuffs. It would also be required for the manufacture of urea and soda ash, when these are developed, but for these, it would be prepared in the factories themselves.

**X. COAL TAR PRODUCTS.**

93. Of coal tar products, we have considered only naphthalene, creosote, phenol and cresylic acid under the category of Heavy Chemicals. There are nine tar producing and five tar distillation plants in India (Appendix VIII), average annual production of the four chemicals mentioned above on the basis of the present working of the tar distillation plants being as follows:—

- 25 tons of phenol
- 60 tons of cresylic acid (commercial).
- 600 tons of naphthalene.
- 500,000 gallons of heavy creosote oil.

We understand, however, that production at present is much less, only 3,000 gallons of tar being available per month for distillation, while before the war, out of 7,000 tons of coal tar manufactured per month, 5,000 tons were being distilled. We understand that the total annual output of benzol is 2.4 million gallons from which 1.2 million gallons of pure benzene can be obtained; benzol is being used now as liquid fuel in admixture with petrol. We are of the opinion that cheap benzene is essential and should have the benefit of a reduced duty. We consider that production of all these chemicals has to be increased but as a special Indian Coalfields' Committee has been appointed, we have not examined this question in any detail, at this stage.

**XI. MISCELLANEOUS.**

94. We have not also considered the manufacture of dyestuffs as the question had been referred to the Dyestuffs Exploratory Committee of the Board of Scientific and Industrial Research, whose report has since been published. We understand that an industry is now being started by an Indian concern in association with a British firm. For the same reason, chemicals such as phosphorus chlorides, sulphur chlorides, chlorosulphonic acid, etc., which are required for the manufacture of dye stuffs are not referred to in this report.

95. We understand that in many countries which do not possess mineral oil resources, crude petroleum is imported and industries have been established for cracking and refining it. This has enabled many chemical industries to be developed in those countries. Indian resources of mineral oils are not plentiful and we recommend that Government of India should give facilities for importing crude petroleum and for the installation of plants for cracking and refining it. This would be a very desirable industry in India.

96. Although reliable figures are not available regarding the consumption of explosives for civilian purposes, the quantity is considerable. Except for the manufacture of explosives in the Ordnance factories, there is no manufacture of modern explosives in India. In future India, we estimate that very large quantities of explosives will be required in the Post-war schemes such as highway and dam construction development of mining industries, etc. We, therefore, recommend that manufacture of explosives for civilian purposes should be taken up by the Government of India very early.

## PART II.

## ELECTRO-CHEMICAL INDUSTRIES.

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## ELECTRO-CHEMICAL INDUSTRIES.

In addition to the extensive use of electricity in modern chemical plant for driving machinery, for lighting, recorders, communication, signals and temperature control, there are applications where electrical energy is directly responsible for chemical decompositions resulting in production of useful substances and in other cases, for supplying heat through the agency of which chemical reactions are brought about. Although electro-chemical industries are of comparatively recent origin, electricity has proved to be a most valuable tool in the hands of the chemical engineer and has not only revolutionised older methods of chemical manufacture, but has also been responsible for altogether new industries.

### Electro-Chemical Vs. Chemical Processes.

2. In the former category, the older purely chemical have to compete against the newer electro-chemical processes. Lime-soda caustic is still competing successfully against electrolytic caustic soda. Hydrogen is being manufactured both from electrolytic cell and by the watergas method. Electrolytic zinc has not completely displaced spliter from the older retort processes. In many cases, however, the older methods have been completely supplanted. Where the older processes have survived, it is generally due to some special circumstances such as availability of cheap raw materials, non-availability of cheap electricity or hesitation of the owners of older plants to scrap them and change over.

3. The electric furnace and electrolytic cell have been responsible for entirely new industries. Aluminium, magnesium carbide and artificial abrasives might not have become commercial products except for the electric furnace. Electrolytic caustic soda has given so much cheap chlorine, that new uses have been found for it and many of the outlets would never have been possible except for the cheapness of the gas. Synthetic chemical industry has benefited enormously by the production of metallic sodium in electrolytic cell at less than a tenth of the cost by the older method.

### Classification:

4. Electro-chemical industries are based on electrolytic and electro-thermal processes or a combination of both. In the electrolytic process, electrical energy is entirely responsible for the chemical reaction. In the electro-thermal, it is used only as a thermal agent, after having been converted into heat; extremely high temperatures can be attained in a very clean way by this means. The former requires direct current; for electro-thermal industries, either direct or alternating current may be used, preferably the latter.

### Importance of Cost of Power.

5. In many of these industries, electrical energy forms the major portion of the cost of the product, success or otherwise of the industry being largely dependent on the rate at which power is made available to the industry. In such cases, the industry has to be located very near the site of power generation, as for example, in the case of aluminium, magnesium, carbide, ferro-alloys and abrasives. In some industries, e.g., electro-plating, manufacture of storage batteries, organic chemicals, etc., however, cost of energy may form only a minor portion of the total cost, and in those cases, other considerations may prevail to determine the location. Individual cases have to be decided on their own merits, taking all factors into account. In view of the importance of electrical power for these industries, we are of the opinion that cheap and abundant power is essential for them.

### Development in Other Countries.

6 The greatest developments in electro-chemical industries have taken place mostly in Norway where electrical power is available at extremely low rates and in the U.S.A. and Canada also. Price of electrical energy supplied to electro-chemical industries in different parts of the world compared with rates in India is given in Appendix IX. As regards the power consumed in these industries, in the U.S.A., we find from published data that in 1939,  $73 \times 10^9$  KWH were consumed in industries of which chemicals alone consumed  $9 \times 10^9$  KWH being second only to iron and steel and paper industries; but in 1944,  $32 \times 10^9$  KWH were consumed by chemical industries—the highest in a total consumption of  $168 \times 10^9$  KWH by all industries. The consumption by chemicals was not all for electro-chemical industries only. Table I gives a fair idea of analysis of consumption of electrical energy in the U.S.A. by different industries just before the recent war and in a typical war year.

### Almost no Development in India.

7. In India, there has been very little development except for one or two areas. We anticipate, however, that with the completion of the hydro-electric projects now being planned, abundant power will become available and it will be possible to establish many electro-chemical industries. Capacity and location of the existing electric power stations, as also of new stations planned, are given in Appendix X.

8. A comprehensive list of electro-chemical industries is given in Appendix XI. Cost of power related to the price of product in the U.S.A. is indicated in Appendix XII.

TABLE I.

Industry group.	Thousands of Kilowatt-hours.	
	1939	1944
<b>MANUFACTURING INDUSTRIES—</b>		
Chemicals . . . . .	9,356,998	31,859,753
Non-ferrous metals . . . . .	6,085,358	23,901,486
Iron and steel . . . . .	12,781,648	25,192,502
Paper . . . . .	9,462,556	11,980,422
Textiles . . . . .	6,272,654	9,278,018
Transportation equipment . . . . .	493,310	8,071,418
Stone, clay and glass . . . . .	4,503,209	5,978,131
Food . . . . .	4,521,733	5,753,495
Machinery, except electrical . . . . .	1,805,704	5,672,008
Automobiles . . . . .	2,432,205	4,590,833
Electrical machinery . . . . .	1,392,951	3,747,589
Rubber . . . . .	1,557,227	2,034,946
Lumber . . . . .	1,132,235	1,525,728
Miscellaneous . . . . .	339,803	810,939
Furniture . . . . .	412,043	604,609
Leather . . . . .	294,516	373,409
Printing . . . . .	289,933	346,165
Tobacco . . . . .	81,255	108,432
Apparel . . . . .	72,585	102,673
All manufacturing . . . . .	66,399,859	152,902,999
<b>EXTRACTING INDUSTRIES—</b>		
Coal mining . . . . .	3,035,015	4,617,680
Metal mining . . . . .	1,993,912	3,234,810
Non-metallic mining . . . . .	536,477	805,994
Petroleum and natural gas . . . . .	549,001	619,050
All extracting . . . . .	6,114,405	9,277,534
Government . . . . .	609,688	5,983,123
All industries . . . . .	73,123,952	168,163,656



## I. ELECTROLYTIC PROCESSES.

**Caustic Soda, Caustic Potash, and Chlorine; Potassium Chlorate**—These have been considered in Part I, paras 39-53.

**Oxygen and Hydrogen.**—These have been considered in Part I, paras 90-91.

### Hydrogen Peroxide.

9. We understand that hydrogen peroxide is fast becoming a serious competitor to chlorine for purposes of bleaching and is often preferred in some cases, because it leaves no harmful traces. In India, its use has not been developed to any extent. If commercial production is started, there may be good demand in the manufacture of superior class of fabrics. We understand that the Government of India have granted an import licence for a plant of 350-400 capacity per year to be installed in Bombay. More plants may be permitted to be installed in textile centres where there is a definite demand. Reference may be made to the new anthraquinone autoxidation process for the production of hydrogen peroxide which basically consists of the union of hydrogen and oxygen to form hydrogen peroxide, 2-ethyl anthraquinone acting as a carrier for hydrogen. Nickel-aluminium and silver-nickel catalysts are used and the 20 per cent. solution of hydrogen peroxide obtained has to be subjected to two distillations for raising the strength to 85 per cent. The process may be presumed to be satisfactory as the Germans had planned to instal two very large factories, each of them of capacity to produce 24,000 tons of hydrogen peroxide, 85 per cent. strength per year. Whether this new process which has been patented, is of direct interest to India for the present is doubtful since apart from the special catalysts, 2-ethyl anthraquinone, very highly purified benzene and a mixture of secondary alcohols (C7 to C11) are necessary.

## II. ELECTRO-THERMAL PROCESSES.

**Phosphates.**—These have been considered in Part I, paras 73-75.  
**Calcium Carbide.**

10. The chief applications of calcium carbide are in the manufacture of calcium cyanamide fertiliser, of acetylene required in oxy-acetylene welding and in chemical synthesis of a variety of organic compounds used as medicines, dyestuffs, solvents and for the manufacture of synthetic rubber. Calcium carbide is produced only in the electric furnace, a large block of power being required for its manufacture. Electric furnaces used are of the submerged arc type. Heat is produced by short arcs taking place between the electrodes, the crushed materials closely surrounding them. Power consumption is about 3,500 KWH per ton in the modern furnace. Electrode consumption is also heavy, forming about a sixth of the cost of the product. Production in the U.S.A. before the war was about 150,000 tons, electric power consumed being nearly 500 million KWH. Pre-war average imports into India of carbide were about 3,500 tons per annum most of it for the production of acetylene gas; during the war, demand was, however, about 7,000 tons, including war requirements. In the absence of chemical industries depending on calcium carbide, we do not think that future requirements are

likely to exceed this figure in the first five-year-period and we recommended 7,000 tons as the target. We understand the Government of India have granted an import licence for a 5,000 ton plant to be installed in Bihar. For the balance of 2,000—2,500 tons, we recommended that a plant may be put up in South India where electric power is available immediately, as in the Jog area. It is understood that the necessary equipment which is already available in Mysore is being used now for manufacture of ferro-silicon, but that shortly, it is proposed to instal a larger unit for the latter, when the existing equipment can be utilised for manufacture of carbide.

**(b) Calcium Cynamide.**

11. Calcium cynamide is obtained by passing purified nitrogen obtained from air over calcium carbide maintained at a temperature of 2,000F. Its use as a fertiliser has not been established in India and there seems to be no urgency to take up this question in preference to other nitrogenous fertilisers, as it is understood that its use as a fertiliser is declining in other countries. Its manufacture could be considered, if necessary, when the carbide industry is well established in India.

**Ammonia.**—This has been considered in Part I, paras 63-65.

**(c) Carbon Disulphide.**

12. Carbon disulphide is an important chemical required in the manufacture of rayon by the Viscose process. For each ton of rayon, 0.4 ton of disulphide is necessary; the Rayon Panel have, we understand, fixed a target of 60 tons of viscose rayon per day, which would require about 8,760 tons of disulphide per year. We consider, however, that the chemical should be prepared in the rayon factories themselves in suitable units. Large quantities of carbon disulphide would also be required for the manufacture of carbon tetrachloride required in the oil industry as a solvent in the solvent extraction process. We are not able to arrive at a decision as regards the quantity required in the absence of the recommendations of the Soaps and Oils Panel. Carbon disulphide is made from sulphur and charcoal in the electric furnace which is found to be more convenient and durable, although the reaction takes place at a comparatively low temperature.

**(d) Artificial Abrasives.**

13. The enormous increase in the use of artificial abrasives in recent years, has made possible the grinding and polishing of high-alloy steels and high speed precision grinding. India has taken up the manufacture mostly of coated abrasives, abrasive papers and cloth only. Annual imports are of the value of about Rs. 10 lakhs while the value of indigenous production is about Rs. 5 lakhs. Precision grinding wheels are also being fabricated by one or two firms, most of the abrasive grains being imported. Garnet sands are found in the Tinnevely District of Madras, Jaipur and a few other Indian States. We understand that Indian emery is not suitable and hence Turkish emery has to be imported. Natural corundum is found in many parts of India, but no organised production seems to have been taken up. We recommend that the question of utilisation of all these should be carefully examined,

14. Artificial abrasives are manufactured only by electro-thermal methods in the furnace. Carborundum and a few other carbides, and fused alumina are of importance. There is no manufacture of these in India at present, but in any scheme of development of electro-chemical industries, they must find a place, especially as the raw materials are all easily available and cheap electrical energy may be expected to become available shortly.

#### **Silicon Carbide (Carborundum).**

15. Silicon carbide is made by heating silica sand and excess of carbon to a high temperature. A ton of silicon carbide requires about 1,000-10,500 KWH for its manufacture. It is extremely hard and possesses excellent cutting properties, but we understand that because of its brittleness it cannot be used for grinding wheels of high tensile strength and does not therefore form a satisfactory substitute for natural emery.

#### **Fused Alumina (Corundum).**

16. Fused alumina is a very important abrasive and has, we understand, largely replaced natural emery. Calcined bauxite is mixed with carbon, sufficient to reduce the impurities to the metallic condition, but insufficient to react with alumina. The starting materials have to be chosen very carefully in order to make a satisfactory product. Electrical energy consumed is 2,600-3,200 KWH per ton.

#### **Boron Carbide.**

17. Boron Carbide made from boron oxide and carbon in the electric furnace is one of new abrasives recently come into prominence and has been claimed to be the "hardest material ever made by man."

18. There is no manufacture of artificial abrasive grains in India, as already stated. Information as to how much of these are imported is not readily available. The manufacturers of coated abrasives are small establishments scattered all over the country and in these circumstances, it is difficult to collect any data as regards the demand for these. We recommend, however, that to begin with, furnaces with a capacity of 2,000 tons for each of these abrasives may be installed near a source of power. We understand that some firms who have already established the manufacture of bonded abrasives successfully are desirous of preparing the grains also, provided some concessions such as cheap power etc., are given. We are of the opinion that they should be encouraged. Since this is such an important industry, we are of the opinion that the manufacture of grains should be developed on cheap seasonal power, and further, as some firms have demonstrated that they can manufacture bonded and coated abrasives successfully Government should give them very cheap power and other concessions to develop this industry.

#### **(e) Artificial Graphite.**

19. Pure carbon cannot be transformed into graphite merely by heating, but it must pass through the stage of a carbide. Anthracite, petroleum coke or any other carbon carrying enough ash matter can be used for the furnace charge, the ash furnishing the metallic portion necessary. For manufacture of electrodes, the powder is moulded first

into shape with the use of tar or pitch binders and then graphitised. If only praphite powder is required, the carbon powder itself is used in the furnace. Power consumption is highly variable depending on the size and condition of the charged materials, the required degree of baking or graphitising, etc. We understand that the average is about 3,600—9,000 KWH per ton of product.

20. All electro-chemical industries require electrodes—graphite or carbon, which are continuously consumed. Those which deliver energy to the electric furnaces and many of the electrolytic cells are massive rods or plates of carbon or graphite and are themselves manufactured in the electric furnace. Although many types of carbon-aceous matter were used as starting substances in the beginning only two are chiefly used now, low ash coals with very little volatile matter and petroleum coke. They are first freed of their volatile matter by heating to a white heat and then ground to a fine powder in special machines. Mixed with the binding material—coal tar or pitch, in steam-jacketed mixers, the hot plastic mass is made to pass through extrusion presses to give the required dimension and shape, and then cooled under a spray of cold water when it becomes comparatively stiff. These are called 'green' electrodes. The first baking is done in furnaces at a temperature of not more than 1,100°C. During this process, the binder is carbonised and freed of all volatile matter. The electrodes are then gradually cooled. A second baking is done in electric furnaces (4,100°C) for graphite electrodes or in gas-fired furnaces for carbon electrodes as the case may be. The importance of electrodes in electro-chemical industries can be seen from the fact that they are essential for the manufacture of electric steel, ferro-alloys, calcium carbide, aluminium, magnesium, electrolytic caustic, phosphorus, etc. Table II gives an indication of electrode consumption in some of these.

TABLE II.

Product.	Pounds per ton of product.	
	Carbon.	Graphite.
Non-ferrous castings . . . . .	..	2.8—11
Iron castings, cold scrap . . . . .	..	5.6—11
Iron castings, duplex . . . . .	..	3.4—15.5
Electrolytic Chlorine . . . . .	..	7
Steel castings . . . . .	10—22	..
Steel ingots . . . . .	19—33	..
Calcium carbide . . . . .	33—220	..
Aluminium . . . . .	1700—2250	..
Ferro-silicon (15%) . . . . .	25—50	..
Ferro-silicon (50%) . . . . .	50—75	..
Ferro-silicon (80%) . . . . .	80—120	..
High-silicon ferro-silicon . . . . .	150—300	..

Although electrodes are being used in many factories no data are available for the consumption of electrodes in India at present. The demand will increase with the development of electro-chemical industries. We

understand that a company has been started in Travancore, with a capital of Rs. 25 lakhs to manufacture carbon and graphite materials required for electro-chemical industries. We consider manufacture of electrodes of the utmost importance for all electro-chemical development and are of the opinion that Government of India should itself instal one or two plants, if manufacture does not materialise within a reasonable length of time in the factory planned in Travancore. We recommend in this connection that in order to save freight charges, petroleum coke should be supplied to the electrode plants only after first calcination has been carried out in the oil refinery itself.

### III—ELECTRO-METALLURGY OF METALS.

#### (a) Iron & Steel.

21. In place of coke or charcoal, the use of electricity as a thermal agent for the smelting of iron and steel will be of special value in places where fuel is expensive and not easily available, electrical supply being cheap and plentiful. Power consumption per ton of pig iron produced is 2,800 KWH. Application of electrical energy does not eliminate the use of coke or charcoal altogether but the quantity is curtailed to a third, the function of the carbon becoming only that of a reducing agent. We understand that the electro-metallurgical process is in use in Norway and Sweden (in Italy and Japan before the war). In India, where metallurgical coal resources are not plentiful and large scale hydro-electric developments are being planned, electro-metallurgical processes will be valuable especially in those areas where there is no adequate coal or charcoal supply and electric power is available. Mysore Iron & Steel Works are planning to instal electric blast furnaces, in order to save charcoal which is expensive and in short supply. For manufacture of special steels which are obtained by methods of refining and alloying involving high temperatures and accurate process control, the electric furnace possesses special advantages. Such furnaces are working in India in many places.

We have not considered this subject in our report in any detail, as it belongs more legitimately to the Iron & Steel Panel.

#### (b) Ferro-Alloys.

22. Alloy steels require the use of small quantities of ferro-alloys for their manufacture. These ferro-alloys which are electric furnace products contain more of the other metal constituent than of iron. In small proportions, some of these non-ferrous elements are responsible for the removal of impurities from iron while in larger proportions, they enter into combination and give rise to special steels. Ferro-alloys are produced in electric furnaces of the submerged arc type.  
**Ferro-Manganese.**

23. Ferro-manganese is now manufactured in the blast furnace at Jamshedpur as for ordinary grades (40—70 per cent manganese) electric furnace is not considered more advantageous. For higher grades containing 80 per cent manganese, however, we understand that the electrical process is more satisfactory. The raw materials are manganese ore and carbon, and power consumption is about 4,500—5,000 KWH for

product containing 75 per cent. manganese and 6,700—7,850 KWH per ton for 80 per cent. ferro-manganese. We are informed that excellent manganese ore and iron ore of good quality are available in the Sandur State and it is probable that electric power also will become available shortly. We recommend, therefore that this area may be considered as suitable for manufacture of ferro-manganese in large quantities and also later, steel of good quality.

#### **Ferro-Silicon.**

24. The raw materials are quartz, iron scrap and charcoal. There are no technical difficulties and 70 per cent. grade is usually manufactured. The energy consumption for 50 per cent. ferro-silicon is 5,500—6,750 KWH per ton, for 75 per cent. product 10,000—12,000 KWH per ton, and for 90 per cent. alloy 15,000 KWH per ton. The total Indian demand is estimated at about 4,000 tons, but may be expected to go up to 10,000 tons in five years. We understand that Mysore is manufacturing ferro-silicon with two small 1,500 KVA furnaces of 1,000 tons capacity each per annum and supplying it to all the Iron and Steel manufactures in India and that it is proposed to increase production to 4,000 tons or more if necessary in the Jog area. No further action seems to be necessary.

#### **Ferro-Chromium.**

25. Anticipated demand in India is about 3,000 tons. The raw materials are chromite ore and charcoal or coke. This ferro-alloy is essential for production of stainless steel and 60 per cent. grade is usually used. The power requirements are about 12,000 KWH per ton of low carbon alloy and 6,000—7,000 KWH per ton of high carbon alloy. We understand that one of the Mysore furnaces was earmarked for ferro-chrome, but since more ferro-silicon was required during the war, this could not be taken up. Chrome ore is available in plenty, but most of it is of poor quality and would require beneficiation to render it suitable. Development of ferro-chrome which is linked with the manufacture of stainless and other chromium steels can be taken up when the programme of development of the Steel Industry is decided.

#### **(c) Aluminium.**

26. Alumina dissolved in a molten bath of the double fluoride of aluminium and sodium (cryolite) to which some calcium fluoride (fluorspar) is added, is electrolysed to extract this important metal. It occurs generally in the mineral bauxite to the extent of 50—60 per cent. as alumina. Indian resources of bauxite are—enormous, the reserves of the better grade being estimated roughly at 250 million tons, proved workable deposits being those of Jubbulpore and Balaghat districts of the Ranchi plateau in Bihar and the Shevaroy hills of the Salem District and small occurrences in Mysore, Central India, etc. With such large resources, India should hold a leading position in the world, but very little progress has been possible for want of very cheap power which is essential and is the determining factor. Although Canada possesses none of the raw materials with the possible exception of fluorspar, it imports bauxite from British Guiana and with the advantage of cheap hydro-electric power, it has developed the largest aluminium producing centre in the world.

27. The raw materials for the production of aluminium (per lb.) are:—

TABLE III.

Electric power	10 KWH.
Bauxite	4 lbs.
Caustic soda	0.15 lb.
Cryolite	0.05 lb.
Aluminium fluoride	0.03 lb.
Fluorspar	0.01 lb.
Petroleum coke	0.65 lb.
Pitch	0.07 lb.
Coal	3.50 lbs.

The quantity of caustic soda required is quite small and can easily be supplied from local manufacturers. Natural cryolite and aluminium fluoride have to be imported, the former from the only source, Greenland. Fluorspar although available in India, is not, we understand, upto the purity required and it may not prove profitable to introduce special purification methods in view of the small quantities required. Petroleum coke and pitch are required for the manufacture of electrodes; the former is available at the oil refineries at Digboi and the latter can be obtained from the coke ovens in Bengal and Bihar. High cost of transport and want of cheap electric power are impeding the development of this industry in India. We are informed that it is cheaper to ship bauxite from South America to a factory in Northern Canada than it is to transport it from the C.P. to a factory in Bihar. Bauxite itself costs little, but the transport charges are much higher. A factory on the West Coast of India can get petroleum coke cheaper from the U.S.A. than from Digboi.

28. U.S.A. consumes 2 lbs. of aluminium per head per annum, U.K. 1 lb., but India less than 0.025 lb. There was no production in India before the war, imports being on the average about 4,000 tons per year. Most of this quantity was used for manufacture of utensils, industrial uses having been negligible. There are now two firms manufacturing aluminium, one in Travancore and the other in Bengal. The total productive capacity is about 15,000 tons of alumina and about 7,500 tons of aluminium per year with provision for developing it to 10,000 tons.

29. It is difficult to foresee the demand in future industrial India. With the development of the engineering industries, estimates have been put up as high as 20,000 tons, which may not be improbable considering the large developments—electrical, mechanical and chemical, planned. As regards demand for utensils, even if we plan on the basis of one plate and one tumbler per head for a half of India's population, the demand for aluminium will be very large. Since Indian resources of copper and zinc are very scanty, we are of the opinion that aluminium should be utilised in a greater degree for utensils. We understand that if metal of sufficient purity is used, the utensils are not corroded by highly spiced food. Transport services could consume the metal in large quantities. Taking all these into consideration we recommend that production should be raised to 15,000 tons per annum immediately, with provision for 20,000 tons later. Government of India are therefore, requested to arrange for

another aluminium plant of 5,000 tons immediate capacity ultimately to be raised to 8,000—10,000 tons near a source of power supply. We are of the opinion that this industry requires special treatment for the next five years or a shorter period if power situation improves after which it may be expected to stand competition if railway concessions comparable to Canadian and U.S.A. rates are given and the present tariff rates continued. In this connection, it is of interest to compare the freight rates in Canada and India (Table IV). In order to safeguard the fabrication industries, we suggest that during the interim period, they also should be protected, if they are not able to get the metal at the same rate as the imported material. We, therefore, recommend a suitable subsidy to this industry, based on a periodical examination of costs.

TABLE IV.  
*Rates per Ton—Mile.*

Commodity .	Canadian	Dollars.	Rupees.	
	India.	Canada.	India.	Canada.
Aluminium Ingot . . . . .	.0180	.0050	0 0 11	0 0 2.9
Aluminium sheets and circles	.0090	.0060	0 0 5.5	0 0 3.5
Bauxite . . . . .	.0205	.0160	0 1 0	0 0 9.3
Alumina . . . . .	.0237	.0068	0 1 1	0 0 4.0
Petroleum coke * . . . . .	.0060	.0050	0 0 4	0 0 2.9
Pitch . . . . .	.0158	.0080	0 0 9	0 0 4.6

\*This is the rate in India chargeable as Coke. However, it is now proposed to classify this material, used for electrodes, as carbon black, which will result in this rate being practically doubled.

(d) Magnesium.

30. This metal is one-third lighter than aluminium with most of the latter's desirable properties, its value being in alloys, the most important of which carries about 95 per cent. magnesium and 5 per cent. of other constituents like aluminium, chromium, manganese and antimony. Such alloys are specially strong and rigid in the different fabricated forms and have found extensive use in the manufacture of aircraft and other light structural products. The only difficulty seems to be in imparting corrosion resistance to them. Magnesium is used also in incendiary explosives. In the U.S.A., the present rated output of all the magnesium plants is about 260,000 tons, although the highest production in any one year has so far been only 165,000 tons. The rated output is manufactured by different processes in the following proportions: electrolytic 72.4 per cent., ferro-silicon 23.5 per cent. and carbon 4.1 per cent. For the electrolytic process, magnesium chloride is the raw material, calcined dolomite and ferro-silicon for the ferro-silicon process, and magnesia for the carbon process. Magnesium industry consumed in 1939 nearly  $72 \times 10^6$  KWH which increased to  $6,000 \times 10^6$  in 1944. This gives some idea of the enormous development of the industry in the U.S.A. during the war.



31. Only the two standard processes, electrolytic and the more recent ferro-silicon need to be considered for our purposes. In the first, anhydrous magnesium chloride is the electrolyte, the equipment used being very much the same as for aluminium. Consumption of power is about 29,000 KWH per ton. In the ferro-silicon process as developed by Pidgeon, magnesia of calcined dolomite is reduced by means of ferro-silicon at a temperature of about 1160°C, the necessary condition being that the reaction is carried out in a vessel with a very high vacuum 0.05 mm. Appendix XIII gives some details of the process worked in one of the magnesium plants in Canada. Ferro-silicon process is stated to give a metal of higher purity, the capital cost being only a third of the electrolytic process. Power consumption including that for ferro-silicon is about 21,700 KWH per ton.

32. In India, there has been no manufacture so far although the raw materials for either process are available, but unless aircraft and automobile production resulting in demand for special alloys develops, we are not able to see any immediate use for magnesium. Both developments must be taken up *pari pasu*. In view of the importance of the metal, we recommend that a small plant producing 3-5 tons a day by the Pidgeon Process may be put up by Government as a measure of national importance, although capital cost may be high for such a small plant. It is understood that magnesium is available at a low price in U.S.A. and Canada. In order to create a market for the metal and to encourage the manufacture of its alloys, we recommend that Government of India should purchase and stock 1,000 tons of this metal and make it available to Indian manufacturers at cost price.

#### (e) Copper.

33. Copper pyrites containing 34.5 per cent. copper, 30.5 per cent. iron and 35 per cent. sulphur is the principal copper mineral and is fairly widely met with in India. The metal seems to have been manufactured in the old days as evidenced by the enormous heaps of slag in Jaipur State, in Bihar, in Sikkim, Patiala, Madras, Alwar, Rewa and other areas in the Himalayas and to a small extent in Mysore State. India's consumption of copper and its alloys in 1943 was estimated to be 72,400 tons and if Ordnance factories requirements of 21,5000 tons are not taken into account the demand works out to about 50,000 tons. Exclusive of brass and bronze, 10,000 tons of copper used to be imported before the war. Only one mining concern produces now about 6,000 tons of refined copper annually by treating roughly about 340,000 tons of the ore, containing only about 2.5 per cent. copper. Electric refining is not practised and the copper which is produced is inferior to the imported product from Africa and the U.S.A. This firm manufactures brass sheets which stand foreign competition successfully, but all electrolytic copper has to be imported. The Non-ferrous Metal Industries Panel have estimated the average annual consumption of copper during the next five years at:

Copper for copper base alloys	..	25,000—30,000 tons
Electrolytic copper	..	16,000—20,000 tons

Indian resources of copper ores, as at present known, are slender and

are not sufficient for the manufacture of these large quantities of the metal. We recommend that for the present attempts must be made to produce 10,000 tons annually. Reference has been made in this report,

Part I, para 11(iii) to the possibility of importing copper pyrites from Spain and manufacturing both copper and sulphuric acid. If this be found possible, we recommend that the target for electrolytic copper may be raised to 16,000 tons.

34. Copper industry has to be developed in two directions (1) production of electrolytic copper and (2) increase of production. For increase of production, the opinion of geologists is that the ores are widely distributed and there is no concentration of the pyrites in workable loads, veins or masses so that as at present known, the resources of India in these materials may be considered small. In other countries, ores containing 1—2 per cent. copper are being used to extract the metal and it should be possible even in India to utilise the power grades of ore to obtain this important metal. At present the only proved deposits in Ghatsila are being worked. We recommend that the deposits in Jaipur, Sikkim, Khetri and Darjeeling also should be examined. Utilisation of scrap seems to possess great possibilities. We understand that in Germany, many primary metals used to be recovered in considerable quantities by electro-chemical separation from about 250,000 tons of scrap annually. We recommend that this be followed in India also, both locally available and imported scrap being utilised, which could be done if the industry is located near the sea ports. We are of the opinion that for this purpose, scrap should be permitted to be imported free of duty. We understand that 5,000-ton units would be economical, zinc or zinc oxide, tin, antimony and lead (sometimes gold and silver also) all being recovered by this method and we recommend that one unit with capacity to deal with 5,000 tons of scrap be installed at one of the sea port towns where power is available.

35. In order to conserve the scanty Indian resources of copper, we consider it desirable to utilise all scrap copper and refine it making it suitable for use in industry. The possibility of using low grade copper ores for the purpose of making copper salts would have to be examined.

#### IV. ELECTRO-PLATING.

36. Although no data are available, there is a very large number of small establishments all over the country carrying out refining of metals and electro-plating of small articles. This industry has attained great importance as very valuable and durable articles can be manufactured by coating on a cheap metal a thin layer of a valuable one. This is a very important industry and of great importance to the country. We therefore, recommend that larger units to deal with industrial equipment should be installed.

#### V. GENERAL.

##### (a) Storage Batteries.

37. Electric accumulators are becoming increasingly important in India, with increase in the standard of living of the people. Apart from their essential use in automobiles and railways, they also find extensive

application for radio receivers in those places where there is no electric power supply and to a small extent, as the usual emergency sets in power stations, hospitals, picture houses, etc., the safeguard emergency essential lights in the event of a breakdown of the main supply. Before the war, most of the batteries required used to be imported. No definite data seem to be available as regards the number of batteries required, manufactured and imported annually. Both Dr. Thomas' report and Sea-borne Trade statements give 7-8 lakhs of rupees as the value of pre-war annual imports exclusive of the standard equipment of batteries in cars and other vehicles. The D.G.M.P. also agrees with this figure and estimates about 22,000—25,000 batteries used to be imported annually as standard equipment. If the price of a battery, ex-duty is assumed to be about Rs. 16—20/-, Rs. 8 lakhs would correspond to about 40,000—50,000 batteries. Both the items together make up about 75,000. Some manufacturers have estimated the consumption figure to be very much higher. We consider that 100,000—125,000 batteries per annum would be a fair estimate of the requirement during the next five years. Most of the raw materials are available in India and even before the war, one or two firms were producing acid accumulators in India. Now there are five firms in all, specialising in manufacture of batteries and with assistance they received from Government such as supply of raw material, etc., they did valuable service during the war. There will be keen competition hereafter from foreign sources and we are of the opinion that this important industry can thrive successfully if reasonable protection is given.

We understand that appreciable quantities of alkaline cells are purchased and used by Indian Railways. We are of the opinion that attempts must be made to manufacture them also in India itself.

#### (b) Dry Cells.

38. Dry cells are extremely convenient and handy sources of electrical energy and have deservedly become immensely popular. Manufacture has been by millions all over the world and their chief uses are in the radio, flash-light, ignition and signal systems. There are different sizes and shapes to suit every type of requirement. The raw materials are manganese dioxide, carbon rod, graphite, ammonium and other chlorides, soot, lamp-black, wheat flour, starch and containers. The dolly materials are manganese dioxide (natural and artificial) as depolariser, graphite (natural and artificial) as electrical conductor, carbon rod as electrode and soot and lamp-black as porosity agents. Electrolyte materials consist of ammonium, zinc, calcium, magnesium and mercury chlorides of high purity and wheat flour and starch as gelatinising agents. Containers, caps and connecting strips are made from zinc and brass sheets. Solder flux, sealing compound, wrapping cloth and card-board are the other accessories.

39. Before the war, India used to import about 25 lakhs of rupees worth of dry cells and batteries, 60—70 per cent. from the U.S.A., 10—12 per cent. from Germany, 15—20 per cent. from the British Empire and small quantities from China and Japan. Indian industry has steadily grown and now there are about ten firms. Unfortunately, most of the raw materials valued at about Rs. 10 lakhs (pre-war) are imported

even now; although they are available in India, their quality is not quite suitable. We understand that as a result of investigations carried out by the Council of Scientific and Industrial Research, many of them can be used now after processing. Many Indian firms are using only manually operated or semi-automatic machines which have the advantage of lower initial investment and permit greater flexibility, but rate of production is lower. Before the war, competition from the U.S.A., Germany, China and Japan was very keen; cells from China and Japan were not good, but extremely cheap. We are informed that many Indian concerns are planning to increase their output by installing automatic machinery, zinc rolling mills and carbon electrode plants. We feel, however, that they should also use indigenous chemicals, after some processing if necessary. We understand that dry cells used to be manufactured in Japan on a cottage industry basis. This can be adopted in India also with advantage. A good beginning has been made in the dry cell industry and we are of the opinion that it should be developed further. In order to safeguard its future, we recommend that this industry should be given protection against foreign competition.

## VI. ORGANIC CHEMICALS.

40. Reduction and oxidation of organic compounds have been carried out commercially in other countries through the agency of electrical energy. The important chemicals—anthraquinone from anthracene, chloroform from sodium chloride and acetone, iodoform from potassium iodide and alcohol or acetone, calcium gluconate, sorbitol and mannitol from glucose, para-aminophenol and benzidine from nitrobenzene are being manufactured in this way. Methods are fairly well known, but in some cases, technical difficulties have to be solved. Calcium gluconate is being manufactured on a small scale by some firms in India. The question of large scale manufacture of all these would naturally be taken up when a synthetic organic chemical or dyestuff industry is established and the use of electricity becomes more extensive. This is an important line which has made great progress in the U.S.A. in recent years and we think that in India also it should be developed by encouraging planned and systematic research in established scientific institutions.

## GENERAL CONSIDERATIONS AND CONCLUSIONS.

It is seen from the foregoing pages that Heavy and Electro-Chemical Industries can be divided into three broad groups:—

(i) Sulphuric acid and salts; (ii) Soda ash and lime-soda; and (iii) Chemicals which can be manufactured only where plenty of cheap electrical energy is available; electrolytic caustic soda would belong to this group. Although it would have been desirable at the outset to locate these groups in specially selected areas, thereby creating industrial centres, it is not possible to do so now as heavy chemical industries have already been located in many places distributed all over the country.

In conclusion, we recommend as follows:—

2. (i) Heavy and Electro-Chemical industries should be developed in India. For want of these, India suffered considerably during the recent war. In view of the large hydro-electric developments being planned in different parts of India, the availability of raw materials in many cases and the importance of electro-chemical industries to the country, conditions are specially favourable for the establishment of these industries also on a large scale.

(ii) In order to establish these industries on a sound footing, the Government of India should have a staff of experts whose services would be available to the various industries, particularly small scale ones.

(iii) Government should give the necessary protection against imports to those industries which find it difficult to compete, due to the higher cost of these Chemicals (manufactured in India) they require for their manufacture. Relevant examples are soap which requires caustic soda and glass which depends on soda ash.

(iv) Excise duties as in the case of salt, alcohol, benzene, etc., or any other disabilities, e.g., licence required for the storage of sulphur which are not conducive to development should be removed.

(v) Raw materials including fuel oils, plants and scientific instruments for these industries should not be subject to any duty.

(vi) Cheap transport of raw materials and finished products from and to the different parts of the country is an essential condition for the successful development of these industries, which in the case of electro-chemical industries have to be located at sites of power generation to which raw materials have to be transported. There have been persistent complaints that freight charges are very heavy in India. We have already referred to the case of raw materials for aluminium manufacture. We feel that railways have to consider enable them to thrive and face foreign competition, by the grant of specially low freight rates.

(vii) The development of electro-chemical industries and their successful working depends on the supply of cheap abundant power to these industries. Heavy Chemical Industries also would benefit by the supply of cheap power. Calculation of power costs in the

old orthodox way allowing for interest, depreciation, etc., will put up the cost of power with the consequence that the consuming industries will be strangled. Even though a hydro-electric project may not by itself, pay an adequate return on the basis of orthodox canons of finance, the indirect benefits to the country by the development of these industries will more than compensate for this apparent loss. The importance of the use of electricity in India where the fuel resources are not too plentiful and even those available are concentrated in one area cannot be too strongly emphasized. Rates for electrical energy in foreign countries for such industries are, we understand, as low as £3 or even less per H.P. year. In India, 0.1 to 0.15 anna per KWH would be a fair rate for those electro-chemical industries in which cost of power is a major factor. Such a low rate is essential, when one takes into account the other disadvantages such as smaller production, heavy freight charges, etc., suffered by them. Reference may be invited to Appendix IX, in this connection.

(viii) We understand that minerals which form important raw materials for chemical industries belong, at present, to the Governments of the Provinces and States, in which they occur. In order to ensure the development of the mineral resources on an All-India basis, we recommend to the Government of India that mineral resources must be included among the Central Subjects.

(ix) Manufacture of electrical equipment—electrodes, furnaces and transformers, is being carried on to some extent now, but has to be developed much more if India is to be self contained with regard to these industries. Special mention must be made of electrodes, large quantities of which are consumed continuously by these industries. Appendix XIV deals with the electrical equipment required for electro-chemical industries.

(x) We understand that planned dovetailing of seasonal employment has been taken up in the U.S.A. and the possibility of organising it in India also may be examined. Cheap secondary power could be made available during the flood season; in some places, we understand that old machinery whose cost has been completely recovered is available and we recommend that such machinery should be utilised for generation of secondary power; in such cases, power would be available at almost no cost. This could be utilised by the electro-chemical industries with profit. During the period when no secondary power is available, these industries will either have to suspend operations or be worked on power from thermal stations. The latter may not be economical in most parts of India. Even if these factories are closed during the off-season, the staff and labour can be usefully employed in any cottage or other industries not requiring much power. If this is possible, it is only capital cost charges that will have to be distributed over half the years' production. This scheme requires careful organisation and goodwill and we recommend that it may be examined by the Government and by the other Panels.

(xi) We should also like to refer to the desirability of manufacturing machinery and equipment required for chemical industries in India itself. This, however, may not be possible immediately. We

understand that the Industrial Plant & Machinery Panel is examining this question in detail. We should like to recommend, however, that a beginning may be made by taking up the fabrication of such equipment as may be possible with the capital machinery already available in India. In many cases, lease of patents may not be necessary.

3. As stated at the beginning of the report, the consumption of these chemicals depends on the development of the consuming industries, the extent of which is difficult to estimate in view of the continuously changing conditions in the world to-day. Therefore, it has not been easy for us to fix with any accuracy five-year-targets for Heavy Chemicals, whose consumption will depend upon various other factors, such as expansion of and competition from industries in other countries, the support Indian industries will get from Government, etc. Synthetic dye and explosives industries are large consumers of Heavy Chemicals and development of this industry will depend on the successful establishment of those industries. Reference has been made (*vide* para 94) to the contemplated early start of synthetic dyestuffs industry in India. The effect of this industry will be large on development of other chemical industries—coal tar distillation, heavy chemicals, etc., which supply the raw materials and others like fine chemicals, pharmaceuticals, synthetic resins, explosives, etc., which develop from the dye industry. Some of the raw materials for the dyestuffs industry will have to be manufactured by the industry itself while some others will have to be obtained from other sources. There has been no attempt so far for starting the manufacture of peace-time explosives, but it will have to be taken up soon. Therefore, while the targets suggested are based on a consideration of the existing conditions, those who will be entrusted with the task of giving effect to our recommendations may have to modify them suitably, should the changed conditions at the time of execution require it.

4. Reliable statistics form the basis of any well organized plan or development. We were handicapped at the very outset by lack of co-ordinated and reliable data relating to the industries dealt with in this report. Attempts have been made at different times by various Departments and bodies including the Indian Tariff Board to collect reliable figures of production and distribution of many articles in this country, but it would be difficult indeed to accept as strictly accurate the data collected by any single individual or Department or Institution. We have made an earnest attempt to collect the data from various sources and reconcile them. Although we do not claim any finality for our figures, it will be generally accepted, we are sure, that our report will serve a useful and practical purpose when dealing with the chemical industries in India.

#### ACKNOWLEDGMENTS.

We are thankful to many officers, Departments and Institutions for supplying us the data contained in this Report.

The Panels had the benefit of discussions at separate meetings with Mr. Morton S. Cressy, Chemical Expert from The Chemical Construction Corporation of America, who had been invited by the Government of India to advise them on the development of chemical industries in India. We are thankful to the Government for giving us this opportunity of discussing with Mr. Cressy the scope of Chemical developments in India. Mr. Cressy toured all over India with our Secretary, Dr. K. A. N. Rao and his report on chemical industries will, we understand, be submitted to the Government of India shortly. Owing to the desire of Government for early submission of our report, we have not had the full benefit of Mr. Cressy's views.

We wish to thank Mr. D. N. Wadia, Mineral Adviser to the Government of India, who attended all the meetings of the Panels and gave valuable suggestions on all the subjects relating to minerals. To assist the Panels in their consideration of the subject of common salt, the Central Board of Revenue deputed Mr. H. A. C. Gill and Dr. S. S. Aiyar to meet the Panels and clarify certain points. The Public Health Commissioner also kindly deputed Major T. C. Puri, Deputy Public Health Commissioner to clarify some points about DDT. Our thanks are due to all of them.

We wish to place on record our appreciation of the arduous work of our energetic and hard-working Secretary, Dr. K. A. N. Rao. He came to us, apart from his scientific attainments, with a fund of research and industrial experience, and we would like to express our thanks to him for his valuable work. The Secretary's staff have put in excellent teamwork and they also deserve special mention.

*Heavy Chemical Industries Panel.*

Shri Ram.  
M. S. Patel.  
V. Seshasayee.  
S. G. Sastry.

*Electro-Chemical Industries Panel.*

J. C. Ghosh.  
B. K. Ram Prasad.  
Kenneth Hall.  
M. S. Patel.

K. A. N. Rao, Secretary.



## PART I.

## SUMMARY OF MAIN RECOMMENDATIONS.

Importance of a sound Heavy, Chemical Industry for the industrial advancement of India.

*Sulphuric Acid:*

Present production	.. ..	About 59,000 tons.
Existing capacity	.. ..	About 77,000 tons.
Present consumption	.. ..	About 55,760 tons.

(i) Five-year target including the acid required for rayon industry: 152,600 tons.

(ii) This target to be achieved by the installation of fifteen 10-ton per. day units and one Government experimental plant for producing 35 tons of sulphuric acid and 12 tons of sulphur per day from gypsum, in addition to plants for which import licences have been granted. Balance of 23,600 tons to be allocated after location of rayon plants is decided. Cost of capital equipment, Rs. 37.5 lakhs, excluding the Government plant.

NOTE.—All figures are expressed in terms of 100 per cent. Sulphuric Acid.

(iii) Import of Spanish pyrites to be arranged for the manufacture of copper and sulphuric acid.

(iv) *Location.*—Sind, Bombay, Bihar and C.P.

(v) A staff of Government experts to be maintained for paying visits to factories and give technical advice.

(vi) Some scholars proceeding to the U.K. and the U.S.A. to specialise in sulphuric acid industry.

(vii) Foreign technical experts necessary only for the Government experimental plant.

(viii) Bulk purchase of sulphur by a single corporation to be arranged for supplying sulphur to all the industries requiring it.

(ix) Ceiling prices for the acid based on the cost of sulphur to be fixed by Government periodically.

(x) Chamber acid to be used as far as possible for the manufacture of fertilisers.

*Sulphates:*

*Sulphate of alumina.*—Present consumption .. 20,500 tons.

Five-year target .. .. 38,000 tons.

*Magnesium sulphate.*—Total Indian production : 3,500—4,000 tons. This can be increased if necessary.

*Iron sulphate.*—Present production of 2,000 tons sufficient. This can be increased if necessary.

*Copper-sulphate*.—Estimated Indian production 900 tons. Requirements about 2,000 tons.

(i) No increase of manufacture from slender Indian resources of copper.

(ii) Manufacture to be arranged from imported copper pyrites.

(iii) Copper sulphate imported for agricultural purposes should be free of duty.

*Sodium sulphate*.—Consumption about 4,000 tons. Large deposits are available in the Didwana Salt Range Jodhpur, in addition to manufacture in hydrochloric acid and dichromate plants. No action is necessary.

#### *Other sulphur Compounds:*

*Sodium sulphide*: Present demand about 3,700 tons per annum. Five-year target 7,000 tons.

(i) Jodhpur State to be addressed by the Government of India to expedite manufacture.

*Sodium thiosulphate (Hypo)*.—Demand more than 500 tons. Local manufacture is expected to meet the demand. No action is necessary.

*Sodium Hydrosulphite (Hydros)*.—Pre-war requirements 1,600 tons.

(i) Five-year target 2,500—3,000 tons.

(ii) Manufacture to be taken up in India for which cheap zinc and sulphur dioxide are necessary.

(iii) Investigations of alternative processes utilising Indian raw materials should be continued by the Council of Scientific and Industrial Research.

#### *Alkali Industries:*

*Common salt*.—(i) Chemical industries to be supplied common salt by Government at cost of manufacture which should be reduced to as low a figure as possible.

(ii) Salt dust to be given free of charge or at least at the same uniform rate to all industries.

*Lime*.—Lime of guaranteed quality essential for chemical industries.

(i) Installation of modern lime kilns in different areas.

*Soda ash*.—Present consumption 107,500 tons per annum. Present capacity 74,000 tons; production much less.

(i) Five-year target: 270,000 tons.

(ii) To achieve this target, four new plants are recommended; two 50,000-ton plants, one each in Sind and in Bihar, two 30,000-ton plants, one each in South India and in the C.P.

(iii) Collection of the chemical from Reh deposits to be organised properly.

(iv) Estimated requirements of capital goods: about Rs. 6 crores.

(v) Technical advice from abroad necessary.

(vi) Indian chemists and engineers to be trained in the U.K. and the U.S.A.

*Caustic Soda*.—Present consumption about 54,000 tons. Present capacity 12,600 tons.

(i) Five-year target 133,000 tons including requirements of rayon industry (45,000 tons electrolytic and the balance by the lime-soda process).

(ii) Requirements of capital goods: about Rs. 16 lakhs for each 5-ton plant.

(iii) *Location*.—One 11,000-ton mercury cell plant in Bihar and the others distributed in different parts of India.

(iv) Manufacture of 30,000 tons in all of DDT and Hexachlorocyclohexane (666), the two valuable insecticides from the chlorine produced in electrolytic alkali plants.

(v) Government to employ experts to visit plants and give technical advice.

(vi) Indian chemical engineers to be trained in the U.K. and the U.S.A.

(vii) Such protection as will not penalise the consuming industries to be given.

*Potassium chlorate*.—Pre-war consumption about 2,000 tons per year. Existing production about 2,000 tons.

(i) A plant of 1,000—1,500 tons capacity to be installed in one of the alkali plants.

(ii) The raw material, potassium chloride manufactured in India not sufficiently pure and must be made suitable for the manufacture of potassium chlorate.

*Hydrochloric Acid*:

Present production 2,500 tons.

(i) For any extra production required, manufacture from hydrogen and chlorine must be adopted.

*Zinc chloride*.—About 2,000 tons imported annually. Cheap zinc residues essential for manufacture in India.

*Magnesium chloride*.—Indian demand 7,000 tons. Manufacture is more than sufficient.

*Calcium chloride*.—Present Indian capacity is more than sufficient to meet the demand of 1,000 tons.

*Potassium chloride*.—Imports about 3,000 tons.

(i) Existing manufacture from bitterns and from Reh deposits should be increased.

*Barrium chloride*.—Manufacture of 1,000—1,500 tons per year to be taken up in one of the alkali plants.

*Nitric Acid.*—Local supply is equal to the demand of about 1,300 tons.

(i) Five-year target: 4,000 tons.

(ii) Production in Ordnance factories should be utilised for civilian purposes.

*Potassium nitrate.*—Indigenous production is sufficient to meet the demand if this industry is organised properly.

*Ammonia.*—(i) 12,000—15,000 tons of ammonia manufactured at Sindhri or Alwaye should be reserved for the manufacture of ammonium salts and other chemicals.

(ii) No new plants to be installed for the present.

*Urea.*—(i) Five-year target: 10,000 tons.

(ii) To be manufactured at Sindhri from ammonia available there.

*Phosphates.*—(i) Five-year target for superphosphates 100,000 tons per year.

(ii) An experimental plant for manufacture of 10 tons of phosphorus per day and of concentrated phosphates by the electro-thermal process should be installed by Government.

*Calcium Carbide.*—See Part II.

*Dichromates.*—Present capacity of 5,000 tons per year is more than sufficient to meet the demand.

*Glycerine.*—Present production is more than sufficient for Indian requirements.

*Methyl Alcohol and Formaldehyde.*—Large scale manufacture to be taken up at Sindhri.

*Coal Tar Products.*—Manufacture should be increased.

*Other Industries.*—The desirability of developing crude petroleum cracking and refining, and peace-time explosives industries.

## PART II.

Importance of Electro-chemical Industries, which are superior in many cases to the older chemical processes. Importance of cost of electrical energy.

*Caustic Soda, Caustic Potash and Chlorine; Potassium Chlorate.*—See Part I.

*Hydrogen Peroxide.*—One plant of 350—400 tons capacity per year expected to be installed in Bombay.

(i) More plants to be installed when there is a definite demand.

*Calcium Carbide.*—Present Indian demand: 3,500 tons.

(i) Five-year target 7,000 tons.

(ii) *Location*.—One 5,000-ton plant in Bihar and one 2,000—2,500 ton plant in South India.

*Ammonia*.—See Part I.

*Carbon Disulphide*.—Required for rayon and oil industries.

(i) 8,760 tons per year required by Rayon Industry to be prepared in the rayon factories themselves.

*Artificial Abrasives*.—(i) Installation of furnaces with a capacity of 2,000 tons for each of the abrasives given in the report should be installed near a source of power.

(ii) Firms who have already established manufacture of bonded abrasives should be given concession for the manufacture of grains.

*Artificial Graphite and Electrodes*.—Small quantities of carbon electrodes are being made at present in India.

(i) Government itself should instal one or two plants for manufacture of graphite electrodes, if manufacture by the Company started in Travancore does not materialise within a reasonable length of time.

(ii) First calcination of petroleum coke should be carried out in the oil refinery itself before supply of coke to graphite plant; this will save freight charges.

*Ferro-Alloys*:

*Ferro-manganese*.—Sandur State is considered suitable for locating this industry.

*Ferro-silicon*.—Mysore is manufacturing 2,000 tons per annum.

(i) Total Indian demand is expected to be 4,000 tons, which Mysore can supply.

*Aluminium*.—Present total production capacity: 7,500 tons per year, with provision for developing it to 10,000 tons.

(i) Five-year target 15,000 tons per annum, with provision for 20,000 tons later.

(ii) To achieve this target, another aluminium plant of 5,000 tons immediate capacity ultimately to be raised to 8,000—10,000 tons should be installed near a source of power supply.

(iii) Special concessions such as cheap transport and protection (subsidy to protect consumer industries) should be given to this industry during the next five years, which can be reduced if power situation improves, after which it is sufficient if railway concessions comparable to Canadian and the U.S.A. rates are given.

*Magnesium*.—(i) Government should put up a small plant of 3—5 tons a day; Manufacture by the Pidgeon process.

(ii) Government should purchase and stock 1,000 tons of the metal for supply to Indian manufacturers at cost price.

*Copper.*—Present production 6,000 tons. Consumption of copper and alloys 50,000 tons.

- (i) Five-year target: 10,000 tons of copper.
- (ii) Other deposits of copper should be examined in order to develop production.
- (iii) Import of copper pyrites should be arranged for manufacture of copper and sulphuric acid.
- (iv) One 5,000-ton unit for manufacture of primary metals from scrap should be established at one of the sea port towns. Scrap for this purpose should be permitted to be imported free of duty.
- (v) Low grade copper ores should be used for making copper salts.

*Electro-Plating.*—Large units for electro-plating industrial equipment should be installed.

*Storage Batteries.*—Present estimated requirement 75,000 per year.

- (i) Five-year target: 100,000—125,000.
- (ii) Existing five firms will be able to supply the requirements if reasonable protection is given.

*Dry Cells.*—Factories in India are supplying the demand.

- (i) Indigenous raw materials are not being used. This must be done after some processing if necessary.
- (ii) Possibility of manufacture on a cottage industry basis as in Japan should be examined.

No summary of "General Considerations and Conclusions" is given as that section itself is in the nature of a summary. Therefore, that will have to be considered as supplementary to the "Summary of Recommendations" of Part I and II.

#### APPENDIX I.

Industry.	Capital invested in India.
	Rs.
Cotton textiles . . . . .	100 crores.
Iron & Steel . . . . .	*25 crores.
Sugar . . . . .	33 crores.
Jute . . . . .	*30 crores.
Heavy Chemicals . . . . .	5 crores.
Cement . . . . .	17.5 crores.

*Note.*—\*Both preference and debenture capital included.

Regarding Iron & Steel, no statistics are available with regard to money invested in re-rolling mills, as also investment in Engineering Industries.

## APPENDIX II.

## HEAVY CHEMICALS.

I. *Sulphur and its compounds.*—

- (a) Sulphuric Acid:
- (b) (i) Aluminium sulphate and alums.  
(ii) Magnesium sulphate (Epsom salt).  
(iii) Iron sulphate.  
(iv) Copper sulphate.  
(v) Sodium sulphate.
- (c) (i) Sodium sulphide.  
(ii) Sodium sulphate.  
(iii) Sodium thiosulphate.  
(iv) Sodium hydrosulphite.

II. *Alkali Industries.*—

- (a) Common salt.
- (b) Lime.
- (c) Soda ash.
- (d) (i) Sodium bicarbonate.  
(ii) Sodium silicate.  
(iii) Cyanides and Ferro-cyanides.
- (e) Caustic soda & chlorine.  
(Caustic potash).
- (f) Potassium Chlorate.

## III.

- (a) Hydrochloric acid.
- (b) (i) Zinc chloride.  
(ii) Magnesium chloride.  
(iii) Calcium chloride.  
(iv) Potassium chloride.  
(v) Barium chloride.  
(vi) Ferric chloride.

## IV. (a) Nitric acid.

- (b) Potassium nitrate.

## V. (a) Ammonia.

- (b) (i) Ammonium chloride.  
(ii) Ammonium carbonate.  
(iii) Ammonium bicarbonate.

VI. *Fertilisers.*—

## (a) Nitrogenous fertilisers:—

(i) Ammonium sulphate. ✓

(ii) Urea. ✓

(iii) Ammonium nitrate. ✓

(iv) Potassium nitrate. ✓

(v) Cyanamide. ✓

## (b) Phosphate fertilisers. ✓

(Phosphorus).

## (c) Potash fertilisers.

VII. *Other Inorganic Chemicals.*—

Calcium carbide.

(a) Magnesia.

(b) Arsenic.

(c) Borax.

(d) Dichromates and chromic acid.

VIII. *Other organic substances and derivatives.*

(i) Ethyl alcohol. ✓

(ii) Acetic acid.

(iii) Lead acetate.

(iv) Sodium acetate.

(v) Glycerine.

(vi) Formaldehyde.

(vii) Starch and glucose.

(viii) Acetone.

IX. *Industrial gases.*

(i) Oxygen.

(ii) Hydrogen.

(iii) Carbon dioxide.

X. *Coal tar products.*

(Phenol, Cresylic acid, Naphthalene, Creosote and benzene).

XI. *Miscellaneous.*



## APPENDIX III.

## ANNUAL PRODUCTION OF SULPHURIC ACID IN TONS (AREA-WISE).

(Calculated as 100 per cent).

		Total		
		in (1944) (1)	New Plants	
			Recently erected. (2)	Import license granted. (3)
<i>Bengal—</i>				
C	1. Bengal Chemical and Pharmaceutical Works Ltd., Calcutta	3,970		
	2. Bellighatta Acid Chemical Works, Calcutta	695		
	3. India Chemical Industries Ltd., Calcutta	498		
	4. The Indian Iron and Steel Co. Ltd., Calcutta	6,341		
	5. D. Waldie and Co. Ltd., Calcutta	1,403		
			13,000	
C.	One 10-ton contact plant recently installed			3,000
<i>Assam—</i>				
C. *1.	Assam Oil Co., Digboi	1,490	1,490	
<i>Bihar—</i>				
	*1. Rohtas Industries, Dalmianagar	1,433		
C. *2.	The Tata Iron & Steel Co. Ltd.	12,651		
	*3. Timpla & Co., Calcutta	3,241		
	*4. Bararee Coke Co., Calcutta	842		
	*5. Burrakar Coal Co. Ltd., Calcutta	801		
			19,000	
C.	One 10-ton contract plant recently installed			3,000
	One 10-ton contact plant (Import license granted)			3,000
<i>U. P.—</i>				
	1. Cawnpore Chemical Works, Cawnpore	4,436		
	2. Mining & Chemical Industries Ltd., Agra	425		
	3. U. P. Glass Works, Bhajori	39		
			4,900	
<i>Delhi—</i>				
	1. Shambunath & Sons Ltd. Delhi	406		
	2. D. C. M. Chemical Works, Delhi	2,202		
	3. Ajodhya Prasad Chemical Works, Ghaziabad	254		
	4. Frontier Chemical Works, Delhi			
	5. Delhi Acid & Chemical Works, Delhi			
			3,000	
C.	One 10-ton plant recently installed			3,000

<i>Punjab—</i>		(1)	
1.	Cawnpore Chemical Works, Khasa	446	
2.	S. P. Chemical Works, Amritsar	426	
3.	Shambu Nath & Sons Ltd., Amritsar	1,641	
4.	Amritsar Chemical Works, Amritsar	44	
5.	Frontier Chemical Works, Rawalpindi	121	
			2,700
<i>Sind—</i>			
1.	Ganga Ram Khusal Das, Sukkur (Sind)	29.7	
			30
<i>Bombay—</i>			
1.	Dharamsi Morarji Chemical Co. Ltd.	3,594	
2.	Eastern Chemical Co. Ltd.	2,486	
3.	Sonawala Co. Ltd.	1,811	
			7,900
<i>Baroda and Ahmedabad—</i>			
1.	Ramco Chemical Works, Ahmedabad	526	
2.	Star Chemical Works, Baroda	390	
3.	Petlad Turkey Red Dye Works, Petlad	313	
			1,230
C.	One 10-ton contact plant recently installed		3,000
<i>Mysore—</i>			
C. 1.	The Mysore Chemicals and Fertilisers Ltd.	4,170	
			4,170
<i>Madras—</i>			
**1.	The East India Distilleries and Sugar Factories Ltd. (Managing Agent: M/s. Parry & Co. Ltd.)	1,680	
			1,680
	One 35-ton gypsum-sulphuric acid plant (import licence granted)		10,500
<i>Hyderabad—</i>			
1.	Hyderabad Chemicals & Fertilisers	159	
			160
<i>Travancore—</i>			
1.	Travancore Fertilisers and Chemicals		3,000
	Capacity @ 59,000		
	Capacity 65,000	Cap.77,000	Capacity 93,500

## Note :—

\* Producing acids mostly for their own consumption.

\*\* Messrs. Parry & Co. propose to expand production to 4,000 tons. This extra production will be used up to manufacture superphosphate for supply to the Government of Madras.

|| This firm proposes to put up a 75-ton plant per day, but only 3,000 tons will be available for sale.

C Contact plants.

@ Production in 1944.

## APPENDIX IV.

EQUIPMENT FOR A CONTACT SULPHURIC ACID PLANT DAILY CAPACITY:  
10 TONS.*Blower:*

It is understood that there is no commercial concern in India manufacturing these blowers at present. Ordnance factories are, however, manufacturing other types of blowers and they could make these also provided they are supplied machine drawings.

The V-Belt drive, complete with sheaves, can also be manufactured in India, it is understood.

20 H.P. Motor can be made in electrical workshops.

2. Sulphur melter, sulphur burner shell, converter shell, intercooler,  $\text{SO}_3$  cooler, drying tower shell and absorbing tower shell can all be made in India, except for tubes.

3. *Molten sulphur pump*.—It is understood that some engineering firms and Ordnance factories can manufacture these pumps, but experience alone will show whether they will be satisfactory.

1 H.P. Motor with starter can be manufactured in electrical workshops.

4. *Vanadium catalyst*.—This will have to be imported.

5. *98 per cent. acid and oleum tanks and pumps*.—The tanks can be manufactured if drawings and detailed specifications are available. Pumps for 98 per cent. acid pump tank and oleum pump tank cannot be made in India as the internal bearings, journals and impeller clearance rings have all to be of Illium.

5 H.P. totally enclosed motors can be made in India.

The pump packings and packing rings cannot be made in India, as they must be hard burnt and vitrified and of approved chemical acid resisting ware.

6. Chemicalware orifices cannot be made in India.

7. It will be necessary to import an oil burner and perhaps a blower for starting the plant.

8. It is understood that acid-proof bricks are available, but use alone can decide whether they will be suitable.

Whether acid proof cement is also available is not known with certainty. Insulating concrete may be available in India. Quartz pebbles for tower packing and other purposes may perhaps be obtainable in India. Whether all these are satisfactory has to be examined carefully.

It is understood that there are no facilities in India now for manufacturing gas or acid pipes.

Valves and fittings also have to be obtained from outside.

All indicating and recording instruments will have to be imported at least for some time to come.

It has to be stated that since the number of units required will be small, the cost of manufacture would be high compared to that of the imported machinery. Further, in all the cases, complete working drawings and specifications from the designers will be necessary. Whether these can be obtained without payment of royalty fees has to be examined.

## APPENDIX V

Analyses of the type of salt used in America for electrolysis and a few typical samples of Indian salts are given below:—

Rock salt considered suitable for electrolysis in the U.S.A.		*Clean rock salt from Khewra mines.	
Sodium chloride	98.5 %	Sodium chloride	98.31%
Insoluble matter	0.57%	Insoluble matter	0.11%
Moisture	0.07%	Moisture	0.10%
Calcium oxide (CaO)	0.23%	Sodium sulphate	0.44%
Magnesium Oxide (MgO)	Trace	Calcium sulphate	0.71%
Sulphate as SO <sub>3</sub>	0.12%	Magnesium sulphate	0.33%
Iron as Fe <sub>2</sub> O <sub>3</sub> *	Trace		
<b>*Rajputana Salt—</b>		Sambhar.	Pachhadra.
Sodium chloride		98.14%	97.10%
Insoluble matter		0.43%	0.32%
Moisture		0.65%	0.90%
Sodium sulphate		0.27%	
Calcium sulphate		0.34%	1.29%
Magnesium sulphate		..	0.27%
Magnesium chloride		..	0.12%
<b>*Kharaghoda and Kuda salts—</b>		Kharaghoda.	Kuda.
Sodium chloride		96.99%	98.47%
Insoluble matter		0.13%	0.31%
Calcium sulphate		1.66%	0.81%
Magnesium sulphate		0.19%	0.08%
Magnesium chloride		0.90%	0.32%
Potassium chloride		0.08%	
Calcium carbonate		0.03%	
Magnesium bromide		0.02%	
		**Bombay Presidency salt.	**Madras salt.
Sodium chloride		95.43%	92.72%
Insoluble matter		0.94%	2.82%
Calcium sulphate		1.12%	0.98%
			(calcium salts)
Magnesium sulphate		1.10%	1.36%
Magnesium chloride		1.41%	2.12%
<b>*Salt imported into Bengal—</b>			
Moisture			3.4%
<b>ON A DRY BASIS :</b>			
Sodium chloride			97.5%
Insoluble matter			0.2%
Calcium sulphate			1.4%
Magnesium sulphate			0.3%
Magnesium chloride			0.6%

Note:—\*These figures have been taken from Kapilram H. Vakil's monograph on "Salt."

||These analyses obviously refer to dry basis.

## APPENDIX VI.

The following are examples of important Indian limestones with their analyses:—

Serial No.	Locality.	Composition					Remarks.
		CaCO <sub>3</sub>	MgCO <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub>	Silic. Insolub- les.	Other impur- ities.	
1	Katni, Jubbulpur, C. P. . . .	94.65	2.98	..	1.79	0.58	Practically inex- haustible.
2	Malhar (Rewa), C. I. . . .	96.03	1.75	0.96	1.15	0.11	Practically inex- haustible.
3	Bisra (Gangpur), Eastern States Agency . . . . .	95.18	1.57	1.04	1.87	0.34	Very large ex- tent, but asso- ciated with dol- omite bands.
4	Sylhet (Assam) . . . . .	95.4	1.81	1.72	0.58	0.49	Practically un- limited.
5	Chela (Khasi Hills Assam) . . . . .	98.6	0.55	0.3	0.55	..	Very large, but exact exten-
6	Hanspathar, C.P. . . . .	83.43	0.78	..	16.18	0.7	unknown. Very large.
7	Dalli, Drug, C.P. . . . .	83.5	2.0	0.9	13.6	..	Very large.
8	Kandara, Chanda, C.P. . . . .	94 to 96.8	..	3.0 to 1.2	2 to 2.5	..	Quantity un- known, but pre- sumably large.
9	South of Rohri, Sind . . . . .	98.67	0.43	1.02	0.18	0.025	Very large.
10	Wardha Valley (Penganga) . . . . .	96.8	..	1.2	2.0	..	
11	Palavanatham, Madras . . . . .	98.24	0.43	0.06	0.57	0.7	
12	Anantagiri, Vizagapatam . . . . .	96.73	2.50	0.23	0.56	..	

## II. (1) Bihar and Eastern States.

High grade limestones occur at many places in Bihar, but data of their phosphorus content are wanting. Supplies of limestones for metallurgical purposes come from Birmitrapur in the Gangpur State. According to Dr. M. S. Krishnan, the reserves are approximately 137,500,000 tons. Of this quantity, 10 per cent. can be classed as first grade and 25 per cent. as useful for lime making. The above figures are a conservative estimate. Very large quantities of Gangpur limestone are annually burnt for lime and for cement making.

The best limestone in Bihar occurs in the Shahabad district, the Rohtas limestone. In Mirzapur district, it occurs in beds, 700 ft. in maximum thickness. There are a good number of other limestone deposits in Bihar, but the deposits are not so pure and not of such wide extent. Hanspathar limestone (SiO<sub>2</sub> upto 16 per cent.), comes under this category.

(2) *Bombay*.—Limestones of good quality for use in the High Explosive Factory, Kirkee, are found in the Ahmednagar district, the local

ties being about 80 miles from Poona. The reserves, however, are not large, about 15,000 to 20,000 tons.

(3) *Central Provinces & Central India.*—C.P. contains valuable deposits of limestone, fit for burning to lime for Sugar Factories. There is also a large quantity of high grade limestones, fit for fluxing purposes. These limestones have been examined recently for their suitability for use in the manufacture of Calcium Carbide. Analyses of samples and other data may be obtained from the G.S.I. Limestones, carrying upto 1 per cent. MgO and 2 per cent. SiO<sub>2</sub>, have been used successfully in carbide manufacture, provided phosphorus content is below 0.04 per cent. The reserves are not estimated in all cases, but it is probable that large quantities are available and are being worked for supplying to sugar factories, to lime kilns and to the iron works.

The following are the chief limestone areas of the C.P.:—

(a) *Jubbulpur—Katni—Satna area.*

(i) Katni area.

(ii) Jukehi—Kymore area.

(iii) Maihar area.

(iv) Satna area.

(b) Raipur district.

There are several quarries situated within two miles from Raipur town. The Katni limestone is quarried to the largest extent in the C.P. It is largely used for lime burning. The limestone is tough, massive and dark grey in colour. The CaCO<sub>3</sub> content varies from 93.20 to 96.4 and the MgO is below 2 per cent.

(4) *Madras.*—The limestone deposits of the Salem district have been examined by the G.S.I. for their suitability for Calcium Carbide manufacture and also for lime burning. The majority of the Salem limestone is found to be of good quality, rich in CaCO<sub>3</sub> with very small amounts of impurities. But some of the limestones are partly dolomitic. Preliminary prospecting gives a figure of about 700,000 tons.

Very high grade crystalline limestone (in part dolomitic) occurs in the Tinnevely district, suitable for lime burning and for cement manufacture. Part of the limestone of Tinnevely is of chemical grade. These latter are estimated at about 200,000 tons. Other deposits have been located in Madura district.

(5) *Punjab.*—Limestone is abundant in all the districts of Northern Punjab, and N.W.F.P., a large proportion of which is of excellent quality, according to Mr. E. R. Gee of the G.S.I.

*Salt Range.*—Enormous deposits of fine quality limestone occur here along almost the whole length of the Range. A number of analyses shows 95 to 98 per cent. CaCO<sub>3</sub>, silica less than 2 per cent. generally, alumina 1 to 1½ per cent., MgO less than 1 per cent. It is possible to select beds of the required composition and purity, from the limestones of different ages occurring in this Range.

*Kalabagh, Makarwal and Kohat districts.*

The large limestone deposits of this area are also of similar nature, both as regards quality and quantity.

*Post-war area.*—The limestone deposits of Wah analyse upto 98 per cent.  $\text{CaCO}_3$ , and are largely quarried for cement manufacture. Besides these, the hilly areas of Kalachitta and neighbouring hills contain large stones of good limestone.

(6) *Rajputana.*—The limestones of the Arawali hills are usually impure and dolomitic and are not fit for burning for lime. There are, however, a few deposits, *e.g.*, Makrana marble, which yield excellent lime.

*Jodhpur State.*—Sojat—Bilara limestone are burnt for lime. Makrana limestone (a high quality marble) contains 98 per cent  $\text{CaCO}_3$ , insoluble residue about 1 per cent. and  $\text{MgO}$  under 2 per cent.

*Sirohi State.*—The quality of the limestone of Sirohi varies greatly, but a large number of kilns use it for burning.

*Udaipur State.*—Exports large quantities of limestone in flags and slabs. It is also good for making lime. Ajmer-Merwara, Alwar State, Bundi State, Jaipur State, Jaisalmer and Jodhpur, produce marble of good quality and of variegated colours. This limestone is put to use as an ornamental stone as well as for lime making.

(7) *United Provinces.*—A considerable amount of limestone, as a source of chemical lime and for the manufacture of Calcium Carbide occurs round Mussourie. The G.S.I. estimate conservatively the reserves at about 34 million tons. The  $\text{CaCO}_3$  content varies from 95 per cent. to 99.10 per cent.; Silica varies from 0.15 to 0.02; Alumina varies from 0.25 to 0.1 and  $\text{MgO}$  from 0.36 to 0.07.

### III. Production of limestone in the principal Provinces of India in an average year.

Bihar	680,000 tons.
C.P.	550,000 tons.
Eastern States Agency	1,000,000 tons.
Madras	about 200,000 tons.
Other areas	1,000,000 tons.

(Note by Mr. D. N. Wadia).

## APPENDIX VII.

### List of Dichromate Factories in India.

	Capacity.
<b>Bombay—</b>	
Pioneer Chromates	500 tons per annum.
Premier Chromates	700 " " "
Indentors Syndicate	250 " " "
Golden Chemicals	300 " " "
<b>Calcutta—</b>	
Bengal Chemical and Pharmaceutical Works	200 tons per annum.
Chemical Corporation of India	100 " " "
Krishna Chemical Works	75 " " "
Chemical Industries Co. Ltd.	80 " " "
Zenith Commercial Co.	Just commenced, capacity not known.
<b>Madras—</b>	
Buckingham Carnatic Mills	1,200 tons per annum.
Masore Government Factory, Belagula	350 " " "
National Chemicals, Masaulipatam	Just commenced, capacity not known.
<b>U. P.—</b>	
Cawnpore Chemical Works, Cawnpore	1,200 tons per annum.
<b>Total</b>	<b>4955 tons.</b>

## APPENDIX VIII.

## TAR PRODUCTION PLANTS IN INDIA.

Company.	Location.	Capacity per month.
Tata Iron & Steel Co.	Jamshedpur	4,000 tons.
Indian Iron & Steel Co.	Hirapur	1,500 „
	Kulti	500 „
Barrakar Coal Co.	Layabad, Jharia.	200 „
Bararee Coke Co.	Kusunda, Jharia.	300 „
Bhowrah Coke Co.	Jharia	150 „
Lodna Coke Co.	Lodna, Jharia	150 „
E. I. R. By-Product Coking Plant	Girdih	75 „
Oriental Gas Co.	Calcutta	250 „
Bombay Gas Co.	Bombay	250 „
		7,375 tons

## TAR DISTILLATION PLANTS IN INDIA.

Company.	Location.	Capacity per month.
Shalimar Tar Products Co. Ltd.	Lodna, Jharia	4,000 tons
Bengal Chemical and Pharmaceutical Work Ltd.	Calcutta	400 „
Bararee Coke Co.	Kusunda, Jharia	300 „
Bihar Chemical Traders Mumtaz & Co.	Howrah	150 „
	Calcutta	50 „
		4,900 tons.

Apart from these, there are at least 5 others mostly in Calcutta and Howrah whose plants had been working before the War but may not be considered as efficient ones.



## APPENDIX IX.

## POWER COSTS AT CERTAIN ELECTRO-CHEMICAL CENTRES OF THE WORLD.

Source of power Locality.	Source of power.	Power cost anna per KWH.
Alabama U.S.A. . . . .	Steam . . . . .	0.167 to 0.270
California U.S.A. . . . .	Steam . . . . .	0.167 to 0.270
Montana U.S.A. . . . .	Hydro . . . . .	0.131 to 0.176
Massena U.S.A. . . . .	Hydro . . . . .	0.167
Niagara Falls U.S. . . . .	Hydro . . . . .	0.131
St. Louis U.S.A. . . . .	Steam . . . . .	0.176 to 0.220
Tennessee U.S.A. . . . .	Steam . . . . .	0.167 to 0.270
Arvida Canada . . . . .	Hydro . . . . .	0.044 to 0.066
Ontario Canada . . . . .	Hydro . . . . .	0.066 to 0.176
Shawinigan Falls Canada. . . . .	Hydro . . . . .	0.044 to 0.066
England . . . . .	Steam . . . . .	0.176 to 0.220
Scotland . . . . .	Hydro . . . . .	0.131 to 0.176
French Alps. . . . .	Hydro . . . . .	0.090 to 0.131
Germany . . . . .	Steam . . . . .	0.154 to 0.176
Switzerland . . . . .	Hydro . . . . .	0.131
Norway . . . . .	Hydro . . . . .	0.044 to 0.066
Sweden . . . . .	Hydro . . . . .	0.044 to 0.066

Note.—Rates in India vary considerably in different provinces and no special rates have been fixed for electro-chemical industries, such industries being very few in India. The lowest rate charged by the Government of Mysore is 0.125 anna per KWH and that by the Government of Madras, Rs. 60/- per KW year.

## APPENDIX X.

	Installed generating capacity (Kilo-watts).			
	Steam	Diesel	Hydro	Total
<b>BRITISH INDIA</b>				
Assam . . . . .	208	1,706	500	2,414
Bengal . . . . .	330,007	4,174	2,360	336,541
Bihar Public Utilities . . . . .	23,200	3,886	..	27,086
Tata Iron & Steel Co. . . . .	107,200	..	..	107,200
Bombay . . . . .	67,407	16,494	232,114	316,015
C. P. . . . .	12,639	3,894	..	16,633
Delhi . . . . .	17,900	4,386	..	22,286
Madras . . . . .	47,150	6,035	69,650	122,835
N. W. F. P. . . . .	..	1,030	9,600	10,630
Punjab . . . . .	26,478	12,907	49,750	89,135
Sind . . . . .	2,025	15,365	..	17,390
U. P. . . . .	109,995	8,120	22,700	140,815
<b>STATES.</b>				
Baroda . . . . .	..	4,761	..	4,761
Bikaner . . . . .	4,000	..	..	4,000
Hyderabad . . . . .	9,750	3,151	..	12,901
Kashmir . . . . .	..	265	4,315	4,580
Mysore . . . . .	..	..	61,000	61,000
Travancore . . . . .	..	1,543	15,400	16,943
Other States . . . . .	8,824	27,506	410	35,740

(H. M. Mathews, Journal, Institute of Engineers, India, page 7, vol 26, No. 1. September 1945).

APPROXIMATE FUTURE DEVELOPMENTS ARE NOTED BELOW :—

*Bombay—*

Tata Hydro Elect. Agencies Ltd.	30,000 KW
Future Govt. Developments	50,000 KW
Ahmedabad Electricity Co. Ltd.	50,000 KW
Bengal (including developments of Calcutta Electricity Co. Ltd., and Indian Iron & Steel Co.)—	120,000 KW
Madras (Hydro).	50,000 KW
Bihar (Including Tata Iron & Steel Co. and Patna Electricity Supply Co.)	3,5000 KW
Damodar Scheme	300,000 KW
U. P. (including hydro and steam) Stations . . . . .	15,000 KW
Punjab (including hydro and steam) . . . . .	30,000 KW
Mysore . . . . .	100,000 KW
Travancore . . . . .	15,000 KW

Dr B. K. Ramprasad,

APPENDIX 'XI.

ELECTRO-CHEMICAL INDUSTRIES.

I. *Electrolytic Processes.*

- (a) Caustic soda, Caustic potash and chlorine.
- (b) Potassium Chlorate.
- (c) Oxygen and Hydrogen.
- (d) Hydrogen Peroxide.

II. *Electro-thermal Processes.*

- (a) Phosphates.
- (b) Phosphorus.
- (c) Calcium carbide.
- (d) Calcium cyanamide.
- (e) Ammonia.
- (f) Carbon disulphide.
- (g) Artificial abrasives.
- (h) Artificial Graphite.

III. *Electro-metallurgy of metals.*

- (a) Iron and Steel.
- (b) Ferro-alloys.
- (c) Aluminium.
- (d) Magnesium.
- (e) Copper.
- (f) Zinc.

IV. *Electro-plating.*

V. *General.*

- (a) Storage batteries.
- (b) Dry cells.

VI. *Organic Chemicals.*

APPENDIX XII.

Products.	Unit of measure.	Unit of Selling Price (1).	Unit electric energy requirements (2).	Ratio of electric energy cost to selling price of finished product at selected unit costs—percent.												Energy costs of representative producers.	
				Average unit cost of energy in cents per kilowatt-hour.													
				0-1	0-2	0-25	0-3	0-35	0-4	0-5	0-6	0-7	0-8	0-9	1-0		
<i>Electrolytic</i>				KWH													Cents per KWH(3)
Aluminium	Short Ton . . . .	406-00	23-988	6-0	12-0	15-0	18-0	21-0	24-0	30-0	36-0	42-0	48-0	54-0	60-0		
Copper (electrolytic leaching)	Do. . . . .	220-00	2,820	1-3	2-6	3-2	3-8	4-5	5-1	6-4	7-7	9-0	10-3	11-5	12-8	0.65	
Copper (electrolytic refining)	Do. . . . .	220-00	367	0-2	0-3	0-4	0-5	0-6	0-7	0-8	1-0	1-2	1-3	1-5	1-7	0.70	
Zinc	Do. . . . .	100-00	3,714	3-7	7-4	9-3	11-1	13-0	14-9	18-6	22-3	26-0	29-7	33-4	37-1	0.25,0.	
Magnesium	Do. . . . .	600-00	20,000	3-3	6-7	8-3	10-0	11-7	13-3	16-7	20-0	23-3	26-7	30-0	33-3	(3)	
Sodium (metallic)	Short ton of metallic sodium and 3083 lbs. of chlorine	(5)	(4)														
Chlorine and caustic soda	Short ton of caustic soda and 1770 lbs. of chlorine .	376-28	14,400	3-8	7-7	9-6	11-5	13-4	15-3	19-1	23-0	26-8	30-6	34-4	38-3	0.35	
		(6)	3,009	2-8	5-5	6-9	8-3	9-6	11-0	13-8	16-5	19-3	22-1	24-8	27-6	0.35	
<i>Electro-thermal</i>																	
Ferromanganese . . . .	80% Long ton . . . .	102-50	(4) 7,280	7-1	14-2	17-8	21-3	24-9	28-4	35-5	42-6	49-7	56-8	63-9	71-0	(3)	
Ferrosilicon	50% do. . . . .	69-50	(4) 6,160	8-9	17-7	22-2	26-6	31-0	35-5	44-3	53-2	62-0	70-9	80-0	88-6	0.3,0.5	
Fused alumina . . . .	Short ton . . . .	56-04	3,143	5-6	11-2	14-0	16-8	19-6	22-4	28-0	33-7	39-3	44-9	50-5	56-1	0.35	
Silicon carbide	Do. . . . .	72-03	(7) 9,380	12-9	25-7	32-2	38-6	45-0	51-4	64-3	77-2	90-0	102-9	115-8	128-6	0-3	
Calcium carbide	Do. . . . .	100-00	3,150	3-2	6-3	7-9	9-4	11-0	12-6	15-8	18-9	22-0	25-2	28-4	31-5	0-3	
Anhydrous ammonia	Do. . . . .	90-00	1,530	1-7	3-4	4-2	5-1	6-0	6-8	8-5	10-2	11-9	13-6	15-3	17-0	0.3-0-	

- (1) Represents manufacturer's prices as of January 3, 1938 from prices published by the Oil Paint and Drug Reporter, Engineering and Mining Journal, and Industrial and Engineering Chemistry except as noted.
- (2) Represents all energy directly chargeable to each product for the operation specified, including electrolytic, electrothermal, motor; lighting and incidental loads.
- (3) Representative data are not available.
- (4) Represents energy directly chargeable to process only.
- (5) Based on a price of 15.5 cents per pound for metallic sodium and 2.15 cents per pound for chlorine.
- (6) Based on a price of 2.7 cents per pound for caustic soda (76 per cent solid) and 2.15 cent per pound of chlorine.
- (7) Average value of United States and Canadian production of crude material during 1936, from data published by the U.S. Bureau of

## APPENDIX VIII.

Note on the Pidgeon Process of Mg. production at the works of Dominion Magnesium Co., Haloy, Ontario.

For plant yielding 14.3 tons of distilled Mg. per day, the quantities of materials required to make a ton of distilled metal are as under:—

Raw Dolomite . . . . .	9.3 tons
or Calcined Dolomite . . . . .	4.9 "
Ferro Silicon . . . . .	1.06 "
Fluor Spar . . . . .	0.17 "
Coal for calcining dolomite . . . . .	1.7 "
Power required per ton distilled metal :	
Heating retorts . . . . .	11,000 K.W.H.
Manufacture of ferro-silicon . . . . .	10,700 K.W.H.
Total . . . . .	<u>21,700 K.W.H.</u>

The loss on melting distilled metal appears to be in the order of 1 per cent. owing to some fine powder being discarded.

The ferro-silicon contains on the average 76.5 per cent. silicon.

The dolomite used has the following analysis:—

Raw	MgO	22.2%	Calcined	MgO	40.5%
	CaO	30.1%		CaO	58.1%
	R <sub>2</sub> O <sub>3</sub>	0.2%		R <sub>2</sub> O <sub>3</sub>	0.8%
	Insol	0.3%		Insol	0.6%

Ratio of dolomite to ferro-silicon:

If theoretical proportion used, yield of Mg is 60 per cent.

If ferro-silicon is 20 per cent. in excess of theoretical needs, yield of Mg is 84 per cent.

Actually about 18—20 per cent. ferro-silicon in excess of theoretical needs is used.

*Preparation of materials:*

Dolomite ground—so that . . . . .	60% passed 200 mesh
Ferro-silicon crushed—so that . . . . .	all passed 55 mesh
Fluorpar (as bought)—so that . . . . .	80 % passed 200 mesh

## APPENDIX XIV.

## EQUIPMENT FOR ELECTRO-CHEMICAL INDUSTRY.

Items of equipment required in the electro-chemical industry may be classified as follows:—

- (1) Transformers for furnace and for rotary convertors.
- (2) Motor generators, rotary convertors and rectifiers for electrolytic works.
- (3) Switchgear and metering equipment for control of the above (including equipment for measurement of temperature; pressure and high voltages).
- (4) Electrodes and electrode mechanisms (graphite, carbon and self-baking types, for all electro-chemical processes).
- (5) Furnaces: Arc, resistance and induction type.
- (6) Materials for the manufacture of furnace and electrolytic cells, refractories for linings, operating mechanisms and elements.

In the following paragraphs will be described the range of capacity of the items mentioned above. Such of these that can be manufactured in India in the immediate future will have to be selected from those

(1) *Transformers.*—The design of transformers differs according to the various applications as noted below and should be properly selected.

(a) For steel furnaces they may be 3 phase and 500 to 5,000 KVA oil-immersed with secondary voltage taps rating 250—235—205—175—118 with on load or off load tap changing gear. Primary voltages may be 11,000 volts, 6,600 volts or 3,300 volts according to the nature of the supply available in a particular locality. The tabular statement of the capacities for various sizes of steel furnaces is noted below:—

Dia.	Normal charge.	Transformer rating.
4 ft.	800—1,000 lbs.	250—350 KVA.
5 ft.	1,500—2,000 lbs.	500—750 KVA.
6 ft.	3,000—4,000 lbs.	750—1,000 KVA.
7 ft.	5,000—6,000 lbs.	1,000—1,500 KVA.
8 ft.	7,000—9,000 lbs.	1,500—2,000 KVA.
9 ft.	10,000—12,000 lbs.	2,000—3,000 KVA.
10 ft.	16,000—20,000 lbs.	2,500—3,000 KVA.

(b) For ferro-alloys such as ferro-silicon and ferro-chrome. the size of the transformers ranges from 2,500 to 10,000 KVA and the secondary rating will be 140|130|120|110|100|80 (open circuit and the primary voltage will be 11,000, 6,600 or 3,300 depending upon the locality).

(c) For carbide furnaces, the transformers will be slightly different in tapping arrangement and the sizes range from 5,000 to 10,000 KVA. Three phase transformers can be used for ranges upto 5,000 KVA and above that single phase transformers are preferable. Secondary volts are 150|144|138|126|114 volts.

(d) For graphite and carborundum; single phase transformers ranging from 1,000 to 2,000 KVA would be required. The initial

low tension voltage will have to be about 220 and capable of being adjusted down to about 75 volts in steps of about 10 volts from beginning of operation to the end of the run.

(e) Special transformers for rotary converters and rectifiers are required.

The smaller size transformers can be manufactured in India in one of the existing transformer factories. The windings for the transformers may be made locally, as the Indian Cable Co. can supply the copper wire or strips. Stamping from alloy steel plates may be obtained from the Tata Iron & Steel Co.

(2) *Motor generators, etc., for electrolytic work.*—For plants engaged in electro-plating and electro-winning work, small motor generator sets upto 100 KW with D.C. voltage ranging from 30 to 220 volts would be required. The motors would normally be squirrel cage type and generator of the Standard Types. These motor generators may be constructed in the motor works in India.

For large scale plants such as alkali-chlorine and hydrogen manufacture, equipment ranging from 5,000 to 10,000 amperes would be required and the machinery will be of the order of 3,000 to 4,000 KW. The power supply may be from motor generator sets, the motor being of the synchronous type and with a voltage of 3,300 volts. Rotary converters will also work satisfactorily and will probably be slightly lower in initial cost. For large size machines, it may not be possible to obtain all the necessary equipment in India, but the major items can be made locally.

Mercury arc rectifiers of about 500 and above volts are satisfactory for large plants of electrolytic work. With the present trend of development of vacuum type equipment, the possibility of its manufacture in India needs careful examination.

(3) *Switchgear and metering equipment.*—Switchgear for the transformers and motor generator sets will all be of the standard type. The larger sizes will have to be imported for some time more. But several firms in India are already manufacturing the small size equipment and will be able to supply the needs of the electro-chemical industry to a certain extent.

They will consist of :

- (1) Oil circuit breakers.
- (2) Disconnecting switches.
- (3) Fuse-gear.
- (4) Bus bars and supports.
- (5) Switchboard panels with meters, relays, etc.

(4) *Electrodes.*—This is a very important item which is needed in large quantities by the existing industries and will be required in large quantities as extensions are carried out. There is a small factory in Travancore to manufacture graphite electrodes and similar plants may be started in Northern India. The graphite electrodes have got current carrying capacities varying from 500 to 30,000 amperes according to the

diameter, as per the scale of current capacity noted below. The raw materials for electrodes are anthracite coal and petroleum coke. For binding purposes, tar or hard and soft pitch are necessary.

Sizes and current capacities are noted below:—

	Graphite.	Carbon (Amp.)
2"	600/1,000 Amps	
4"	1,800/3,000 "	
6"	3,100/5,400 "	
8"	5,500/9,000 "	2,000/3,000 Amps.
10"	7,800/12,500 "	3,000/4,800 "
12"	11,300/17,000 "	
14"	15,400/21,500 "	5,400/8,500 "
16"	20,100/26,100 "	
18"	25,500/30,500 "	
20"	28,300/34,600 "	11,000/17,300 "
24"		5,800/24,800 "
30"		24,700/35,300 "
40"		37,700/50,200 "

(5) *Furnaces: Arc, resistance and Induction Types.*—The following types of furnaces would be required:—

(a) Register type using either carbon plates or carborundum rods or resistor wires.

(b) Carborundum and graphite furnaces are of the simple combined resistor type and all their materials are available in India and the designs are very simple. The graphite electrodes have to be of large sizes and could be manufactured locally. The capacity of the furnaces will be ranging from 1,000 to 2,500 KVA and they are very simple in operation.

(c) Special types of tunnel kilns would be required for porcelain, enamel and glass manufacture. The designs are simple and the materials for construction can be locally obtained.

(d) Arc furnaces of 3 phase type are required for ferro-alloys, steel manufacture and carbide production. The furnace capacities are noted below.

3 Phase furnaces for ferro-alloys and steels.

Chamber will be a steel bowl with a refractory lining. In steel furnaces, roof is removable, dome shape refractory structure carried on steel roof ring. Temperature around 1600°C. Design-Holding capacity shell Dia. Pouring capacity melting rate, are to be worked out.

Single phase furnaces used for Non-ferrous alloys (docking type). Ranges in 25|100. 250|600 KW sizes.

80 to 7,000 lbs. capacity. (Two vertical electrode types are also used).



(e) *Induction furnaces.*—Induction furnaces of the standard and also high frequency type are going to be in use as metallurgical developments improve. Standard frequency furnaces range from 50 to 200 KW with a voltage rating on the primary side of 220, 440 or 550. The construction is simple and the windings are of the transformer type. The lining is made of insulating bricks and with the binding materials of cement. For larger sizes upto 2 tons 3 phase furnaces would be necessary.

High frequency furnaces ranging from 400 to 1,200 cycles are built in 500 to 100 KW units. The voltage rating would be about 500 to 2,000 volts, but the majority of them operate at about 600 volts and 1,000 cycles. The equipment for producing the high frequency, consists of either spark gap type which can be easily constructed locally, using some of the special items imported from abroad. For large sizes, special motor generator sets upto 300 KW are required.

(6) *Materials for the manufacture of furnaces and electrolytic cells, refractories for linings, operating mechanisms and elements.*—(a) The shells are to be specially designed. Furnaces of 2,000 KVA would be the usual for ordinary requirements, but in special cases, furnaces of 10,000 KVA may be necessary. In South India, as production of pig iron in electric furnaces is being contemplated, furnaces of 12,000 KW are being designed. The designs are simple, the materials for the furnaces can be obtained locally and electrode holders, regulating mechanism and the relay equipment could also be made in the country. However, in the beginning, the relay equipment will have to be imported.

For small size furnaces for non-ferrous metal work, single phase furnaces of the rotary type ranging from 25 to 600 KW would be required with a capacity of quarter of a ton to 3 tons. Most of these can be manufactured locally and arrangements should be made for immediate investigations therefor.

(b) In the electrolytic industry, alkali chlorine cells of various types are in use in the country and if suitable arrangements can be made with the patentees, most of the cells can be built locally. The important types are: (i) Vorce cylindrical type, (ii) Billiter, Bell jar type, (iii) Allen Moore, and Nelson rectangular type and (iv) Mercury type. Items (i) and (ii) would require stoneware containers, whereas, items (iii) and (iv) would require cement and asbestos materials. The cathodes can be built of steel plate and the anodes of graphite electrodes.

(c) For hydrogen and oxygen production, several standard types are in use in the country, *viz.*, steel tank type, and filter press type. The steel containers are easily built and the electrodes and diaphragms can be made locally.

(d) *Refractories.*—Most of the refractories used in furnace could be manufactured in India including silica, chromite and carborundum bricks whichever is suited to the particular requirements. Refractory bricks are being manufactured in Bengal, South India, C.P. and Bombay, as all the required raw materials are available. The possibility of making special refractories should be investigated.

*Conclusion.*—It seems possible to make a start on the manufacture of small size transformers and motor generator sets, the transformers ranging in size 100 to 3,000 KVA and the motor generator sizes from 100 to 500 KW. It is understood that two factories are already manufacturing transformers, motors and generators, and a third one is likely to start operation. These firms should be in a position to make the required machinery for electro-chemical work. The insulation materials, wires, cables for windings for the machines will have to be obtained from the Indian Cable Co., and the stampings for the core of transformers and machines from the Tata Iron & Steel Co. The lamp and glass factories may take up the manufacture of rectifiers on a small scale and develop bigger units. Steel rectifiers are covered by special patents but they can be worked out by arrangements with the patentees.

As already mentioned, all electrodes, furnaces and refractory lining materials could be made locally.

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