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Report by the Salt Commissioner to the Honourable Minister for Industries, Industrial Research and Fisheries upon the Potentialities of the Salt Industry in Ceylon

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REPORT BY THE SALT COMMISSIONER TO THE HONOURABLE MINISTER FOR INDUSTRIES, INDUSTRIAL RESEARCH AND FISHERIES UPON THE POTENTIALITIES OF THE SALT INDUSTRY IN CEYLON.

(A) General.

1. *The Problem.*—It has to be decided, after very careful consideration, whether Ceylon is to continue with the present out-of-date methods of salt production, or to adopt modern processes, with the object of producing very valuable by-products in addition to salt. The transfer to a modern organization will require a very heavy initial outlay, although it is anticipated that the more economic results will justify the expense. In order to define clearly the factors involved in the proposal to modernize the Salt Industry, the following monograph has been prepared, in which calculated effort has been made to reconcile the technical aspect of the complicated problem with the non-technical requirements of the far more numerous laymen who will be interested.

2. *The Sea.*—The sea is an inexhaustible reservoir of several products, having great commercial value, such as common salt, magnesium compounds, gypsum, potash, &c. Statistical data on the point are quoted in Appendices I and II attached. Using these primary products as base material, and employing other readily-available substances as ancillaries, many more valuable products can be obtained by recognized chemical processes. Unfortunately, the concentration of salts in the sea is comparatively small (about 3.5 %), and they are not always easily separable. The exploitation of sea water for the economical manufacture of products having commercial value depends primarily on:—

(*a*) availability of seabrine; and

(*b*) cheap means of concentrating it.

Obviously only coastal areas have ready access to seabrine. Further, it is uneconomical to concentrate seawater by the use of " dead fuel ", while biological processes are far too slow and cumbersome for present-day technique. The sun and wind are natural agencies which promote the concentration, while rain and cold have the opposite effect. While commercial solar evaporation (for concentration) cannot be had altogether free of cost (because of the machinery and structures necessary for control), nevertheless the operating costs are so much less than in the case of artificial evaporation, that under favourable conditions the costs of solar evaporation can be regarded as comparatively negligible. Sunshine, heat, strong winds, and prolonged droughts are more and more marked towards the tropics, and it is the tropical countries therefore which can make most use of natural agencies on which to found a salt industry capable of competing in the open market with countries more highly industrialized, but having to pay hard cash for the initial concentration processes which are essential. Few countries in the world make full use of solar evaporation because the effect is negligible in temperate climates while industry is backward in the tropics. The south-western states of the U. S. A., have, however, made great progress in recent years in the use of solar evaporation, and it is to these areas that we must look for most guidance in this field. It may be mentioned at this stage that as the brine becomes more and more concentrated its value rapidly increases so that at a certain point artificial evaporation may become more economical than solar evaporation, despite higher capital costs, owing to the overhead on idle machinery and personnel, and risks of loss of strong brine by rain, under solar evaporation.

3. *The Coast Line.*—Ceylon is a small Island, and therefore possesses a long coast line compared to its area. It is also situated in the tropics within the monsoonal belt, so that bright sunshine, heat, strong dry winds, and droughts, are prevalent. The topography is such as to afford very large extents of flat clayey lands on the coast line, eminently suited for solar evaporation, while the central mountainous massif collects sufficient rainfall for all the needs of water and hydro-electricity of a modern chemical industry. Almost three-fourths of Ceylon is uncultivated land of very little value, so that large extents are available at low cost. All these factors would help Ceylon considerably in competition against other countries industrially more advanced than Ceylon, but deficient in these natural advantages.

4. *Salt Making. Ceylon's Advantages.*—Additional factors contributing to the strength of a Ceylon salt industry are the following:—

(*a*) the availability of ready-made markets in the neighbourhood, from which large quantities of various commodities (chiefly food-stuffs) are imported into Ceylon. This would enable a practically self-contained cargo boat system to be maintained, and thus freight costs to be greatly reduced both for exports of saltern products as well as imports of foodstuffs in the reverse direction;

(*b*) the long freight haul from countries supplying the large quantities of inorganic fertilisers needed for the Ceylon plantations. The freight cost is so much subsidy to a local industry producing potash fertiliser;

(*c*) the precarious dependence of Ceylon on three plantation products of rapidly diminishing value, and hence the urgent need to establish chemical and manufacturing industries to restore the balance;

(*d*) the development of industries like cement manufacture, buildings, &c., which creates an increasing demand for products which could be economically manufactured in a seabrine industry.

5. *The Modernized Method.*—Conditions are therefore very propitious for the establishment of a large scale chemicals manufacturing industry in Ceylon, based on seawater. A small industry has existed for hundreds of years, but the methods are most primitive, the output insignificant, the only produce common salt, and the quality very poor. This local manufacture of a crude salt can hardly be dignified by the description of " industry ". Up till 1931, vested interests continuously and successfully prevented any worth-while development of the industry. In the period 1936-1940, an attempt was made to create a co-ordinated industry in Ceylon, but the direction was almost entirely deficient in technical knowledge, and the attempt was a failure. Besides, it was only the last ten or twelve years which saw a technical development all-important for the success of a modern industry, namely, the effective filtration of magnesia; and also created a huge demand for magnesia. It can now be definitely stated that the processes devised will work successfully in practice. Whether they would be economic in Ceylon is another matter entirely, so important as to demand special discussion. The immediate necessity for the full-scale development of the industry in Ceylon is the demand by the Cement Factory for about 5,000 tons of gypsum, and by the Agricultural Department for 50-60,000 tons of potash fertiliser annually. Both these can be easily produced in a modern seabrine industry, but the scale of the latter will be about 50 times the scale of the former, and the first question to be decided when the economics of the scheme are taken up for consideration is which scale is to be applied. For reasons which will be detailed below, the scale once chosen will not be capable of expansion in the foreseeable future, and if the smaller scheme only is sanctioned, it would be so much dead loss when the scheme comes to be expanded. Besides, the strength of the scheme

will be reduced far more than in proportion if the smaller scale is adopted, as certain ancillaries become economic possibilities only with the larger scale scheme.

(B) TECHNICAL CONSIDERATIONS.

6. *Salinity of the Sea.*—While the gross salinity of the sea may vary from place to place, the relative proportion of the various constituents is remarkably uniform. Appendix I contains most of the relevant statistics on the point. While no complete analyses of seawater seem to have ever been done in Ceylon or India, the vast amount of data collected over many years of oceanographic expeditions is amply sufficient to take the average quoted salinities for the Bay of Bengal as applying to any part of the coast line of Ceylon. There are bound to be minor variations, but they cannot be at all significant, at any rate, to decide whether the scheme is to be taken up or not. Once a favourable decision has been taken, accurate analyses can be made, if only to decide exactly what quantities of various raw materials would be needed.

7. *Solar Evaporation.*—Under the present system of salt manufacture in countries adopting the solar evaporation system (Ceylon, India, Italy, France, Spain, Mexico, U. S. A., &c.), seabrine is taken into a saltern (or salt factory) and simply exposed in successive stages to the evaporative effect of sun and wind. Nothing is done to remove any constituents hindering the process. The result is that evaporation is slowed down, the output reduced, and the quality of salt impaired. No improvement was possible so long as the filtration of magnesia was so difficult, and the market for the magnesia so very limited. Now that these two obstacles no longer exist, the time-honoured method has become obsolete, but no doubt natural inertia and momentum will permit the system to continue for some time longer till economic considerations kill it finally. Nevertheless, in view of its historical importance, the present practice deserves brief mention. Appendix II reproduces analytical figures collected 100 years ago (but still the standard work on the subject) showing succintly what happens when sea water is allowed to evaporate at normal air temperatures. In easier language, on progressive evaporation, the following stages are clearly distinguishable:—

(*a*) separation of iron rust and chalk as a slimy mud;

(*b*) separation of hydrated calcium sulphate (gypsum);

(*c*) separation of fairly pure common salt;

(*d*) separation of common salt with larger and larger content of various impurities;

(*e*) a liquid residue no longer evaporable by solar agency.

After about two-thirds of the salt in the brine has separated, the process becomes more and more complicated, the products more and more impure, and the resultant affected to greater and greater extents by small variations in external conditions. Hence it is usual to discard the brine at this stage, and start again with fresh brine.

8. *Magnesium.*—The most troublesome constituent of the brine is the magnesium portion. The existence of this substance not only retards the rate of evaporation, but it also contaminates the salt produced, and introduces serious corrosion problems. It is quite easy to cause the magnesium to separate as the oxide (magnesia) or carbonate by the addition of an alkali (lime, soda ash, and caustic soda are the only practicable alkalis), but immense difficulties were encountered in effectively removing the magnesia, which exists as a pasty, slimy jelly, quickly clogging up any filters used. Recently, however, processes have been worked out, chiefly in the U. S. A., which enables filtration to be done at economic cost. However, it must be observed here that during the War a " successful " process did not necessarily mean an economically successful process, and that several plants in the U. S. A., and the U.K., had to close down after the War. Whether this was due to technical difficulties or to other

considerations (political or commercial) is not known, but the fact that the world's biggest producer of magnesium, and the U. S. A., Government plants, still continue to obtain their requirements of magnesia from sea water should be sufficient to establish that the scheme is technically feasible under peacetime conditions (*i.e.*, at economic cost). Anyhow, this is the first point which will be completely verified. According to the most recent authorities (*e.g.*, Armstrong and Miall—Raw Materials from the Sea) this process is actually the most economic under present-day conditions. In reference to the production of magnesium, these authors say—

> "it would appear that the electrolytic process based on seawater or brine has the best chance of existing after the war demand has ceased."

9. *The Alkali.*—Now, all the magnesium can be removed by the addition of lime, which is a very cheap source of alkali. But this would mean that the magnesium in solution is merely replaced by calcium. A part of this calcium will be removed in due course by combination with the sulphate in solution, but the rest would remain, and therefore the same objections as to the presence of magnesium in the brine would continue to exist though of course to a lesser extent. Hence it is necessary that only enough lime must be used to combine with the sulphate and disappear from the brine by the time it has become saturated with common salt. The rest of the alkali needed must be added in the form of caustic soda, the only product of which is common salt again. Chemically, the reaction is almost exactly the same, but caustic soda in Ceylon is over ten times as costly as lime, and the entire success of the scheme depends on whether caustic soda can be produced on site at a sufficiently low cost. The point is so important that it requires separate discussion.

The chemical reactions described are more simply expressed as follows:—

$$Mg^{\cdot\cdot} + 2OH' + XH_2O — Mg(OH)_2 \cdot XH_2O$$
$$Ca^{\cdot\cdot} + SO_4'' + 2H_2O — CaSO_4 \cdot 2H_2O$$
$$MgSO_4 + Ca(OH)_2 + (X + 2)H_2O — Mg(OH)_2 \cdot XH_2O + CaSO_4 \cdot 2H_2O$$
$$MgCl_2 + 2NaOH + XH_2O — Mg(OH)_2 \cdot XH_2O + 2NaCl.$$

The use of soda ash is not discussed here as its manufacture is more complicated, and its use in the process is costlier and attended with more difficulties than in the case of caustic soda.

10. *Alkali Treatment.*—The actual treatment of the brine with alkali is really a matter of detail which it is unnecessary to discuss in this memorandum. The tentative flowsheet (Appendix IIIA) shows what appears to be the best process, but it can be altered, even radically if necessary, without affecting costs very much as the principle would remain unaltered.

The working of the scheme is briefly as follows:—

(*a*) Raw seawater which is slightly alkaline (pH 7.8—8.8) is treated with a small quantity of alkali to rid it of its bicarbonates and iron. The reactions are as follows:—

$$HCO_3' + OH' — CO_3'' + H_2O$$
$$Ca^{\cdot\cdot} + CO_3'' — CaCO_3$$
$$Fe^{\cdot\cdot\cdot} + 3OH' — Fe(OH)_3$$

The normal practice is to use lime for this dosing as it is very cheap. But in Ceylon lime is likely to be costlier than the wet magnesia precipitate, so the scheme also envisages the use of the magnesia slime to increase the alkalinity of the brine. The magnesia is likely to be more effective than lime as it would be in a more reactive state. If magnesia is used in this preliminary stage, of course a correspondingly larger quantity of lime will have to be used at a later stage.

(*b*) The slightly alkaline brine is then treated with an alkali containing both lime and caustic soda, the first to react with the magnesium sulphate content of the brine, and the caustic soda to precipitate the remainder of the magnesia. The reactions may be written simply thus:—

$$MgSO_4 + Ca(OH)_2 \quad - Mg(OH)_2 + CaSO_4$$
$$MgCl_2 + 2NaOH \quad - Mg(OH)_2 + 2NaCl$$

The reason for not using lime exclusively has been explained before.

(*c*) The alkali treatment results in the immediate precipitation of magnesium hydroxide, which is filtered off. The brine is then exposed in open ponds to solar evaporation in at least three successive stages. In these ponds gypsum forms, the middle ponds collecting the largest deposits, as seen from the graph in Appendix IV. Even under the present system quite good gypsum is collected annually from salterns at economic cost. When the quantity is increased three-fold, and the ponds worked on a cycle of years, the collection should prove very profitable. This graph also show that at the stage when salt just begins to form, the brine contains only a very small quantity of gypsum left. But even this quantity is objectionable for use in diaphragm caustic electrolysers or in vacuum evaporators, though its presence would not matter in solar manufacture of salt. For electrolyser and evaporator purposes, therefore, the brine is teated with soda ash (cell liquor and carbon dioxide may form a much cheaper equivalent) to remove calcium, and barium carbonate to remove the sulphate. Barium carbonate alone can be used to effect both objects if it is cheap enough. Doubtless synthetic resins could soon be manufactured to perform these functions at cheaper cost.

(*d*) The brine so treated is suitable for boiling down in vacuum evaporators, but for the electrolyser stage yet another purification is required, to remove the bromine and iodine. This is done by chlorinating the hot acidified brine and drawing off the vapours, whch are then dealt with in the separate de-brominating stage. The purified brine is freed of its surplus chlorine in flash vacuum pans followed by a hot air blast and is then suitable for electrolysis. Only about half the brine need be so treated, but of course it comes back into circulation after passing the electrolysers.

(*e*) At this stage, then, the untreated brine is saturated with respect to common salt, and contains appreciable amounts of potash, bromine and borax. First about 95 per cent. of the salt is removed. This can be done either in solar pans or in vacuum evaporators run on artificial heat. The quantity involved is very large, and if all the salt is marketable, in the long run the artificial heat process is the more economical and easier to work. On the other hand, if the salt is not marketable, then it would be sheer waste to boil down all the brine for the sake of the potash. The common salt *must* eventually be sold if the scheme is to be fully successful, but the establishment of markets might take some time and entail some losses in the initial stages. The final scheme must therefore include the costs of the full vacuum evaporator capacity needed for boiling down all the brine, but provision could be made for solar evaporation in the first instance, being gradually replaced by vacuum pans over a period of years. This would also enable very considerable savings of initial cost to be made, if necessary.

(*f*) The residual brine would contain about equal parts of common salt and potash, appreciable quantities of bromine and borax, very small quantities of iodine, and traces of many elements of minor importance. The methods of working up a brine of this nature have been thoroughly established over several decades in Germany, France, the U.S.A., &c., and are now standard practice, so that it would be needless to load this preliminary note with complicated technical detail on the point. It should suffice to say that a value can be placed on this brine, and the economics assessed on this basis.

(C) Engineering Considerations.

11. *Solar Salterns.*—A separate memorandum treats in complete detail the requisites of a solar saltern, and it is needless to recapitulate the particulars here. The principal requirement is a sufficiently large extent of coastal flat land in the arid zone at or near sea level, with a clayey impervious soil pan, suitably oriented with respect to wind directions. This land has to be divided into six or eight main areas by earthen bunds for the retention of the brine in the successive stages. A supply channel or creek should be available always open to the sea. Such land is available in Ceylon and the precise location of the plant will be discussed in the proper place.

12. *Chemical Engineering Requirements.*—The chemical engineering requirements are:—

(*a*) lime kiln, hydrator, doser, and accessories;

(*b*) caustic soda plant;

(*c*) batteries of vacuum evaporators, refrigerators, crystallisers, &c.;

(*d*) filters, dryers, calciners, &c.;

(*e*) the other auxiliaries of a chemicals factory.

All these are standardized equipment, only the estimated cost of which is material at the present stage. Similarly with the buildings, water supply schemes, pumping plants, transport organization, research, repair and maintenance, &c.

13. *Fuel.*—one matter is of great importance—the question of fuel and power, shown diagrammatically in Appendix IIIb. As regards the first, Ceylon has no resources of coal or oil, and if an indigenous fuel is required, special wood-fuel plantations must be established. Provision is made accordingly, but in the initial stages there would be almost complete dependence on imported coke and oil. It would be premature to discuss the conversion to wood fuel, and costs are therefore based on imported oil as standard. After the conversion, the cost would probably be reduced appreciably.

14. *Power.*—Power is very important, being the principal deciding factor in the cost of caustic soda. If the scheme is established at Hambantota, there is very large hydro-electric potential about 40 miles away, simply crying out for development. Locations are shown in the map annexed—Appendix VIIIb. There are six or seven possible schemes with a drop of up to 700 feet each, available in very favourable locations, whose flood-plains are fertile lands, with a gentle gradient eminently suited for cultivation. Much of the cost of the hydro-electric scheme will be met by the value of the irrigation water, another part by the 30 miles of waterway communication each, still another part by the domestic water supply requirements, and only the rest of the cost need be met by the electrical generator. Naturally there will be a thermal station too, as large quantities of steam will anyway be required for the vacuum evaporators. Consequently, the costs of the power scheme should be quite satisfactorily low. However, since the other available sites do not have such excellent facilities, and since the site cannot be decided till the scheme has advanced considerably further, the costs are calculated at the highest rate—namely, on imported fuel oil.

15. *Cost.*—Many of the processes involved are standard, and no detailed description of machinery is required to arrive at the approximate cost of the final products in Ceylon. It should therefore be sufficient to state merely the cost of the product, without going into how the cost was worked out. Anyone who wants to check the figures, can do so if certain basic costs such as land values, wage levels, freight and power costs, &c., are quoted, for this would enable a maximum cost to be evaluated, based on export from the United Kingdom, and installation in Ceylon. Appendix V contains a few of the basic data required for the purpose, and no further details of calculation will therefore be given. Some costs depend on the location of the plant, but the variation

cannot be large. It is therefore proposed to treat the scheme as if it was located at Hambantota. Departures in either direction, if the location is elsewhere, can easily be worked out in respect of each item of cost.

16. *Annual Return.*—Before proceeding to the costs of the scheme it would be well to have an idea of the annual return, which is obviously a ceiling overall cost of an economic scheme, excluding self-sufficient ancillaries like generation of power, transport of produce, marketing, &c., and also taking no credit for intangible benefits such as creation of employment, increasing value of land, water and other natural resources, soil conservation, forest development, improving the health of the locality, &c., all of which are of immense value, but which it is difficult to estimate in terms of money. Appendix VI gives a statement of the quantity of various products and their ex-factory values. It is seen from this statement that a gross aggregate *income* may be expected as follows:—

		Rs. (Millions.)
(i) produce for which guaranteed markets exists in Ceylon	..	8·5
(ii) produce for which definite export markets exist	..	39·5
(iii) produce which will have to be sold in open world competition		17·0
Total	..	65·0

Excluding the last item as being somewhat uncertain, there is every prospect of an annual return of Rs. 48 millions, and it should be perfectly safe to incur up to this amount in the scheme. The limit of Rs. 48 millions will, of course, include the annual value of capital expenditure. There is ample margin in the last item for profits over and above those which may be reasonably expected from any industrial undertaking. The intangible benefits are purely local and would therefore be of no interest to any foreign shareholder, but to the Ceylon Government they should be added attractions.

17. *Markets.*—It must be pointed out, however, that while under item (ii) above markets are definitely known to exist and that the Ceylon produce can easily hold its own in these markets if the competition is free, the actual availability of those markets would generally be decided at political levels. While there is little reason to anticipate that the Governments of those territories would discriminate against Ceylon in view of the produce of those countries being taken in exchange, nevertheless it would be distinctly advisable to make doubly certain of co-operation by offering those Governments a direct financial interest in the enterprise. This point is discussed in a succeeding paragraph.

18. *Method of Calculation.*—While it was my intention to avoid overloading this paper by a mass of facts and figures, it is difficult to give a clear appreciation of the scheme without actually quoting figures. There follows, therefore, a discussion of the calculations involved. Naturally, in a scheme of this magnitude, the calculations are purely theoretical, and subject to considerable revision in either direction by experts. To that extent they are tentative, but as only a general idea is needed at this stage to decide whether or not to have the scheme thoroughly examined by expert consultants, no attempt is made at any exactness in computation. What the figures are precisely likely to be, how the scheme should be modified in principle, and on which items reductions are possible to start a pilot experimental enterprise are subjects to be dealt with by the experts.

19. *Pumping.*—Roughly 20,000 million gallons of raw sea brine must enter the factory over a year to produce the full yield desired. Tidal life alone is too small in Ceylon to be dependable, and anyway the height of lift required is too much for tides alone. Hence positive pumping is required. Assuming 300 working days in a year, and 21 working hours a day, with 20 per cent. standby and wastage capacity, the pumping capacity required is roughly 65,000 gallons per minute or 160 cusecs—which is quite a moderate capacity, so far as irrigation pumping plants go. This is for the first pumping, and involves the

lifting of the brine through about 25 feet. The whole subsequent process requires transfer of brine at least six times by pumping approximately as follows:—

Point.		Density (degrees Baume).	Volume.	Pumping Head. Feet.
Sea		3.5	—	—
Pumping		—	1,000	25
Preliminary doser		—	—	—
Gravity		—	—	—
Sedimentation tank		—	—	—
Gravity		—	1,200	—
Main doser		—	—	—
Gravity		—	1,200	—
Filter		—	—	—
Gravity		3·5	1,200	—
Primary pond	Ent.	6°	700	7
Pumping	Exit.	6°	—	—
Secondary ponds	Ent.	10°	450	7
Pumping	Exit.	10°	—	—
Gypsum ponds	Ent.	20°	240	5
Pumping	Exit.	20°	—	—
Gypsum ponds	Ent.	24°	200	5
Pumping	Exit.	—	200	15
Purifier and doser		—	—	—
Gravity		—	—	—
Sedimentation tank		—	—	—
Filter		25°	200	30
Pumping		—	—	—
Storage tanks		—	—	—
Gravity		—	—	—
Vacuum evaporator		—	—	—
Electrolyser				

The total pumping power (and cost) involved is approximately double that of the first stage.

20. *Cost of Pumping.*—The costs of pumping for irrigation has been exhaustively investigated in America, and there is a mass of published data on the subject. The minimum costs are reported to be about Rs. 0.50 per million gallons per foot of lift. Although those figures are only for intermittent pumping 2 or 3 times a year, and though it was reported that technical progress was tending to reduce this minimum cost, it would be unsafe to assume less than twice this minimum figure for Ceylon. The annual cost of all pumping through the whole system would then amount to about Rs. 1½ millions inclusive of buildings, machinery, amortisation, power, salaries, fuel, &c. This is moderate compared to the other costs involved.

21. *Area of Solar Pans.*—The volume of seabrine is to be reduced by 90 per cent. in the solar pans alone. Assuming a minimum excess of evaporation over precipitation of 72 inches per working year (the figure could be considerably exceeded with proper management), roughly 14,000 acres of brine must be exposed to solar evaporation, and at least this extent of solar pans will be needed. The full extent would be divided somewhat as follows:—

	Number of Bays.	Total area Acres.
Reservoir	2	5,000
Primary Ponds	4	3,000
Secondary Ponds	6	2,000
First Gypsum Ponds	10	1,500
Second Gypsum Ponds	25	1,000
Crystallisers	100	1,500
		14,000

Assuming that strong bunds have to be built round each enclosure to a height of 8 feet above ground level (although in most of the places natural high ground exists) and with somewhat weaker internal divisions, the quantity of earthwork involved would be roughly about 600,000 cubes. The land is flat and the soil free from rocks or sandstone, so that work with machines would be very cheap. Even at present-day costs, and taking the full quantity as requiring to be done, the work cannot cost more than Rs. 1½ millions, all costs included. This being non-recurrent capital, the annual value is comparatively small.

22. *Lime.*—The next item to be considered is lime. There are deposits of shells or outcrops of limestone in large quantities within a few miles of the working sites, and the cost of the milk of lime needed should not exceed Rs. 12 per ton (calculated as CaO). The slaking, creaming and dosing proportionation may be taken to add 25 per cent. to this cost, and the total cost of dosing with lime may therefore be taken as Rs. 15 per ton, calculated as CaO. Nearly 100,000 tons lime would be needed, and the gross overall cost of the liming will therefore amount to Rs. 1½ millions per annum. As what is required is actually a mixture of lime and caustic soda, and as it is undesirable to introduce additional freshwater into the scheme, it is proposed to hydrate and slurry the lime with the caustic soda cell liquor itself. This can easily be done as cell liquor would not contain more than about 11 per cent. caustic and about 14 per cent. of salt: hence it can easily take up even 20 per cent. of lime to be held in suspension. A part of the salt might crystallize out, but this would not matter. For exact proportionation the slurry can be mixed with the proper marginal quantity of pure cell liquor.

23. *Vacuum Evaporation.*—(*a*) A word is needed about the cost of vacuum evaporation, compared to solar evaporation, starting from saturated brine containing appreciable traces of calcium sulphate. In solar evaporation, the brine need not be purified, but can be run straight into the ponds, and further, little or no expense is incurred in actually evaporating the brine, whereas if the brine is to be boiled down in vacuum evaporators, substantially all the lime sulphate must be removed by treatment with costly chemicals, and the steam needed for evaporation too will cost appreciably.

(*b*) On the other hand, some expense is incurred every year in preparing the beds of solar pans, and the cost of collecting and transporting the salt to a central storage area is comparatively very high. Besides, collection is entirely dependent on the weather, and can be done at most only during about 100 days in the year, which creates labour difficulties. The salt is also much less pure, and is therefore saleable only at a discount. Finally, the water is totally lost, whereas the vacuum evaporators would yield large quantities of water which can be sold or used within the factory.

(*c*) As for the bare costs, they can be summarized as follows, per ton per annum capacity:—

	Operation.	Solar Pans. Rs.	Vacuum Evaporators. Rs.
1.	Annual cost of preparing ground and running machinery, including capitalization, maintenance, repair and replacement ..	1·2	2·5
2.	Cost of purifying brine, storage, piping to site, &c.	0·2	1·0
3.	Cost of evaporation, including pumping, fuel, salaries, &c.	2·0	4·0
4.	Cost of collection, transport, and storage ..	2·0	0·2
5.	Miscellaneous	0·1	0·3
	Total ..	5·5	8·0
6.	Add for cost of idle storage space and over-head, and difficulty of collecting residual brine ..	1·0	0·2
7.	Add discount for impure salt	2·0	—
	Nett cost ..	8·5	8·2

According to this estimate, it is definitely more profitable to manufacture boiled salt than solar salt. However, as the capital outlay on the former is about 25 times that on the latter, and as huge quantities are involved it might be better to start off with a small capacity of steam evaporation, and on actual costing complete the steam installation over a period of years. There will be appreciable savings as the cost of machinery must drop in the next few years, and besides there is time to build up export markets. For the solar salt production, the gross capital outlay will be of the order of Rs. 2 millions or thereabouts.

24. *Caustic Soda.*—(*a*) The question of the caustic soda is all-important, as it is indispensable, and on it depends the entire success of the scheme. The Ceylon Government has already obtained a full detailed report from a professional consulting expert in the U.K., Dr. A. J. V. Underwood. This expert has carefully evaluated the costs of a small caustic soda installation with an output of 5 tons caustic daily. Essential particulars of his report are abstracted in Appendix VII. Dr. Underwood arrives at an inclusive cost of £140 for the 5 tons of pure caustic as cell liquor, and its equivalent of chlorine, and estimates the cost of the caustic alone at £14 per ton. It may be said at once that unless the cost of caustic to the saltern scheme is less than half this cost, the whole scheme would be uneconomic.

(*b*) It is shown in the Appendix that the caustic soda on the saltern need not be pure or concentrated. Further, saturated brine will be available in a directly usable form on the saltern at very low cost. Altogether, even on Dr. Underwood's conservative estimates, it is probable that sufficient quantities of caustic soda can be produced on the saltern at scarcely more than £3 per ton. This entirely economic.

(*c*) Detailed figures by another expert caustic consultant in the U.S.A., appearing in a recent issue of an American technical journal, confirm this conclusion. Particulars are also quoted in the Appendix.

25. *A Typical Plant.*—(*a*) A general description of one plant in actual operation may not be out of place here. The Dow Chemical Company of Midland, Michigan, U.S.A., started in 1917 producing magnesia from brines 1,500 feet below the ground and holding 3-4 per cent. magnesium chloride. Magnesium metal itself was first obtained direct from seawater in 1941, at the Company's factory at Freeport, Texas. The plant intake is 30 feet below the surface of the water. There are four centrifugal pumps, each with a capacity of 71,000 gallons per *minute*. 300 million gallons of brine are pumped daily into the factory (four times as much as the figures suggested for Ceylon.) The brine is treated with milk of lime prepared from oyster shells clacined in a rotary kiln 300 feet long. Five thickeners are used, each with a diameter of 150/200 feet and a depth of 18 feet. The magnesia is filtered in a plate filter 90 feet long, with 100 leaves. (The filter design has since been changed).

(*b*) It may be noted that the scheme succeeds at all because it is on a sufficiently large scale.

(*c*) Similar processes are worked by several other equally big enterprises, mostly for the U. S. A. Government-owned Defence Plant Corporation. The same process was also worked in the U.K., Germany and Japan.

26. *Capital required.*—(*a*) It is quite impossible, even for professional experts, to give any accurate idea of the eventual gross capital needed, or of the running costs of the scheme, without very exhaustive investigations, probably spread over several months. For the limited purposes of this report, however, rough estimates will be given, on the clear understanding that the estimates may be considerably out, although the order of the estimates will probably be reasonably dependable.

(*b*) *Annual Value* of all costs including interest, amortisation, construction capital, maintenance, repair, renewal, &c.

	Rs. (Millions)	Rs. (Millions)
(i) Earthworks	0·15	
(ii) Buildings, tanks, reservoirs, &c. ..	0·60	
(iii) Miscellaneous, including acquisition, compensation, land value, &c.	0·25	
		1·0

	Rs. (Millions)	Rs. (Millions)
(c) *Raw Materials*		
(i) Lime	1·5	
(ii) Caustic Soda	10·9	
(iii) Sundries	0·6	
	——	13·0
(d) *Operations*		
(i) Pumping	1·5	
(ii) Dosing and purification	2·0	
(iii) Storage, sedimentation, &c.	0·8	
(iv) Filtration	0·6	
(v) Drying, calcination, &c.	0·8	
(vi) Storage	1·8	
(vii) Packaging	2·0	
(viii) Sundries	1·0	
	——	10·5
(e) *Evaporation and Crystallization*	19·0	
(Although the annual requirement is only Rs. 13·1 for solar evaporation, the higher value, *i.e.*, for vacuum evaporation is taken as this would be the eventual cost—*vide* para 23 above).	——	19·0
(f) *Allow for Contingencies*	1·5	
	——	1·5
		45·0
Grand Total Rs. 45 millions.		——

(g) This amount is well within the Rs. 48 millions of permitted expenditure, and there is ample margin for variation. But a word of caution must again be sounded, namely, that the economics of the scheme depends on the cost of caustic soda and the sale value of the salt produced. No effort will be too much to arrive at some final reliable conclusions on these two points. It must also be remembered that the capital value of the scheme may be at least seven times the annual value, and that if the full value of self-sufficient ancillaries are taken into account, perhaps several times more.

27. *Administration.*—(a) The question of financing and administering the scheme now arises. The scheme must be managed by a semi-Governmental central authority with Government powers, but with much wider discretion in administration. It is noted that the Auditor-General himself recommends such a course for profit-earning Government undertakings.

(b) There are several key interests concerned with the working of the scheme, who may be classed as follows:—

(i) Manufacturers of machinery, including equipment for manufacture, storage, and transport of products, fuel, and power, chemical plant, &c.;

(ii) Marketing and disposals of products including shipping and trading interests;

(iii) Consumers;

(iv) Vested interests, including foreign chemical cartels;

(v) Governments.

If the scheme is to be fully successful, all these interests must be given direct inventives to promote the scheme. The best way of doing so would be to allocate shares in the concern to those interests. The Ceylon Government must retain policy control, of course but this can be effected by Ordinance or articles of association. There will be some loss of profits to Ceylon, but the sacrifice would probably be amply justified in the long run. The actual details of organization and finance will have to be dealt with at a much later stage. The structure will probably be a tight federation of interlocking, but separate affiliates, each separately financed by the interested parties.

(J) APPLICATION IN CEYLON.

28. *Solar Salt Factory.*—The general requirements of a solar salt factory has been fully discussed in a separate monograph, and details need not be repeated here. Briefly, the following are the principal requirements:—

(*a*) accessibility to sea throughout the year;
(*b*) clayey soil with bare rocky land on windward side, completely protectable against floods;
(*c*) dependable dry hot climate with strong winds and prolonged droughts;
(*d*) port facilities throughout the year;
(*e*) lime, building materials, timber, &c., in neighbourhood;
(*f*) cultivable hinterland for food production, fuel reserves, labour settlements, &c.;
(*g*) water supply and hydro-electric potential sufficiently close by;
(*h*) non-interference with established populations and vested interests;
(*j*) accessibility to the principal markets.

Appendix VIIIA is a map of Ceylon, showing the principal requisites, and whereabouts they are fulfilled. All the coastal area, excluding the south-west quadrant, fulfils the climatic conditions, but several sectors are inadmissible for one reason or another. The sites which fulfil most of the conditions are quite limited. They are:—

*(i) Puttalam
*(ii) Masar
(iii) Chundikulam
(iv) Mullaitivu
(v) Kuchchaveli
*(vi) Nilaveli
(vii) Panichankeni
(viii) Hambantota.

Each of these eight sites has something peculiarly advantageous and disadvantageous too. All things considered, the last would appear to be the best, although the climate is somewhat erratic, and the rains unseasonable compared to other parts of Ceylon. But everything else is in its favour. A map of the Hambantota area is appended (Appendix VIIIB) showing distinctly how the various requirements are met. Other specially suitable sites are the three asterisked. It is, however, pointless to discuss the pros and cons of each individual site at this stage, and the map should be sufficiently informative to enable a decision to be reached on the main point.

29. *Ceylon Costs.*—It is stressed again that the costs will be increased out of all proportion as the scale of the manufacture is reduced, and if the scheme is to be a permanent feature, it is advisable to retain the full scale of production envisaged in this report. Nevertheless, if it is desired to evaluate the probable costs of the scheme by actual practical experimentation, it should be possible to launch a pilot plant scheme on a scale, say, one-fiftieth of the final scheme. Certain capital items cannot be operated on a pilot scale at all, and costs on these items therefore cannot be reduced, but even if it eventually decided not to pursue the scheme any further, the capital expenditure on these items will not be a total loss as the major portion thereof will be of value for other nearly as useful purposes.

30. *References.*—Appendix IX contains a few of the works deserving of special reference. There are of course many more which will have to be consulted as the discussion proceeds.

E. B. TISSEVERASINGHE,
Acting Salt Commissioner.

Colombo, March 10, 1948.

APPENDIX Ia.

Composition of Brines from various Oceans of the World.

	Challenger.			Dow Co.		Ratton.
	I.	II.	III.	IV.		
Calcium Carbonate	0·0090	0·0112	0·0012	0·0038	0·0178	?
Calcium Sulphate	0·1211	0·1371	0·1189	0·1365	0·1268	0·136
Sodium Chloride	2·5685	2·9078	3·1239	2·7919	2·7319	2·606
Magnesium Sulphate	0·2039	0·2309	0·2751	0·2256	0·2537	0·182
Magnesium Chloride	0·3244	0·3673	0·3849	0·3337	0·3307	0·281
Potassium Chloride	0·0640	0·0725	0·0690	0·0533	0·0793	0·120
Potassium Bromide	0·0024	0·0090	0·0075	0·0067	0·0076	?
Others	0·0010	0·0011	0·0048	0·0028	0·0083	?
Total.	3·2943	3·7369	3·9853	3·5533	3·5561	3·325+
	A	B	C	D	E	F

A & B Average analysis of ocean brines (weighted mean of 77 analyses).
C Red Sea (middle).
D Indian Ocean (mean of two analyses) (Clarke—Data of Geochemistry 4th Edition (1916), page 123).
E Analysis of Marine Chemicals Co., South San Francisco. (Ind. Eng. Chem. *28* (1936) 383).
F Bay of Bengal (Ratton—Handbook of Common Salt (1882), page 58).

APPENDIX Ib.

Ceylon Seabrine.

The following results may be taken as representative of an average Ceylon seabrine free of organic matter and suspended solids:—

Cations.	%	Anions.	%
Sodium, $Na^{\cdot}$	30·40	Chloride, Cl'	55·20
Magnesium, $Mg^{\cdot\cdot}$	3·70	Sulphate, SO_4''	7·70
Calcium, $Ca^{\cdot\cdot}$	1·16	Bicarbonate, HCO_3'	0·35
Potassium, $K^{\cdot}$	1·10	Bromide, Br'	0·19
Strontium, $Sr^{\cdot\cdot}$	0·04	Borate, BO_3'''	0·07
Other	0·06	Other	0·03
	36·46		63·54

The actual total solids content of seabrine may be taken as averaging 3.54%. This last figure is subject to considerable variation, especially in landlocked shallow lagoons where, during the rains the amount may be reduced to nearly zero and at the tail of a prolonged fierce drought to nearly 8%. But the proportion of the constituents is remarkably stable.

2. The anions and cations may combine to form any desired solids, and in fact the art of manufacture consists in directing the combination of the most valuable solids. Assuming that—

(*a*) all the sodium combines with chloride;
(*b*) all the calcium combines with sulphate;
(*c*) all the rest of the sulphate combines with magnesium;
(*d*) all the bromide combines with magnesium;
(*e*) all the rest of the magnesium, and the strontium combines with chloride;
(*f*) the concentration of the brine is $3\frac{1}{2}$%;
(*g*) no account is taken of water of crystallization;

the composition of the seabrine may be written as follows:—

	Percentage of total Solids.	Tons per million gallons.
Sodium chloride $NaCl$	77·39	120
Calcium sulphate $CaSO_4$	3·94	6·1
Magnesium sulphate $MgSO_4$	6·15	9·6
Magnesium bromide $Mg\ Br_2$	0·22	0·34
Megnesium chloride $Mg\ Cl_2$	9·69	15·1
Strontium chloride $Sr\ Cl_2$	0·07	0·11
Potassium chloride $K\ Cl$	1·92	3·0
Potassium borate $K_3\ BO_3$	0·16	0·25
Other	0·46	0·72
	100·00	155·2

Other combinations are, of course, possible. The actual products recovered from the seawater are generally hydrates of the above salts or different compounds of the ions.

APPENDIX II.

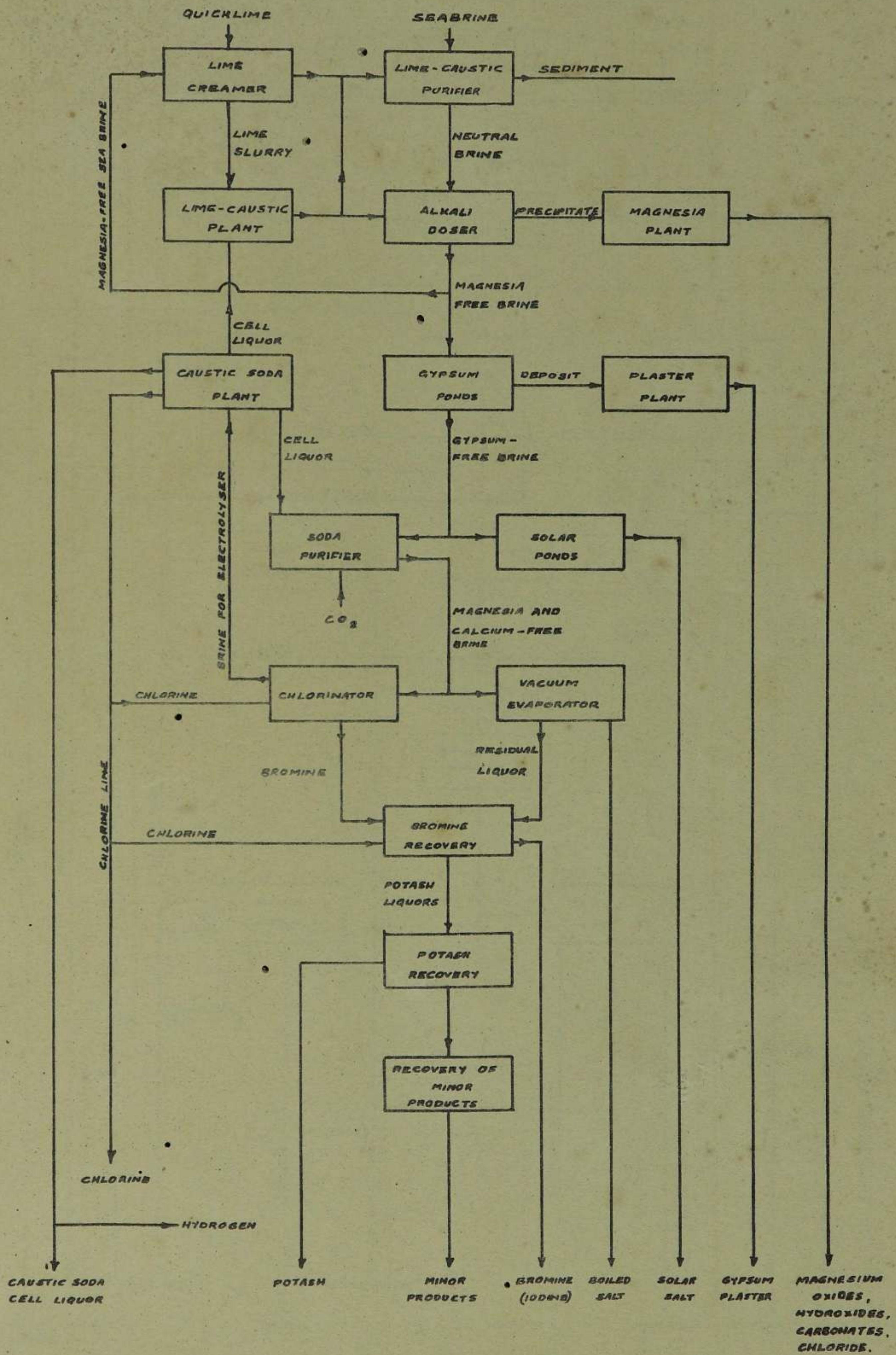
SEPARATION OF SALTS ON PROGRESSIVE EVAPORATION OF SEAWATER (MEDITERRANEAN).

Degrees on Beaume scale at 21°C.	Density of brine at 12.5°C.	Balance after evaporation and removal of salts in litres.	Fe_2O_3	$CaCO_3$	$CaSO_4$ $2H_2O$	NaCl	$MgSO_4$	$MgCl_2$	NaBr	Kcl	Total salts separated out	Cumulative total of Salts: Separated	Cumulative total of Salts: In solution.
3·5	1·0258	1.000										0·000	38·4472
7·1	1·0506	0.533	0·0030	0·0642	—	—	—	—	—	—	0·0672	0·0672	38·3800
11·5	1·0820	0.316	—	Traces	—	—	—	—	—	—	Traces	0·0672	38·3800
14·0	1·1067	0.245	—	Traces	—	—	—	—	—	—	Traces	0·0672	38·3800
16·75	1·1304	0.190	—	0·0530	0·5600	—	—	—	—	—	0·6130	0·6802	37·7670
20·60	1·1653	0.1445	—	—	0·5620	—	—	—	—	—	0·5620	1·2422	37·2050
22·00	1·1786	0.131	—	—	0·1840	—	—	—	—	—	0·1840	1·4262	37·0210
25·00	1·2080	0.112	—	—	0·1600	—	—	—	—	—	0·1600	1·5862	36·9610
26·25	1·2208	0.095	—	—	0·0508	3·2614	0·0040	0·0078	—	—	3·3240	4·9102	33·5370
27·00	1·2285	0.064	—	—	0·1476	9·6500	0·0130	0·0356	—	—	9·8462	14·7564	23·6908
28·50	1·2444	0.039	—	—	0·0700	7·8960	0·0262	0·0434	0·0728	—	8·1084	22·8648	15·7624
30·20	1·2627	0.0302	—	—	0·0144	2·6240	0·0174	0·0150	0·0358	—	2·7066	25·5714	12·8758
32·40	1·2874	0.023	—	—	—	2·2720	0·0254	0·0240	0·0518	—	2·3732	27·9446	10·5026
35·00	1·3177	0.0162	—	—	—	1·4040	0·5382	0·0274	0·0620	—	2·0316	29·9762	8·4709
Total Salts separated ..			0·0030	0·1172	1·7488	27·1074	0·6242	0·1532	0·2224	—	29·9762		
Remainder in mother liquor (0·0162 litres) ..			—	—	—	2·5885	1·8545	3·1640	0·3300	0·5339	8·4709		
Total salts in 1 litre of sea water ..			0·0030	0·1172	1·7488	29·6959	2·4787	3·3172	0·5524	0·5339	38·4471		

After Usiglio—Ann. Chim. Phys. 1849, *27*, 92.
Quoted in Grabau—Principles of Salt Deposition (1920).

APPENDIX III A

PROCESS FLOWSHEET



From Original Supplied by Salt Comm:

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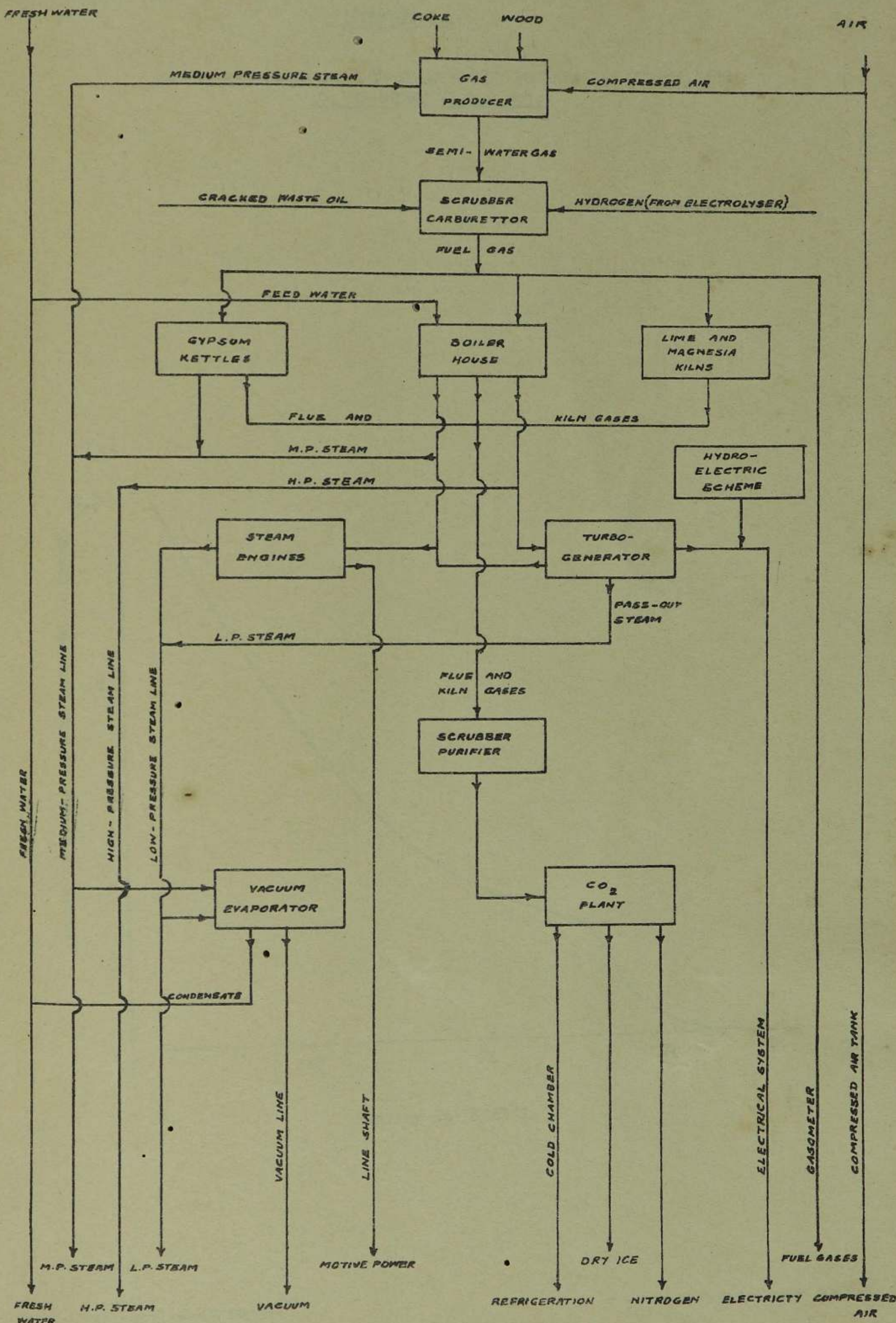
APPENDIX III B

POWER SCHEME-FLOWSHEET

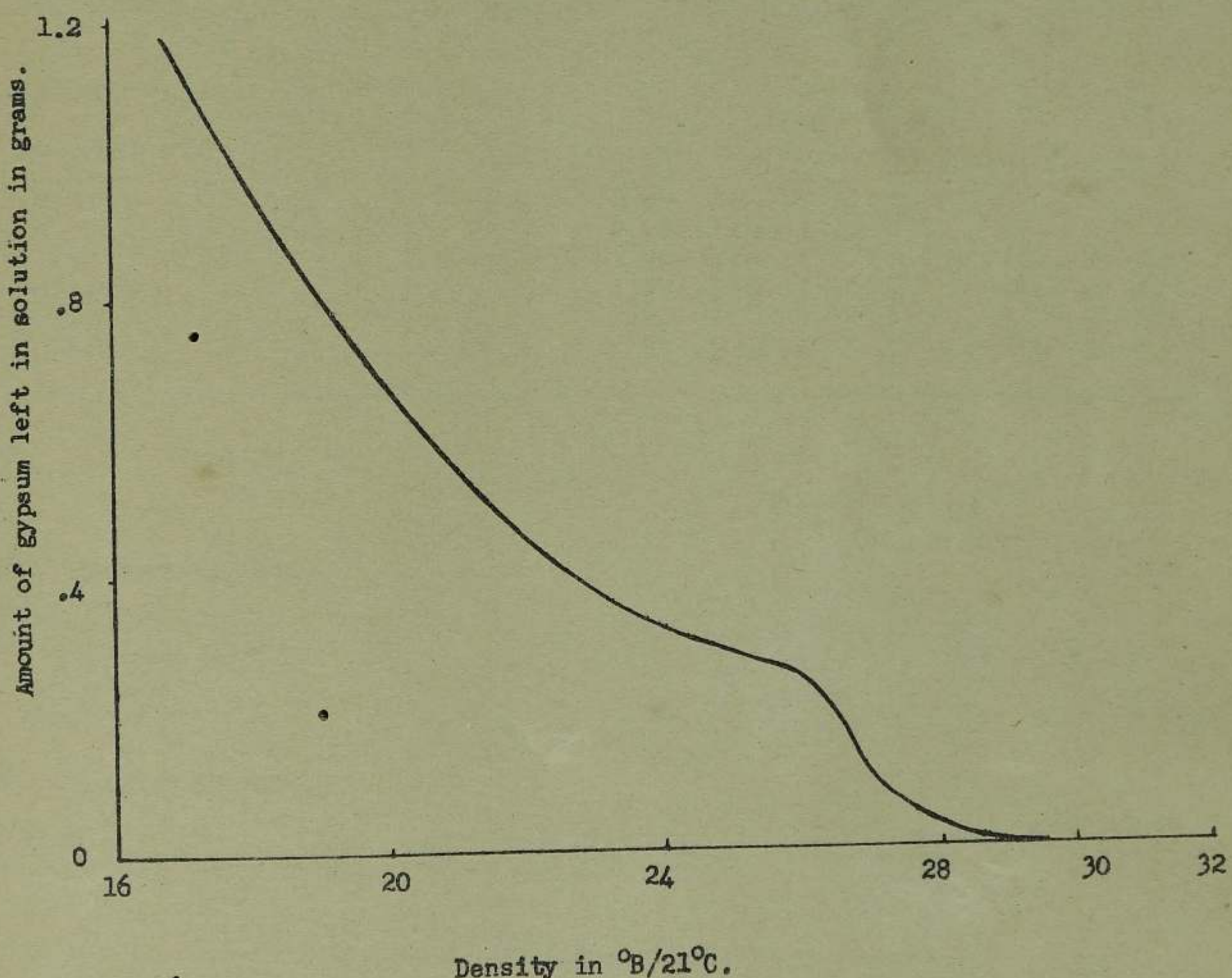


From Original Supplied by Salt Comm:

Printed by Survey Dept., Ceylon. June 1948

APPENDIX IV.

AMOUNT OF GYPSUM LEFT IN SOLUTION ON PROGRESSIVE EVAPORATION OF SEA-BRINE (1,000 gms.)



From Original Supplied by Salt Comm:

Printed by Survey Dept., Ceylon. June 1948.

APPENDIX V.

Local Cost Data.

(One Rupee = 1s. 6d. *i.e.*, Rs. 40 = £3).

I.—*Labour Wages.*

Type.	Grade.	Basic Pay—Rupees.	
		Per diem.	Annual equivalent.
A.—*Technical Grades*—			
1. Unskilled—			
Boys		0·80 / 1·00	— / —
Women	—	1·00—0·04—1·24	—
Men	—	1·24—0·04—1·80	420—12—540
2. Semi-skilled ..	II	1·44—0·04—2·20	444—12—660
	I	1·60—0·04—2·40	480—12—720
3. Skilled	II	2·00—0·12—3·44	660—42—1,164
	I	3·56—0·16—5·00	1,080—42—1,500
4. Supervisors ..	II	2·72—0·24—5·12	840—72—1,560
	I	4·00—0·24—6·64	1,200—72—1,992
5. Apprentices ..	Various	1·00—3·60	—
B.—*Agricultural Grades*—			
1. Unskilled			
Boys	—	0·68—0·04—0·76	—
Women	—	0·76—0·04—1·12	—
Men	—	1·00—0·04—1·36	420—12—540
2. Semi-skilled ..	—	1·40—0·04—1·84	444—12—660
3. Skilled	II	1·80—0·12—2·88	660—42—954
Supervisory ..	I	3·00—0·16—4·28	954—42—1,248

II.—*Freight.*

	Rs. per ton.
A.—*United Kingdom–Colombo*—	
1. Heavy goods, hold	30
2. Heavy goods, deck	20
3. Light goods	50
4. Dangerous cargo	100

B.—*Ceylon* (*Cents per ton-mile*)—

Rail Freight	4–15
Road haulage, Principal roads ..	20–150

III.—*Materials* (*Exclusive of Transport*).

	Rs.
Cement (to Government) per ton	80
Aggregate, coarse, per cube	16
Aggregate, fine, per cube	2
Bricks per 1,000	40
Lumber per cubic foot	10
Good timber, per cubic foot	18
Scaffolding per 100 1 ft.	2
Rope per cwt.	30
Fuel oil per 100 gallons	31
Diesoline per 100 gallons	42
Petrol per 100 gallons	85
Coke per ton	30

2——J. N. 12800 (5/48)

APPENDIX VIa.

Tentative Costing Scheme.

(*Note.*—Each process is taken as a single unit as far as practicable, and detailed costs within the unit are not shown, though they are included in the overall unit cost.)

I.—*Raw Materials used.*

Item.	Unit of Calculation.	Quantity (Thousand Tons).	Unit Cost: Rate per Ton. Rs.	Unit Cost: Gross Amount Rs. (Millions).
(*a*) Pumped seawater	—	92,500	—	1·5
(*b*) Lime	CaO	96	15	1·5
(*c*) Caustic soda	NaOH	270	40	10·8
(*d*) Incidentals	—	—	—	2·2
			Total	16·0

II.—*Annual Cost of Processing.*

Process.	Quantity treated (Thousand tons)	Unit Cost: Rate per ton. Rs.	Unit Cost: Gross Amount. Rs. (Millions).
(*a*) Brine purification, dosing, filtering	95,000	—	4·2
(*b*) Brine storage (surface and elevated)	25,000	—	0·7
(*c*) Evaporation	80,000	—	7·0
(*d*) Crystallization (artificial heat)	3,000	4	12·0
(*e*) Collection, purification and storage of solids	4,000	0·2	0·8
(*f*) Collection, purification and storage of gases	250	4·0	1·0
(*g*) Miscellaneous	—	—	2·3
		Total	28·0

III.—*Annual Return.*

Item.	Unit of Calculation.	Quantity (Thousand tons).	*Ex* Factory Value: Rate per ton. Rs.	*Ex* Factory Value: Gross Amount Rs. (Millions).
(*a*) Common salt	NaCl	2,000	10	20·0
(*b*) Magnesium products	MgO	200	60	12·0
(*c*) Gypsum	$CaSO_4 . 2H_2O$	450	20	9·0
(*d*) Potash salts	KCl	70	100	7·0
(*e*) Chlorine	Dry liquid	240	30	7·2)
(*f*) Bromine	Dry liquid	6	200	1·2
(*g*) Hydrogen	Dry gas	7	500	3·5
(*h*) Other minor products	—	300	—	2·3
			Total	55·0

(*Note.*—Return from chlorine not taken into account as its cost has not been included elsewhere The net profit can be taken at Rs. 1 million).

IV.—*Intangible Benefits.*

(*Note.*—Although no precise value can be given to any of the following items, a hypothetical estimate is quoted to gauge the order of the benefits derived).

Item.	Hypothetical Annual Value Rs. (Millions).
(*a*) Employment	15
(*b*) Shipping	20
(*c*) Power	20
(*d*) Port facilities	25
(*e*) Food production	60
(*f*) Health	10
(*g*) Foreign exchange	?
(*h*) Natural resources	?
Total	150+

V.—*Profit and Loss Statement.*

	Rs. (Millions).
(*a*) Direct expenditure	44
(*b*) Direct Return	56
Direct profit	12 (= 27%)
(*c*) *Add* profits from ancillary undertakings	13*
Total	25*

(* These figures can be increased or decreased depending on the management of the ancillaries and the value placed on intangible benefits.)

APPENDIX VIb.

Capital Costs.

Working data and details for even tentative costing are almost completely wanting, and would require far too much effort at this stage to collect. Some figures are quoted here, but they must be regarded as pure guesses, based on the very little data which are available. Undoubtedly a small local committee of professional advisers will be able to make within a few months estimates which, while still remaining highly tentative, would be of the correct order, and which can then be submitted to competent experts for final revision.

2. The following points may also be noted in the financing of the venture:—

(*a*) many of the unit items are standard, and can be guaranteed to show a working profit, whatever the capital expenditure thereon may actually be in practice.

(*b*) Under a suggested method of financing the Ceylon Government will not need to find more than about 10% of the capital, and that too spread over a period of years.

(*c*) Overhead and administrative expenses are included in the costs, *e.g.*, State housing for personnel is included in the daily wages.

3. The capital cost depends on the extent to which the undertaking would depend on private enterprise *e. g.*, it might be decided to buy electric current or on the other hand to include generation of electricity as part of the undertaking. In the former case, the capital required would be small, but the annually recurrent charge high, while the reverse would be true in the alternative case. Actually of course, the net cost will be about the same if interest charges are taken into account, with a slight preponderance in favour of the integrated scheme.

4. On the above basis, and subject to the limitations mentioned a rough idea of the capital costs involved will be as follows:—

	Rs. (Millions).
Scheme I.—Only treatment and handling of seabrine	20–25
Scheme II.—As in Scheme I, plus manufacture of lime and caustic soda	40–45
Scheme III.—As in Scheme II, plus general purpose dam and generation and transmission of hydro-electricity	95–100
Scheme IV.—As in Scheme III, plus creation of harbour, port and shipping facilities	150–160
Scheme V.—As in Scheme IV, plus running of shipping line	225–240
Scheme VI.—As in Scheme V, plus fuel-wood and timber plantations, cultivation of land by personnel, and all other ancillaries	250–260

5. Eventually, of course, *all* this capital must be expended as the value of integration is too great to be lightly discarded. But the scheme can proceed step by step, and capital obtained only when required. It is unlikely that more than Rs. 25 millions of commitments will fall due each year, of which only about Rs. 3 millions may need to be found by the Ceylon Government. This is less than the amount presently being spent on the Salt Department, and is less than 1% of the annual revenue of Ceylon.

6. There is no need for a pilot plant, as all the operations are standard, and no benefit can be derived by mere experimentation. Production can be undertaken on a small scale, but there is no point in discussing the details here as the entire basis of the scheme will have to be completely altered, and the benefits to be derived will shrink very much more than in mere proportion.

APPENDIX VII.

Caustic Soda Data.

1. (*a*) The following discussion is based on the report of Dr. A. J. V. Underwood to the Department of Commerce & Industries in 1946-1947.

(*b*) According to this report, the cost of a plant for the production of 5 tons of caustic soda daily is as follows:—

Capital.	£	£
*(i) Salt solution and brine purification plant	6,800	
(ii) Electrolyzer plant	17,000	
*(iii) Concentration plant	12,200	
*(iv) Chlorine liquefaction plant	11,600	
*(v) Bleaching powder plant	21,000	
		68,600
*(vi) Boiler	3,000	
*(vii) Diesel engines	20,000	
(viii) Motor generators	6,000	
**(ix) Auxiliary equipment	4,500	
		33,500
***(x) Carriage, freight, &c.	10,200	
***(xi) Erection	10,200	
		20,000
**(xii) Buildings	28,000	
**(xiii) Ancillary equipment	5,000	
		33,000
***(xiv) Contingencies	23,500	
*(xv) Licence fees	4,400	
**(xvi) Overhead during construction	7,000	
***(xvii) Interest	4,000	
		38,900
		194,400

Running Costs for Caustic Soda as Cell Liquid.	£	£
**(xviii) Salt	12·75	
*(xix) Chemicals	3·25	
**(xx) Power	36·55	
**(xxi) Steam	2·40	
**(xxii) Labour	4·55	
**(xxiii) Salaries (whole plant)	15·00	
***(xxiv) Electrodes, &c.	3·15	
**(xxv) Repairs, &c.	5·00	
	82·65	
Less credit for fuel value of hydrogen	1·65	
		81·00
(xxvi) Depreciation (whole plant)	39·00	
(xxvii) Interest (whole plant)	19·00	
		58·50
		140·00

This gross cost is divided equally between the chlorine and the 5 tons of caustic soda, giving the cost of caustic soda alone, as cell liquor, as £14 (Rs. 190) per ton.

(*c*) Dr. Underwood's estimates are framed on data supplied, certain assumptions, and deductions therefrom. But the requirements of the Saltern factory are quite different. The scale would be very much larger, the cell liquor need not be purified or unduly concentrated, power and steam need not be specially generated for the purpose, the chlorine can be absorbed internally, purified brine suited for electrolysis is available on site at very low cost, and the supervisory staff have other work also. The costs can therefore be very appreciably reduced.

As the details can be appreciated only by professionals, they are not mentioned here. It can be shown, however, that the items marked with a single asterisk in Dr. Underwood's report can be omitted entirely (or at any rate reduced to insignificant proportions), the items marked with a double asterisk appreciably reduced, and those marked with a triple asterisk reduced *pro rata*.

(*d*) Assuming then that Dr. Underwood's scheme will be adapted to the extent necessary for the limited objectives of the saltern project, the cost of the electrolysis may be estimated roughly as follows for a plant producing 900 tons of caustic daily:—

Capital.

		£ (Thousands).
(ii)	Electrolysis plant	2,000
(viii)	Motor generators	50
(ix)	Auxiliary equipment	80
(x)	Carriage, freight, &c.	150
(xi)	Erection	150
(xii)	Buildings	150
(xiii)	Ancillary equipment	25
(xiv)	Contingencies	200
(xvi)	Overhead (during construction) ..	200
(xvii)	Interest (during construction) ..	200
(xviii)	Unforeseen	95
		3,300

Running Costs for Cell Liquor.

	Per diem.	(900 tons caustic). £	£
(xix)	Salt	180	
(xx)	Chemicals	30	
(xxi)	Power	2,000	
(xxii)	Steam	50	
(xxiii)	Labour	200	
(xxiv)	Salaries	200	
(xxv)	Electrodes	450	
(xxvi)	Repairs	250	
(xxvii)	Contingencies	140	
			3,500
	Less credit for fuel value of hydrogen ..	300	
			3,200
	Depreciation	700	
	Interest	300	
			4,200

Now the lowest use to which the chlorine can be put is absorption in magnesia to form magnesium chloride, for use in indoor cement. For this purpose, the chlorine will have a value of at least £2 per ton (the prevailing price in the U. K. is nearly ten times this figure, but only about 730 tons per annum can be sold at the local current figure of £40 per ton). The minimum value of the chlorine would therefore be at least £1,500. The caustic soda will therefore cost, at most, roughly £3 per ton in the form required on the saltern. The cost of the 270,000 tons required annually will therefore be roughly Rs. 11 millions, inclusive of capital, labour, interest, and replacement.

(*e*) In this connection, reference must also be made to a very careful analysis of caustic soda cost by Macmullin (Diaphragm vs. Amalgam Cells Chemical Industries, 1947, *61*, 48) where the subject is treated in even greater detail than in Dr. Underwood's Report. According to the author's figures, the gross cost of 5 tons caustic (and the equivalent of compressed chlorine) need not be more than £70, which is exactly half of Dr. Underwood's estimate. The costs for the saltern scheme are incredibly low. In view of the great aggregate cost of the Ceylon scheme, the author of the article, who is a consulting engineer of the highest standing in the U. S. A., might well be invited to submit an independent report on the costs for the saltern scheme. The following is an extract of the salient points from the article.

2. (*a*) Comparison between Type S Hooker Diaphragm Cell 8,000 amp. capacity and 7 meter I. G. Amalgam Cell 13,000 amps., capable of daily output of:—

Caustic soda (56·3 Short tons =) 50 long tons
Chlorine (50 Short tons =) 44·6 long tons.

Results recalculated from dollars per short ton to rupees per long ton and suitably modified or adapted.

Costs as prevailing in January, 1947.

(*b*) Data

(i) Power plant size 150 KW per daily ton caustic;
(ii) Power consumption 3618 KW. per ton caustic;

(iii) Capital Installations.

	Item.	Costs (Million Rupees). U. S. A. Costs. Hooker Cell.	Amalgam Cell.	Saltern purposes (Hooker.)
1.	Brine handling	0·44	0·59	0·11
2.	Cell room	2·50	5·38	2·50
3.	Mercury	—	0·71	—
4.	Evaporation	2·32	0·17	—
5.	Steam and water	0·70	0·05	0·17
6.	Rectifier	1·20	1·40	1·20
7.	Chlorine liquefaction	1·23	1·23	0·62
8.	Chlorine cars	0·46	0·46	—
9.	Caustic cars	0·33	0·33	—
10.	General plant	1·00	1·00	0·80
11.	Steam Power Plant 7/8000 KW	3·17	3·33	—
		13·35	14·65	5·40

(iv) Working costs.

Per unit of 1 ton Caustic & 0·89 tons Chlorine.

	Item.	Rate. Rs.	Unit.	Costs. U. S. A. Costs. Hooker Cell. Rs.	Amalgam Cell. Rs.	Ceylon. Saltern Plant (Hooker) Rs.
	Raw Materials.					
12.	Salt	10	Ton	17·45	17·45	7·00
13.	Graphite	1,120	do.	3·73	4·78	3·73
14.	Soda	70	do.	0·35	—	0·35
15.	Acid	75	do.	0·07	1·83	0·07
16.	Caustic soda	75	do.	0·35	0·56	0·35
17.	Mercury	9,000	do.	—	1·20	—
				21·95	25·82	11·50
	Power.					
18.	Steam	1	1,000 lb.	11·68	1·20	1·20
19.	Electricity	10	1,000 KWH	30·21	36·06	30·00
20.	Water	7	Million Gals.	2·04	0·07	2·00
				43·93	37·33	33·20
	Labour.					
21.	Operating	4½	Man-hour	14·43	19·15	5·77*
22.	Monthly	5	Man-hour	2·33	2·33	0·92*
	(* Taken as 40 per cent. U. S. A. rate for Ceylon)			16·76	21·47	6·69
	** *Repairs and Maintenance.*					
23.	Labour	4½	Man-hour	5·49	6·62	2·00
24.	Materials	—	—	5·28	5·98	2·17
25.	Overhead	—	—	2·11	2·60	0·95
	(**Taken as equal of 3½ per cent. of investment)			12·88	15·10	5·12
26.	Miscellaneous			3·52	1·62	0·80
	Works Overhead.					
27.	Direct supervisory staff			1·55	0·92	0·62
28.	Indirect (30 per cent. labour plus 3 per cent. investment)			15·90	19·50	6·96
29.	Taxes, insurance, (2 per cent. of investment)			7·32	8·31	2·91
30.	Depreciation (6 per cent. investment)			21·82	24·85	8·73
31.	Amortisation (6 per cent. investment)			21·82	24·85	8·73
				71·93	80·05	27·95
	*Total Production Costs (Round Figures) per Unit.**					
32.	Production cost (unpurified caustic 50 per cent.)			170	179	85
33.	NaOH purification			19	—	—
34.	Production cost (rayon grade caustic 50 per cent.)			189	179	—
35.	Chlorine liquefaction			19	19	19
36.	Total production cost (rayon grade caustic, and dried, purified, liquefied chlorine)			208	198	104**

* Includes value of chlorine.

** Unpurified.

Costs included.	Costs excluded.
Royalties and licence fees	Shipping
Office and laboratory	Maintenance of tanks
Workshops	Interest
Fire Protection	Administration overhead
Preparation of site	Selling expenses
Plant, wiring, buildings	
Stores	
Cell renewal and maintenance	
Amortisation	
Labour Amenities	
Utility distribution	
Insurance	

A minor reference may be made here to reported costs in Germany. According to Turnock (C. I. O. S. Report No. 22/1189 of 1945) the following are the statistics at the Werke Koholyte at Luelsdorf:—

(*a*) *Staff*—

Administration	40
Technical	30
Skilled labour	280
Unskilled labour	520

(*b*) *Description and Date.*

Twenty-four Billiter diaphragm cells in two sets of 112 each, operating at 6,000 amps. and 4·2 volts per cell, at temperature 70°C, installed since 1924. One set operated in four electrical groups in series of 28 cells each in parallel banks of 14 cells, each group operated from a single 750 KW motor generator set generating 6,000 amps. at 120 volts d.c. The other set forming one continuous series of 112 sets, worked off a single 3,000 KW mercury are rectifier. The current supply from a private firm is reduced by them from 100,000 to 25,000 and by the plant to 5,000, 500, and 250 volts.

(*c*) *Capital Cost of Installation*—RM 10—11 millions.

(*d*) *Cost of Fuel and Power.*

Item.	Supply Type.	Unit.	Cost per Unit at Plant.	Monthly Consumption Units.
(i.) Coal	Brown	Ton	6·5	6,000
(ii.) Steam	100 psi.	Ton	3·5	12,000
(iii.) Water	Unpurified	Million gallons	300*	75
(iv.) Electricity	25,000 volts 3 phase 50 cycle AC	KWH	1·8–1·9*	8·5–9 millions

* (*Note.*—The cost figures for water and electricity should apparently be in pfennings and not marks.)

(*e*) *Cost Data of Products.*

Product.	Output per Month. Tons.	Price in RM per Ton. Cost.	Sale.
Chlorine, liquid	900	100	200
Chlorine, gas	300	?	?
Hydrogen, compressed	10	?	?
Hydrogen, low pressure	24	?	?
Caustic soda 50 per cent.	600	170	300
Caustic soda 100 per cent.	650	220	420
Caustic potash 50 per cent.	105	?	520
Caustic potash 100 per cent.	105	?	750
Hydrochloric acid 33 per cent.	150	150	180
Hydrochloric acid 100 per cent.	150	?	?
Calcium chlorate 60°	50	1,000	500
Calcium chloride	40	20	20

[For Appendices VIIIA and VIIIB see following pages.]

APPENDIX IX.

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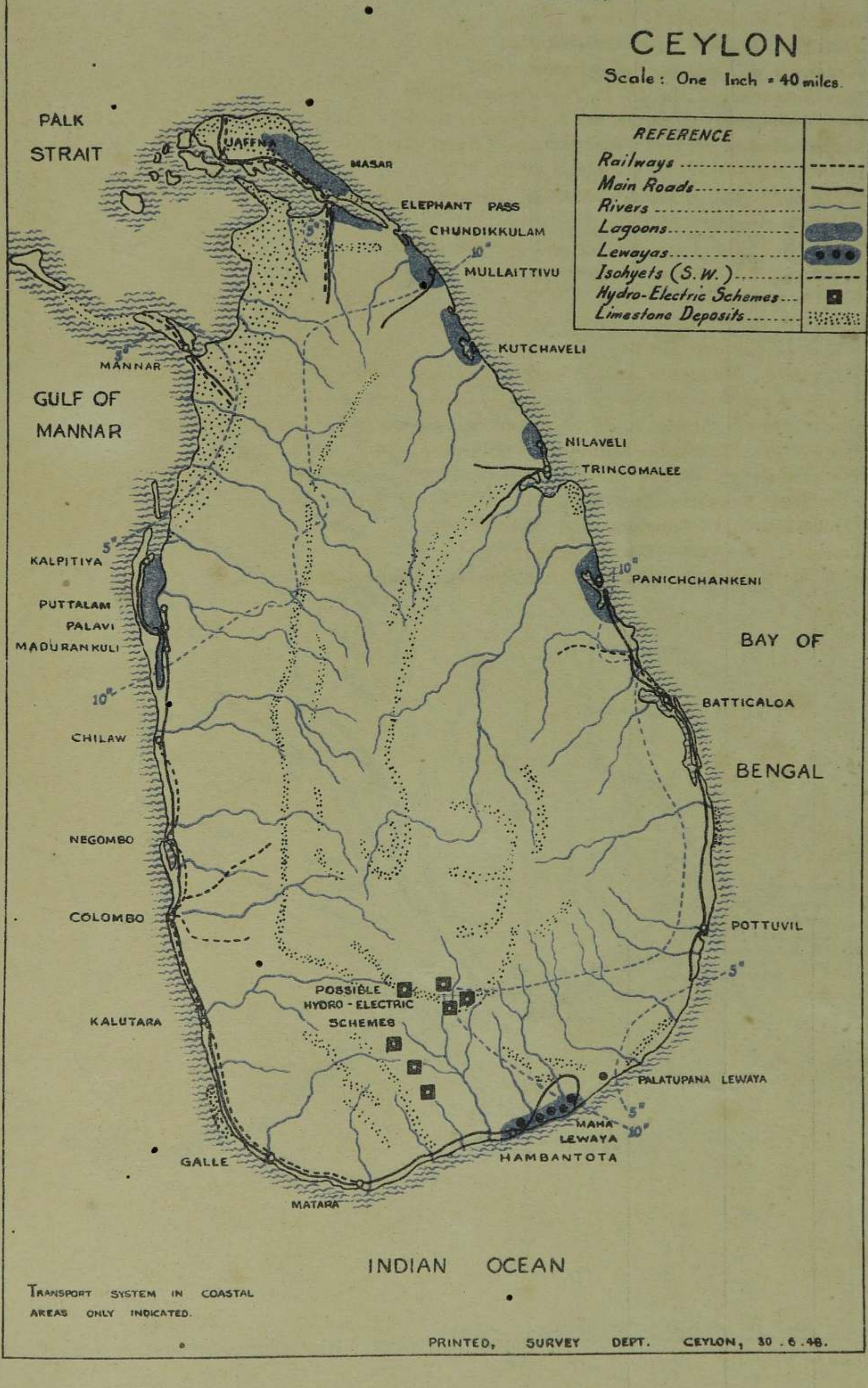
APPENDIX VIII A – SHEWING SUITABLE SALTERN SITES.



APPENDIX VIII B