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NEW STATE-OWNED FACTORIES.

REPORT ON THE MAJOR INDUSTRIAL PROJECTS OF THE DEPARTMENT OF INDUSTRIES.

THE present time, when the New Constitution has just come into being, is appropriate to review briefly the policy followed by the Department of Industries (previously that of the Department of Commerce and Industries) in the past and the plans it has prepared for the establishment of major industries in the future.

2. *Industrial Beginnings.*—The Ministry of Labour, Industry and Commerce established under the Donoughmore Constitution came into being in 1931, but the idea of industrialisation was then in its infancy. A start was made by appointing the Registrar-General, Director of Commercial Intelligence, but it became evident that this was not sufficient. In consequence in 1938 when Mr. G. C. S. Corea was the Minister of Labour, Industry and Commerce, a separate Department of Commerce and Industries was established.

3. *Coir Factory.*—The Department had humble beginnings. The first factory established was the Coir Factory in 1940, one which used very little power and was dependent mainly on human effort. Nevertheless within a few years the factory had earned its capital cost from profits. The success achieved by this factory encouraged the Department of Commerce and Industries to investigate other projects. A number of schemes were prepared but the advent of the war had serious repercussions. For one thing it prevented the Department from obtaining all the machinery required to make the schemes a complete success ; for another, the serious shortage of certain commodities made it necessary to construct factories using local second-hand machinery which was sometimes indistinguishable from scrap and almost inveriably designed for other purposes. As it happened on the whole the factories worked successfully and with profit during the war period, but as was always expected, not all of them have been able to meet normal peace-time competition. Annexure A gives a concise picture of the progress up to September 30, 1945, *i.e.*, up to the date of the last audited accounts.

4. *Plywood and Glass Factories.*—In actual effect, only two factories were built up to anything like the original specifications, *viz.* : the Plywood manufacturing tea chests panels and the Glass making blown glassware. Each cost about half a million rupees and a large part of the capital cost has been met by way of profits. They have, in fact, been run continuously at a profit. Schemes, each costing about a million rupees, have been prepared to increase the production of those factories so that the Plywood Factory makes decorative panels and the Glass Factory an improved form of blown ware in addition to pressed ware. These additions will make the present factories complete units.

5. *Leather Factory.*—The venture of the Leather Factory was less successful. The prospects were bright but the sinking of machinery in the Mediterranean during the war caused a crippling blow from which the factory never recovered. During the war it served a very useful purpose by supplying boots and shoes to the armed and defence services, and was run at a profit. But it never came up to expectations, and a scheme of complete reorganisation has been prepared for the consideration of the Ministry.

6. *Acetic Acid Factory.*—The Acetic Acid Factory has been the most original and exciting venture of the Department. It has been able, by using locally devised methods, to obtain such devious products as charcoal, acetic acid, preservatives, polishes, disinfectants, and pitch from coconut shells. All this has been achieved by using local second-hand scrap machinery manufactured for quite different purposes. The factory can be said to have justified itself and to have demonstrated the need for a completely new factory using specially-designed machinery. It is proposed to make use of a consultant Chemical Engineer from abroad who has already seen the factory to complete this scheme.

7. *Other Factories.*—The other factories were all war-time measures and none of them were equipped to meet unrestricted competition. Owing to impending change of Constitution it was not possible to affect radical changes in their format, but schemes of reorganisation are under consideration.

8. *Size of Factories.*—The experience gained by the Department during the period of the war has indicated clearly that Government should as far as possible confine itself to large-scale projects. Not only are they more economical on account of decreased overheads, but their very vastness justifies the employment of experts to design, build and run the plant. Moreover such schemes are at present beyond the power of individuals to carry out and do not compete with private enterprise.

9. *Necessity for Industrialisation.*—But rather more fundamental is the question of industrialising in itself. Ceylon has been, is and will be primarily an agricultural country and one may well inquire whether there is any real necessity to industrialise. It would be out of place here to present a complete apologia for industrialisation, but the following considerations may be briefly mentioned :—

(i.) Present world conditions with restrictions of trade everywhere and the possibility of future wars makes it essential that every country should have a balanced economy of production, both industrial and agricultural ;

(ii) Industrial development will enable Ceylon to process certain agricultural raw materials such as rubber and copra and thereby gain the premium which accrues to other manufacturing countries who now do the processing themselves ;

(iii) Import prices have risen far more than export prices, and in a short time Ceylon will be hard put to pay for its imports from its exports. Local manufacture will help to bridge the gap and keep up the standard of living ;

(iv) Industrial schemes are new ventures and give new employment ;

(v) Ceylon has valuable raw materials. If other countries can utilise them, there is no reason why, *prima facie*, Ceylon should not do the same.

10. In consequence, in preparing new schemes for consideration of the Ministry, the primary purpose has been to devise large schemes for making use of Ceylon's raw materials, including those which process agricultural produce and thereby gain more money for Ceylon. Broadly the schemes envisage the manufacture of basic products which are either of use to other industries or which are essential requirements for the people of this country.

11. *Procedure of Preparing Schemes.*—The normal procedure for preparing a large scheme is as follows : when the department considers a scheme feasible, it collects the data, prepares a report and then recommends to the Ministry that it be explored further by consultants abroad. The next step is the preparation of the consultant's report, which is based largely on data collected personally in Ceylon by the consultant with the aid of departmental officers. Only at this stage is the proposal submitted to Parliament (or, of old, to the State Council) for approval. It is proposed, wherever possible to get the assistance of the same consultant to put the scheme into operation.

12. *Cement Factory.*—Of the major schemes only the Cement Factory at Kankesanturai has so far been started. It was designed by Messrs. Henry Pooley, who are also consulting engineers for putting up the Factory. Work is progressing satisfactorily though there have been hold-ups due to the delay in machinery arriving from the United Kingdom. The factory should be completed in early 1949. The estimated cost of the factory was 8½ million rupees, but revised estimates are being prepared to cover the increased cost of machinery. Even the revised figures do not affect the main purpose of the scheme which is to produce 100,000 tons of high grade cement at a cost well below the price of imported cement. The factory is moreover well situated. Lime stone is in plenty on the spot and there is excellent clay in abundance near Giants Tank about a hundred miles away. Gypsum, we shall have to import for the time being, but it is hoped that it can be produced at one of the salterns, preferably Elephant Pass which is 40 miles away.

13. *New Schemes.*—The new schemes of the Department of Industries have now reached the stage of consultant's reports. They are five in number—

(i.) Hydrogenated Coconut Oil;
(ii.) Caustic Soda and Hydrogen;
(iii.) Textile Manufacture;
(iv.) Steel;
(v.) Paper.

These schemes are all separate, but it will be seen in the attached chart that they form one co-ordinated plan. In addition, it will be necessary to link them to the policy of Hydro-electric generation and of Railway transport. Only in this way will it be possible to give industry a well balanced structure.

14. *History of the Schemes.*—The history of these schemes is, I think, worth narrating. The idea originated in the fertile mind of Mr. D. H. Balfour, who was then Director of Commerce and Industries. As there were no experts in Ceylon capable of translating these projects into a practical scheme, Mr. Balfour was sent out to England in April, 1946, to find suitable consultants. His visit was very successful and the preliminary talks with the consultants indicated at an early stage that he was proceeding on correct lines. The results were reported to Sir Oliver Goonetilleke, the Financial Secretary, who was on duty in England, and he strongly supported the proposal that the consultants should come to Ceylon and prepare preliminary schemes. Finally with the approval of the Ministry of Labour, Industry and Commerce, the various consultants came to Ceylon in early 1947 and prepared the reports which I now submit to you. I now give a brief account of the various schemes.

15. *Hydrogenated Coconut Oil.*—The scheme for the hydrogenation of coconut Oil arose in this way. Sometime ago it was realised that processed coconut oil was fetching very high prices abroad. Moreover as it was mainly made from copra, the residual poonac was not available to Ceylon. It was fairly clear that considerable advantages would accrue to Ceylon if the processing could be done locally.

16. A scheme for the hydrogenation of coconut oil in Ceylon was therefore designed to obtain for the coconut industry the highest prices for the oil content of coconut and at the same time to retain the major output of poonac which constitutes an essential cattle meal in this country. The scheme envisages the use of a solvent extraction process in order to obtain a high oil yield and to produce an oil cake of the greatest possible value. The plant will further extract oil from mechanically-expelled poonac produced by existing mills, this form of poonac still possessing an oil content which is estimated at 8% to 12%. The oil thus extracted will be refined, deodarised and hardened, the fatty acids resulting from the process being used partly for the manufacture of soap and partly for conversion into Glycerine and fatty alcohol.

17. The processing of ground nut and possibly rapeseed and the subsequent conversion of the oils into vegetable ghee was subsequently included in the scheme as there was much in common with the rest of the process. Quantities of rapeseed and ground nuts could be made available from India, pending the production of home-grown seeds.

18. The survey of the industry was carried out by Major L. H. Manderstam, O.B.E., M.Sc., M.I. Chem.E., M.I.P., M.I.F., F.C.S. The plant is designed to deal with 200 tons of copra, 50 tons of poonac and 50 tons of ground nut or rapeseed per diem, and the chief products are 120 tons of hardened oils, 111 tons of poonac, 30 tons ghee, 14 tons fatty acid and 1 ton Glycerine. The total cost of the scheme is estimated at £335,000.

19. *Caustic Soda, Hydrogen and Chlorine.*—An essential raw material for processing oil is hydrogen. The cheapest method of producing this gas is through a caustic Soda Plant using common salt and water as raw materials. Fortunately it happens

that caustic soda is one of the most vitally needed chemicals, being used in soap manufacture, oil refining, paper making, cotton mercerisation, and indeed almost in every chemical industry.

20. Another by-product of this factory will be chlorine which is less easy to dispose of. A limited use will be the sterlization of water supplies and the bleaching of paper and textiles. A more widespread use will be as a raw material for disinfectants of the D. D.T. type. Investigations are being made in this direction.

21. Dr. A. J. V. Underwood, D.Sc., M.I.Chem., F.I.C., F.Inst.F., F.Inst.Pet., the consultant engaged for the scheme, has recommended the adoption of the electrolitic process for the production of 50,000 c. ft. of Hydrogen, 5 tons of caustic soda and 4·40 tons of chlorine per diem.

22. *Textile Spinning & Weaving.*—Ceylon in the years before the war imported about 70,000,000 yards of cloth per annum. Local production is only a small fraction of this amount. As cotton is a commodity easily prchased in the world market, there is no reason why Ceylon should not follow the example of England and manufacture cloth.

23. It is hoped that gradually more and more cotton will be grown in Ceylon and imports be correspondingly reduced. There are indications that certain areas in Ceylon, particularly Hambantota and Mannar, are capable of producing large quantities of cotton.

24. Mr. Thos. L. Mort, B.Sc. Tech., who is consultant for the textile scheme advises the development of the industry in two stages ; the first stage being two tenths of the final scheme which will be progressively built up in 5 years to weave 30 million yards of cloth absorbing 4,000 tons of cotton. It is estimated that 1,500 workers will be employed in the industry when in full operation, and the cost of the entire scheme is expected to be five million pounds sterling.

25. *Steel.*—All the reports reaching Ceylon, from the United Kingdom and the U.S.A. stress the world shortage of steel for ten to fifteen years. There is, therefore, real need for preparing a programme for steel production to cover this difficult period.

26. The proposal is to make use of and convert all the scrap steel available in the Island. A survey indicates that there are ample supplies available. A ban on export has kept most of the scrap in the Island : otherwise India would take it readily as Japan did before the war.

29. There are of course rich iron deposits in Ceylon, notably in the Balangoda area. But they are surface deposits and are normally expensive to work. Preliminary investigations into their development are being made.

28. A scheme for making steel from scrap was prepared with the assistance of Messrs. John Miles and Partners, consulting engineers and successors to H. A. Brassert & Co. Scrap steel in the Island will be converted into rounds and small rolled sections. The factory will also roll hoop iron, drawn wire, wire nails, bolts and nuts. The consulting engineer's report was gone into at detail and accepted by the Ministry of Labour, Industry and Commerce. The scheme was later approved by the State Council.

29. *Paper.*—The Department ot Industries has also been working on experiments for a continued period to deterime the suitability of local raw materials for the manufacture of paper in this country. Although the original intention was to produce only writing, printing and wrapping papers, yet a new demand for paper in the form of bags for the packing of cement has bought to the forefront the question of the immediate establishment of a paper industry. Mr. Grierson, an Engineer of wide experience on the manufacture of paper from bamboos and grasses, was called upon to finalise the experiments undertaken by the Department. As a result of his investigations on the spot for a period of five months, he has recommended the establishment of a factory for the manufacture of writing, printing and wrapping paper from paddy straw and Illuk grass. The scheme for making paper bags is not yet complete, but Mr. Grierson recommends the use of imported pulp as the local fibres are not suitable.

30. The consultant estimates the cost of establishing a factory at approximately 6½ million rupees. It will manufacture 3,000 tons of paper per annum to supply the full needs of the country, in medium quality paper. The paper bags required are two million a year. A committee of representatives of Departments interested in questions affecting the establishment of this factory are now considering such questions as Railway facilities, sites, raw materials, and water supplies, in order to finalise the scheme.

31. *Sites for Schemes.*—A Committee under the Chairmanship of the Permanent Secretary to the Ministry is being appointed to investigate the matter of sites for all schemes. Certain sites have already been tentatively selected by me, but it is desirable that they be considered by Committee on a broader basis. The recommendations of the Committee will later be placed before the consultants for comment before a final decision is arrived at.

32. *Schemes under Contemplation.*—In order to make this report complete, I should like to mention the other major schemes which are still in a very exploratory stage. They are—

(i.) Fixation of Ammonia from the air in order to make nitrogeneous fertilizers. This involves a further plant for the

(ii.) Manufacture of Sulphuric Acid so that Ammonium Sulphate can be made. This dual project requires enormous quantities of electricity which are not now available ;

(iii.) Sugar manufacture which is *prima facie* practicable but involves the cultivation of sugar cane on a scale hitherto unknown in Ceylon ;

(iv.) The manufacture of titanium paints and alloy steels from the ilmenite deposits on the sea-shore north of Trincomalee.

33. *Hydro-Electricity as a Source of Power.*—No reference has been made earlier in this report to the actual availability of hydro-electric power. The new schemes now recommended are based on the use of imported fuels, primarily oil, with provision to join any subsequent net-work of hydro-electric generation. About 11,000 kilowatts will be required. Should, however, further schemes be started, it will be necessary to explore the possibilities of obtaining electricity from water-power. For instance, it has been roughly estimated that the quantity of electricity required to run an Ammonia-cum-sulphuric acid plant to supply all the local nitrogen fertilizers needed locally will be of the order of 20,000 kilowatts ; though it is probable that an economic unit will be on a much larger scale. Unfortunately the Government Hydro-electric Scheme which is expected to produce 50,000 kilowatts approximately some time after the second stage comes into operation in 1953 is intended primarily for domestic lighting and for smaller industrial units. It is fairly clear therefore that if we are to proceed with larger industrial schemes in the future, it will be necessary to bring in an extension of the present hydro-electric scheme, possibly in the shape of an independent project. According to the information in the Post-War Proposals no power for electro-mechanical or electro-metalurgical purposes will be available until 1957, when the third stage is expected to come into operation.

34. *Copies of Schemes.*—I forward herewith a copy of the reports of the preliminary schemes mentioned in paragraph 13 containing all those passages which are of public interest. Their publication as a Sessional Paper will enable the public at large to realise in some measure, the extent of the task and the careful manner in which all the projects have been prepared. Constructive criticism will be greatly appreciated ; it will help in making the best of the schemes for the benefit of Ceylon.

W. J. A. VAN LANGENBERG,
Colombo, December 8, 1947. Acting Director of Industries.

Enclosures.—Profit and Loss Accounts of Factories. Chart showing the new schemes of the Department.

Annexure A.

Statement of Capital Expenditure and Profits or Losses up to September 30, 1945, the last date of Audited Accounts.

	Capital Expenditure up to 30. 9. 45.	Capital Amount repaid as annuities up to 30. 9. 45.	Net Profit up to 30. 9. 45.	Net Losses up to 30. 9. 45.
Leather Factory	248,247 60	22,326 68	228,547 63	—
Plywood Factory	530,778 44	130,651 5	340,780 98	—
Hat Factory	3,801 22	90 49	—	12,487 61
Quinine Factory	123,071 18	9,158 9	—	28,684 34
Coir Factory	21,623 75	6,857 9	82,034 1	—
Paper Mill	140,741 57	25,697 92	184,202 92	—
Saw Mill	65,615 2	8,487 38	—	—
Glass Factory	519,713 56	29,938 18	95,278 32	—
Steel Rolling Factory	284,565 15	72,162 62	80,764 32	—
Industrial Workshop	53,769 34	—	90,953 91	—
Ceramic Factory	389,665 35	21,972 39	—	57,118 61
Acetic Acid Factory	363,631 73	24,065 4	—	202,743 47
*Sales Development Establishment	—	—	141,795 84	—
	2,745,223 91	351,406 93	1,244,357 93	304,002 88

* Includes profits by the sale on non-Government manufactured products.

	Rs. c.	Rs. c.
Total Capital Expenditure up to September 30, 1945	2,745,223 91	
Less Capital amount repaid up to September 30, 1945	351,406 93	
		2,393,816 98
Total Profits of all factories	1,244,357 93	
Less total losses of all factories	304,002 88	
		940,355 5

[See opposite page for Annexure B]

1.—Hydrogenated Coconut Oil.

L. H. Manderstam & Partners, Ltd.,
Consulting Chemical Engineers,
38, Grosvenor Gardens,
London, S. W. 1.

REPORT ON THE OIL PROJECT FOR THE CEYLON GOVERNMENT.

Introduction.

We were instructed by Mr. Balfour, Director of Commerce and Industries, to investigate and submit our observations on the most economical utilisation of the hydrogen which will be made available from the proposed electrolytic caustic soda production. The quantity of hydrogen was given to us by Dr. Underwood as being about 50,000 cubic feet per day of twenty-four hours.

The main object of the project is to divert the maximum quantity of hydrogen for the processing of oils derived from oil-containing materials produced in the Dominion.

We were advised by Mr. Balfour that the bulk of the oil which will be made available for the purpose of hardening will necessarily be coconut oil. Quantities of groundnut and/or rapeseed oil can be expected in the near future, but should not be relied upon, although these oils could be imported for the time being from India.

It was pointed out to Mr. Balfour from the beginning that, due to the properties of coconut oil, large quantities of that oil would have to be processed in order to employ the bulk of the hydrogen liberated by the electrolysis.

During discussions between Mr. Balfour, Mr. Jayawardena, Mr. Corea and ourselves it was agreed (and confirmed by the Crown Agents) that the scope of the investigation should be enlarged, inasmuch as the proposed industry should not only be based on coconut oil to be purchased from existing local sources which, it was stated, employ somewhat old-fashioned methods of production, but on the processing of oil obtained by treating the raw material available (copra) in an efficient and up-to-date manner. This would as it were set an example to the rest of the industry and at the same time reduce the manufacturing cost of an oil which represents the major portion of the export of the Dominion.

Moreover, we were asked whilst investigating the project to show the effect that the utilisation of the available hydrogen would have on the cost of hardening the various oils which could probably be processed in the plant, as compared with the cost of hardening carried out by industries which have to generate their own hydrogen.

Although terms of reference could not be given to us in any precise manner, our investigation has mainly been based on data imparted to us during the various discussions we had and aims principally at coming to some conclusions as to the economics of the proposed industry, in the light of the availability of hydrogen for the hardening of fatty oils from copra and eventually groundnuts and/or rapeseed.

As can be seen from our report, the following aspects of the project have received our attention :—

(1) The production of crude coconut oil by the best possible methods.
(2) The pre-refining of the coconut oil resulting from the processing of copra for subsequent hydrogenation.
(3) The hydrogenation of the refined coconut oil.
(4) The extraction of oil from poonac, which we were told contains from 8 per cent. to 14 per cent. of oil left in the cake.
(5) The processing of groundnut and/or rapeseed.
(6) The splitting of the oil obtained from the extraction of poonac into fatty acids and glycerine.
(7) The concentration of the glycerine water obtained as a result of the splitting of the copra oil extracted from poonac.

In pursuing the investigation we have complied with Mr. Balfour's wish that we should submit proposals which would entail a plant sufficiently flexible to deal with a variety of raw materials on an economical basis.

We have also made reference in this report to the possibility of manufacturing ghee and fatty alcohols.

Considerations Governing the Throughput of the Proposed Industry.

It should be stated at the outset that we are not in a position to assess all factors which might affect the availability of raw material to the industry, such as estimation of future crops, demand for copra from existing factories, contracts in force between the producers of copra and the consumers or, for that, any arrangements between the Dominion and the British or other Governments.

For the purpose of our investigation we have accepted as a guide the information given to us by Mr. Balfour and Mr. Jayawardena, as set out in our memorandum, a copy of which was forwarded to Mr. Balfour and to the Crown Agents on October 28, *i.e.* :—

(1) That the quantity of copra which could be made available as raw material for the proposed factory without in any way upsetting the economics of the existing oil industry in Ceylon would be at least 60,000 tons per annum. We were told, however, that there is every possibility of this figure being increased to 75,000 tons or even to 100,000 tons per annum in the foreseeable future.

(2) About 15,000 tons of copra cake (poonac) with an oil content varying between 7 per cent. and 10 per cent. (from information received subsequently, a figure of 14 per cent. has been mentioned) could be made available immediately for re-processing from points within the economical radius of Colombo.

Larger quantities of poonac are available in Ceylon but the transport charges would have to be taken into consideration and these might be somewhat high.

(3) About 35,000 tons of poonac are being consumed internally as a cattle feeding medium.

(4) The agricultural policy of the Ceylon Government aims at the development of large areas of fertile land for the purpose of increasing the production of copra and for cultivating oleaginous material other than copra, such as rapeseed and groundnuts.

(5) Quantities of rapeseed and/or groundnuts could be made available from India pending the production of home grown seeds, in exchange for copra if necessary.

Economic Considerations.

In addition to availability of raw material, economic considerations fall under two headings (*a*) the cost of raw material in Ceylon and (*b*) the prices to be obtained for the hydrogenated coconut oil, which will represent the major portion of the product manufactured under the scheme.

We shall concern ourselves with the economics of the products which would be manufactured under the expanded scheme, incorporating the production of ghee and fatty alcohols, at a later stage of this report.

As far as the price of copra is concerned, we were informed by Mr. Balfour that the British Government entered into a contract with the Ceylon Government whereby the producer was paid £33·12·0 per ton f.o.b. Mr. Jayawardena, although confirming Mr. Balfour's figure, indicated that the price for copra delivered to the factory would be somewhat below that being paid by the British Government, and has assured us that we can base our calculations on the cost of copra delivered to the factory being £30 per ton. This was eventually agreed by Mr. Balfour.

As far as poonac is concerned, we were given a price for poonac with an oil content varying between 8 per cent and 12 per cent. of £6·7·6 per ton delivered to the factory, although Mr. Balfour has indicated that, under favourable conditions, poonac can be secured at a price of about £3·10·0 per ton.

As you will see from our calculations, we have accepted the most unfavourable case and based our calculations on the cost of poonac being £6·7·6 per ton.

The position as far as the marketing aspect of the manufactured product is concerned is a very much more perplexed one, inasmuch as there is a very wide discrepancy between prices paid by the British Government and those which the markets outside the British controlled zone are prepared to pay for coconut oil, crude or hardened.

In this connection we should like to say that in no circumstances should we be regarded as marketing experts and our opinion expressed on the marketing of the processed oil should be looked upon merely as relfecting the advice we have received from firms like Messrs. Couper, Friend & Co., Frank Fehr & Co., and Edouard Brackman.

It is generally anticipated that the prices for fatty oils will be maintained at the abnormally high level prevailing today for the next few years. A view has been expressed recently by a leading oil concern in this country that the next four or five years should not see any considerable decrease in the prices for vegetable oils. On this we cannot offer you any comment.

As a matter of interest we should like to mention that the crushing industry in many countries, including the United Kingdom, U. S. A. and the European continent is now experiencing an extremely difficult period owing to the lack of raw material. Amongst other reasons this can be attributed to the tendency of states which hitherto exported seed to switch over to the production of oil. India, for instance, is becoming a seed processing and oil consuming instead of a seed exporting country. The

Argentine also is now encouraging the processing of linseed at home and the export of linseed oil and cake instead of the seed itself. Brazil appears to be displaying the same trend with regard to castor and other seeds.

This tendency has prompted the British Government to seek new sources of supply of raw materials in order to meet the needs of the British seed crushing industry. With this in view various projects are now on foot which in the not very distant future will result in the production of quantities of oil-containing seed.

The British Ministry of Food, for instance, has recently made public its scheme for directly sponsoring large scale mechanised cultivation of grounduts in East Africa, with the immediate aim of bringing the first fruits to market by 1948, also for encouraging present production in West Africa.

In the Belgian Congo, 82,000 acres are to be planted with oil palms, from which in eight years' time it is hoped to obtain annually 25,000 tons of palm oil to supplement the 40,000 tons now produced; 6,000 acres will also be planted with cocoa.

In French Equatorial Africa 10,000 acres are going to be covered with palm plantations in the very near future.

The same to a certain extent also applies to the Portuguese and Spanish Governments, who are proceeding on the same lines as the British, French and Belgian Governments, and are now sponsoring agricultural projects in their oveseas possessions in order to make more raw materials available to their seed crushing industries.

It is therefore not unreasonable to assume that within the next few years quantities of oil-containing materials will be made available to the market in addition to those already being offered, in the form of oil, by countries like the Argentine, Brazil, Uruguay, &c., Unless the demand for such oils rises in proportion to the quantities of oils which will be made available from the new sources, some repercussions on oil prices can be expected.

Coconut oil occupies an extremly favourable position inasmuch as whilst oils such as groundut, sunflower, sesame, maize, &c., can, by appropriate processing, be made as it were interchangeable and used for the same purposes, coconut oil cannot. The soap industry, for instance, could not replace coconut oil for the manufacture of certain qualities of soap. Unlike most other oils, coconut oil can be changed but little in its consistency and chemical and physicial properties, as it is distinguished from other oils by the low average molecular weight of its fatty acids, as evidenced by a high saponification value and a low refractive index.

Coconut oil is also considered by some manufacturers as irreplaceable in the making of shortening and margarine, although the oil does not soften gradually with increasing temperature but is inclined to pass rather abruptly from a brittle solid to a liquid within a temperature range of relatively few degrees. It has a comparatively low melting point but this is not due to a high degree of unsaturation, as in the case of other oils, but to the low molecular weight of its glycerides.

Various statements made in "Soap and Sanitary Chemicals", one of the leading publications in the United States, reveals an opinion that until world-wide levels of fat production and fat and oil stocks are normal (this is not expected for some years to come) there will be a continued pressure from all fat and oil users to obtain supplies of coconut oil, which in the past has always been considered as a very important ingredient in soap-making.

In the opinion of the American Department of Agriculture the world output of fats and oils will be retarded in researching pre-war levels by a number of factors; these include political unrest in the Far East, limitation of whale oil production and a larger than normal consumption for domestic uses in areas producing oils for export.

The United States Department of Commerce, however, indicates that, although the demand will continue at a high level well into 1947, prices for oils and fats might be somewhat affected by changes in the consumer's income, A marked recession in general business, if it occurs, could be accompanied by a decline in the prices for fats and oils despite the apparent scarcity of supplies.

* * * * * * * * *

The above considerations, however, lead us to conclude that the future of the proposed scheme can be viewed with a certain degree of confidence, as far as one can dare under the uncertainties prevailing in world economy.

Having arrived at an outline of the proposed scope of the scheme, we shall now submit to you our considerations with regard to the processes involved and the type of equipment we recommend for the manufacture of the products under investigation.

Production of Crude Oil.

We have given considerable thought to the best method we can recommend for the processing of the oil-containing material which will be placed at the disposal of the factory. As the choice of plant, amongst other things, is predetermined by the peculiarities of the material, in considering the problem we have borne in mind that the plant will be called upon to process three types of oil-containing material :—

(1) Copra with a high oil content (about 65 per cent.).
(2) Poonac with a low oil content (between 8 per cent. and 12 per cent.).
(3) Groundnut and rapeseed (with an oil content varying between 48 per cent. and 32 per cent.).

The costs of processing the oil-containing material by the various methods have been very carefully analysed by us and our choice of plant to which reference will be made has to a great extent been dictated by the results arrived at when working out the cost of manufacture by the different means open to us for that purpose.

All processes for the extraction of crude oil have the same aims in common. They are :—

(*a*) To obtain an oil as free as possible from any impurities, suitable for subsequent economical processing and conversion into various products.
(*b*) To obtain as high an oil yield as possible consistent with the economy of the process.
(*c*) To produce an oil cake of the greatest possible value.
(*d*) The suitability of the process with a view to possible expansion at a subsequent date.

When examining the various means open to us for the processing of the oil-containing material, the following factors were taken into consideration :—

(1) Capital outlay.
(2) Peculiarities of the seed.
(3) Cost of processing.
(4) Oil yield obtained.
(5) Quality of oil obtained.
(6) Disposal of residue.
(7) Maintenance cost.
(8) Rate of depreciation and replacement of parts.
(9) Insurance, &c.

The method which can be considered for the production of crude oil can be divided into two groups :—

A. Mechanical expression.
B. Solvent extraction.

These in their turn can be sub-divided into batch and continuous systems.

MECHANICAL EXPRESSION OF OIL.

Batch Method.

The oldest and most common method of oil extraction is the application of pressure to batches of oil-bearing material held in bags, cloth, cages or other suitable devices.

Modern presses operating on this principal are invariably actuated by a hydraulic system. Thus the term " hydraulic press " is often used when referring to batch pressing in general.

Batch presses may be divided into two main classes consisting of the "open" type, which requires an oily material to be confined in a press cloth, and the "closed" type, which dispenses with the press cloth and confines the material to some form of cage.

The first class is represented by the so called Anglo-American press, the second by the cage press. This method of expression—and this applies to both the open and closed types—is interlinked to a great extent with the "heat pre-treatment" of the seed. This procedure predetermines to a considerable degree the quantity and quality of the oil obtained and the appearance of the produced cake.

These methods can as a general rule only be operated where a source of cheap labour is available, where the cost of power is not of paramount importance and the oil left in the cake, due to its price, does not affect the economics of the process.

On the whole it can be said that, in our opinion, they are out of date, cumbersome in handling and their consumption of power in relation to the oil produced is excessive.

Although the Anglo-American and cage presses have been used in the past in many parts of the world and under certain conditions not without success, we have decided to disregard them as possible means of expressing the oil for the purpose of this project.

Continuous method (mechanical).

This method of expressing oil from any oil and fat containing material has gained a considerable and, we may say, well deserved popularity for the last three or four decades, and is represented by so-called expellers. They are manufactured by a number of firms in this country, also in France, Holland and the United States.

Expellers are being used in many parts of the world, particularly in the United States, to the almost complete exclusion of the Anglo-American and cage presses, which are now considered obsolete. Presses of this type are continuous and in most respects automatic in operation. They effect a large saving in common labour, and have completely eliminated the need for a press cloth.

The principal disadvantage is that their power requirements are relatively high, maintenance and cost of replacement expensive. Furthermore, if a high oil yield is to be obtained, elevated pressures are unavoidable, which build up in the barrel of the expeller (up to 20,000 lbs. per sq. inches), having various repercussions on the behaviour of the oil during subsequent processing.

Solvent Extraction.

This method of de-oiling fat containing material, although developed some years ago—the first patent being granted in 1856—has come into prominence only during the last fifteen to twenty years.

There are two distinct methods of solvent extraction which are based on the application of an organic solvent. This has the property of dissolving the fat substance in oleaginous seeds. One operates on the batch principle, the other is continuous; both of them, however, have the following operational procedure in common.

Milling of the Meterial.

This is an extremely important part of extraction and influences considerably its efficient operation, as the rate at which oil diffuses from a flaked particle of seed is directly proportional to the surface area of the flake and inversely to its thickness. Thus, the rate at which oil is extracted from a given weight of flakes is indirectly proportional to the square of the flake thickness. Therefore it is always attempted to flake the seed prior to extraction to a thickness not exceeding 1 mm. whenever possible.

To emphasise the importance of the flake, it is worth while to observe that theoretically, for example, reducing the flake thickness from ·012 to ·006 inches should quadruple the rate at which the flakes can be reduced to a given residual oil content. In practice, however, there are many other factors which are to be considered in determining the thickness of the flake, as the mechanical strength of the flakes must also be taken into consideration to prevent "powdering" &c.

Solvent Extraction Proper.

The main factors which have in the past obstructed the wide application of solvent extraction plants can defined as follows :—

(1) Imperfection of design.
(2) Explosion and fire risk entailing a high rate of insurance.
(3) Poor quality of cake, which in some cases was not palatable if used as cattle fodder.
(4) Inferior quality of oil.
(5) Application of unsuitable solvent and its high cost in some countries.
(6) Poor utilisation of heat, resulting in high steam consumption, &c.

To discuss all the factors mentioned above would result in a very lengthy report and would be out of place here. It can, however, be said that serious and successful efforts have been made during the last decade to overcome the difficulties encountered with batch, semi-continuous and continuous plants. These have resulted in a reduction of the fire and explosion risks and the production of oil and cake of high quality.

With regard to the latter, a considerable amount of research has been carried out in the United States to ascertain the nutritive value of solvent extracted cake, as compared with cake produced by treating the seed by mechanical means.

Dr. Schiffman, a senior member of the Agriculture Department of the United States, who kindly provided us with some of the data obtained by his Department on the nutritive value of the cake, stated the following : " No evidence is available that the nutritive value of extracted meal, if properly prepared and made palatable by an efficient stripping and, if necessary, toasting, is in any way inferior to an expelled cake ".

Messrs. Mitchells and Butlers have also investigated the nutritive value of copra meal and have had an opportunity of testing meal from commercial extraction plants. Their findings with regard to the protein content and digestibility of the protein and the biological value of the digested protein seem to bear out the views of the Agricultural Depatment of the U. S. A. in that respect.

It might also be interesting to note that Newland Record tests made on young cattle with extracted and expressed palm kernel meal (very similar to copra meal) showed that the extracted meal give better results, although the oil content was less than 2 per cent, whilst the pressed cake contained 6 per cent. Further tests on sheep showed that extracted meal was superior and it is also stated that extracted meal is an excellent base for feeding pigs.

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Batch Extraction.

Two types of batch extraction plant can be mentioned :—

(1) Stationery extractors with or without stirring devices, which operate chiefly on a counter-current principle, with or without a forced solvent circulation.
(2) Rotary extractors which operate as single and chiefly self-contained units.

We have had considerable experience with the two types and it can generally be said that, unless special circumstances prevail, the second type, appears somewhat less attractive that the stationery extractor, especially if forced solvent circulation is employed, which is preferable to " decanting " the solvent.

The main disadvantages of processing oil seeds by the batch solvent extraction method can be summed up as follows :—

(1) Considerable number of extractors involved when dealing with large throughputs (120 tons and over per 24 hours).
(2) High steam consumption (over a ton of steam per ton of seeds processed). This particularly applies when the solvent and oil are recovered intermittently.

(3) Potentially high solvent loss due to the somewhat cumbersome operational procedure involved, numerous joints, connections, &c.

(4) Relatively prolonged periods in which the seed and oil are in contact with heat. This especially applies to stripping operations in a still of conventional design and has a noticeable effect on the quality of oil when seeds containing drying oils are treated.

(5) The impossibility of applying scientific control to the operations and the necessity of adhering to the "rule of thumb" method during operation.

On the credit side of batch extraction, however, it can be said that it offers considerable flexibility inasmuch as a wide range of oil-containing materials (oil seeds, bones, Fuller's earth, fish offal, &c.) can be treated.

There are variations on the batch principle other than those described above, such as Merz, Bohm, &c. Their usefulness, however, is limited and confined chiefly to treating small quantities of seeds, degreasing of Fuller's earth, recovery of paraffin from old grease-proof containers, &c.

Continuous Extraction.

The development of batch solvent extraction plants chiefly in Germany and France led to the adoption by the designers of continuously operating plant on what is commonly known as the counter-current principle, in which the material containing highest proportion of oil is contacted with the solvent, which is rich in oil, and *vice versa.* Such an operation allows the extracted meal to have a final wash with fresh solvent to remove as far as possible the last traces of its oil content before withdrawing it from the system.

It can also readily be seen that, if the mechanism of solvent extraction is considered as a diffusion process, in which equilibrium is attained by the movement of the oil contained in the solid material, the contacting of solvent with little or no oil content with meal having a small oil content will reduce the amount of oil in the meal more than if it were contacted with a solvent oil mixture nearer to the equilibrium conditions.

This principle is now universally adopted in the many different designs of plant put forward for continuous operation.

Whilst in batch extraction the process is carried out by filling single units or a battery of containers with the material to be extracted and the solvent circulates from one apparatus to another until the cycle has been completed, when the extracted meal is normally static, the continuous method provides as a rule the movement of the solid material from the point of entry to the point of exit in opposition to the flow of solvent.

The efficiency and practical application of many of the suggestions regarding the design of continuous solvent extraction plant have hinged on the movement of the solid phase. Such movement has led in many cases to the formation of what is commonly known as "fines", which are small particles of meal formed by the movement of the comparatively fragile flakes with a large superficial area so necessary for the efficient penetration of the solvent.

The production of fines (if not eliminated) would lead to extreme difficulty of operation in the subsequent solvent and oil recovery plants, due to clogging of lines, vessels, &c., and, if they are allowed to be present in the final oil product, they would cause rapid deterioration of the oil and high oil loss in the neutralizing.

Another feature which has become apparent when examining the various systems is the consideration for the prevention of high solvent loss, resulting from the use of many moving parts, which require extremely efficient sealing between the external drive and the internally moving components.

It appears, however, that the manufacturers of the continuous solvent extraction type of equipment claim that the difficulties in connection with high solvent losses have been overcome, and a figure indicating a solvent loss considerably below that normally obtained in a batch extraction plant has been given.

It can be said, however, that the latter feature has not played such an important part in the United States as in other countries, as, with its vast oil reserves and in many cases close proximity to refineries producing solvents, the price of solvent is not of primary importance. To counterbalance this the cost of labour in the United States is high in comparison with other countries, and the adoption of continuously operating plants working more or less automatically allows for a reduction in production cost.

Recovery of Solvent and Oil.

An essential part of any extraction system, whether it is batch or continuous, consists of recovery of the solvent from the extracted meal and miscella. The equipment used for the recovery of solvent from the miscella, freed of any particles, of seed, varies considerably in different systems. It can be carried out in stills or in continuously operating distillation and stripping columns.

The water and the solvent from the stripping plant are separated by gravity settling and the recovered solvent re-used.

In order to produce an oil of good quality, however, it is essential for the entire operation of solvent removal to be conducted rapidly and at a low temperature. We will show later in the report how important it is in operating a solvent extraction plant to keep the losses as low as possible, as the solvent constitutes the most expensive item in the treatment of seed by this method. The solvent is lost mainly in the extracted residual meal, in the oil and during " venting " into air.

While it is relatively easy to remove the solvent from the residue and the oil itself, it is more difficult to separate a solvent vapour and air mixture which inevitably forms during the operation. This, however, can be overcome by incorporating an efficient absorption system based either on the absorption of the vapour plus air mixture by a liquid medium (mineral or vegetable oil), activated carbon, or by bringing it in contact with atomised brine at temperatures considerably below freezing point.

Alternatively, a combination of the methods mentioned above can be considered.

It can be repeated that, with due precautions and understanding of the methods involving a complete recovery of the solvent, the solvent losses from all sources should not exceed 1 per cent., irrespective of whether a batch or continuous system of extraction is chosen.

Although in our calculations we have accepted the figure of 1 per cent. as representing the maximum loss of solvent (the solvent loss is calculated on the intake weight of the raw material) we are confident that in practice this figure can be reduced to a range of 0·6 per cent. to 0·7 per cent.

Observations on the Batch and Continuous Solvent Extraction Methods.

Comparing the two solvent extraction methods, a better argument could be put forward for a continuously operating installation for large through-puts than for the batch method. It has been proved by a number of research workers who attempted to interpret the relative efficiency of the two systems in terms of consumption data, that this is the case, and evidence is available that large scale continuous plants have been successfully operated not only on soya beans but also on other species of oleaginous seed and fat containing material.

This particularly applies to Germany, where to our knowledge Hansa Muhle, Mergel & Brinkmann and others processed by this method large quantities or pre-pressed groundnuts, cotton seed, linseed, &c.

Recently a new continuously operating solvent extraction plant was placed on the market by Messrs. De Smet, Nouvelles Huileries Anversoises, Antwerp, who have come to a licence arrangement with Messrs. George Scott & Co. (London), Ltd. We have had an opportunity of inspecting the plant and watching its operation. Although some features of the plant in our opinion require modification, we are satisfied that it represents a considerable improvement on anything so far offered by engineering firms either in the United States or elsewhere.

It can be added that a continucously operating solvent extraction plant offers an additional inducement inasmuch as it entails an even load of steam and power, which is not the case in a batch plant.

We are now coming to a stage when it would be appropriate to comment on whether or not solvent extraction should be preferred to mechanical expression.

While endeavouring to determine this, we are fully conscious of the fact that it would be somewhat premature to make any final recommendations on definite lines, as it is one of the problems which cannot be dogmatized and can only be decided in the light of a number of factors affecting the issue. Our Major Manderstam will have an opportunity of studying these and the local conditions in the Dominion during his visit, and will also obtain confirmation from you on the availability of solvent, cost of steam and power, if provided from a central steam and power generating plant, &c.

We have discarded the use of the cages and Anglo-American press for reasons stated in the previous part of the report. Having eliminated this method of oil extraction, we will consider the advisability or otherwise of giving preference to expellers or to the extraction method.

Both these methods have their advantages and disadvantages and we have examined them in the light of our experience with both types and our knowledge (somewhat limited) of the conditions under which these plants will be called upon to operate in Ceylon.

Submitting for your consideration our observations on the posibilities of using solvent extraction, we are fully aware of the fact that it might meet with some opposition on the part of experts who are used to a conventional way of processing oilseeds.

We ourselves have been responsible for the solvent extraction of oil seeds in considerable quantities in Portuguese East Africa as long ago as 1932, when a large extraction plant of German design (Rheinmetal-Borsig) was operating on the batch principle under the supervision of Major Manderstam. The same applies to a plant operated by the Epic Oil Mills, Johannesburg.

We should like you to bear in mind that our calculations have been made on the basis of figures given to us by Mr. Balfour in respect of labour costs, price of fuel as given by Dr. Underwood and cost of solvent as given by " Shell ".

The solvent plays an extremely important part in the economics of the process and we therefore consider it appropriate to mention briefly the type of solvent we would recommend, if it is decided to give preference to the solvent extraction method of producing crude oil.

Not every solvent is suitable for solvent extraction if carried out on an industrial scale. The ideal solvent should possess the following characteristics :—

(1) It must not be inflammable and its vapour must be non-explosive.
(2) It must be chemically stable, have a uniform composition, constant boiling point, which should not be too high, low specific heat, low latent heat and a low freezing point.
(3) It should be selective for fatty oils and not extract any coloured pigments ; it should possess penetrating properties and be easily removable from the residual oil and meal.
(4) It must have no corrosive action on the material of which the plant is constructed.
(5) It must not be toxic and have no deleterious effect on either the residual meal or the oil ; its vapours should have no toxic effect when unsealed.
(6) It should not be miscible with water, nor form any constant boiling point mixture with it.
(7) It should have a low specific gravity.
(8) It should be easily procurable and not deteriorate in storage.
(9) It must be cheap.

Since there does not exist a single solvent that would meet all these requirements, a selection muss be made of one possessing as many of the above characteristics as possible to suit your specific problem.

In these circumstances our choice would undoubtedly fall upon a napthenic based product such as extraction benzine, which is obtained from the distillation of mineral oil, and possesses a boiling range from about 67° to 100°C, with a specific gravity between ·663 and ·723. It is usually a mixture of hexane (C_6H_{14}) and heptane C_7H_{16}

This solvent dissolves only traces of water, does not affect either the oil or the meal chemically, and does not corrode mild steel. It has good wetting properties, penetrates the flakes easily and dissolves oils well without showing any appreciable solvent capacity for other constitutents of the seed, such as cellulose, starch and protein. This solvent is easily procurable and is recommended by us as suitable for your purpose. Therefore our calculations relating to solvent have been based on n-hexane.

In calculating the cost we have assumed that the oil rest in the cake, in the case of solvent extraction, will not exceed 1% and, in the case of expellers after final expressing, 6% to 8%. This last figure has been accepted by Messrs. Rose, Downs & Thompson and Messrs. Greenwood & Batley.

With regard to the quality of the oil which the two processes now under discussion would yield, we are prepared to state without any hesitation that the results of our experience for many years indicate that the properly refined product from the solvent extracted oil is equal in most of its characteristics to that obtained from the mechanically expressed oil.

On general lines it can be stated that, as far as the use of a refined oil produced by solvent extraction is concerned, this on the clear understanding that it will not be consumed in an unrefined state for edible purposes, no argument can be made in favour of an expeller produced oil.

From the point of view of the case for refining, it is our experience that an extracted oil lends itself extremely well for processing, inasmuch as it does not usually contain the same amount of mucilage and slime, which are found in the oil produced by the expelling method under conditions of high pressure and relatively high temperatures.

The difference in refining losses between expelled and extracted oil is, however, insignificant, and would in any case not matter so much in your case as you have an outlet in the soap stock, the quantity of which increases in proportion to the higher refining losses.

The position of the solvent extracted oil assumes an entirely different aspect if it is attempted to dispose of the oil for edible purposes without any refining. A freshly expelled oil by first pressing would find a certain market whereas an extracted oil would most probably fail to attract customers, having lost its natural flavour, which is removed in any case from a crude oil, irrespective of its method of manufacture, during the subsequent refining.

With regard to the use of the cake, upon which we have already made some observations, it is evident that a meal with an oil content of 1% instead of 6%, as it would be in the case of the expelled meal, would have a correspondingly higher content of protein in direct proportion to the decreased oil content.

In addition, the solvent extracted meal is preferred for the manufacture of protein, adhesives, fibres, filling materials for plastics, &c., since there is much less denaturation of the protein in the meal than in that obtained by cooking and mechanical processing.

We feel it appropriate to dwell briefly on the relative nutritive value of the extracted meal as compared with the expelled products, should it at any time be ncessary to direct some of the meal for cattle feed consumption.

A number of arguments are put forward in favour of theories concerning the nutritive value of residues dependent on the method of their manufacture. We ourselves have had an opportunity of investigating this problem for one of the largest European chemical concerns, but have come to the conclusion that no one knows the answer yet as to whether or not the heat treatment which is an essential part of producing the meal by the mechanical method, makes the protein of the cake more "available" to cattle than the processing by solvent.

There is a certain amount of evidence available that the action of solvent itself (hexane being used for the extraction of soya beans) increases the biological value of the protein and the digestibility of nitrogen.

Experiments were carried out on expeller produced cotton meal and conclusions reached that the heat treatment of the cake used in biological feeding tests had an adverse effect on the health of rats used in the tests.

We ourselves feel justified in saying that no conclusive evidence is as yet available as to which meal represents a higher value, except that in the case of expelled meal a larger quantity of oil, which is in many cases rancid and oxidized, is made available, whilst in the case of extracted meal there is more protein and less oil, but the general indications are in favour of extracted meal.

With regard to the maintenance costs of the two plants, it can be stated that this item is very much higher in the case of expellers than with a solvent extraction plant, where few moving parts are required for its operation. It is estimated by Messrs. Rose, Downs & Thompson that the cost of replacements is something like £200 on an expeller, the price of which is approximately £1,000, thus representing about 20 per cent.

The same applies to the rate of depreciation, which is considerably heavier for a plant which expresses the oil from the seed by mechanical means.

As far as the insurance rates are concerned, we have allowed Rs. 15 per £1,000 for the extraction and Rs. 5 per £1,000 for the expelling plant ; as we have no reliable data regarding this aspect in our possession, we have accepted the rates prevailing in this country. It can, however, be accepted that the insurance rates for the solvent extraction will always be about three times as high as those for any other type of oil milling machinery.

In our opinion the hazards from inflammability and explosion, when using an inflammable solvent, have been greatly exaggerated. When handled by experts carefully and intelligently, observing elementary precautions, risks of accidents should be practically non-existent. It should not be overlooked, however, that the vapour mixtures are explosive and therfore all motors and other electrical equipment should be of the flameproof type wherever placed in the extraction room. Also the tools used should be made of non-sparking materials.

We have discussed the methods which could in our opinion be adopted for the manufacture of crude oil from the oil-containing material which your plant, will be called upon to treat at some length, in view of its importance for the successful economical and technicai implementation of the project.

We will now attempt to summarise the information which we have imparted to you on this subject :—

Summary.

Considerations in favour of expellers are :—

(1) Smaller outlay of capital.
(2) Comparative ease of operation, not requiring as highly qualified personnel as in solvent extraction.
(3) Easier marketing prospects for the residual cake, if disposed of as cattle feed under normal conditions.
(4) Lower steam consumption.

Against the use of expellers :—

(1) Lower oil yield per ton of material treated.
(2) High power consumption.
(3) Considerable wear and tear and cost of replacement of moving parts.
(4) Lower value of the cake as fertilizer.
(5) Limited use for chemical conversion (vegetable protein, &c.) of the meal.

As far as the solvent extraction method is concerned, some of the advantages are :—

(1) High oil yield (about 99 per cent.)
(2) Small power consumption.
(3) The residual cake lends itself to further processing for the manufacture of vegetable fibre, vegetable protein, &c.
(4) Suitability of the de-oiled residue as a fertilizer, also for cattle feed.

The disadvantages are :—

(1) Bigger capital outlay which is normally the case.
(2) Higher steam consumption.
(3) Need for more technical supervision.
(4) Higher insurance rate.
(5) Greater requirements for cooling water.

In some instances it is suggested that the mechanical expressing should be followed by solvent extraction. This procedure, as a matter of fact, was adopted in Germany during the war, when cake with an oil content of 6 per cent. to 8 per cent. was processed in solvent extraction plants, chiefly of continuous type, and the oil content reduced to 1 per cent.

As a general rule we do not recommend this procedure as, in our opinion, it combines all the disadvantages of the two processes without offering any additional economical or technical attractions.

Without going into an elaborate analysis of the combined system it can be said that it entails :—

(1) High power consumption in the mechanical expression.
(2) High steam consumption in solvent treatment.
(3) Depreciation and wear and tear of the mechanical plant.
(4) High insurance rate due to employment of the solvent.
(5) Solvent loss.
(6) Inferior oil from the residue which was exposed to air in the intermediary stage.

On the whole we do not advise resorting to this method unless there are special circumstances which warrant it, amongst them, for instance, availability of cheap power or an abnormally high price for the solvent.

The position, however, becomes somewhat different if high oil-containing material such as copra is pre-pressed in an expeller, which to all intents and purposes would be employed as part of the pre-milling equipment ; the oil content in the residue reduced to, say, 25 per cent., and the thus partly degreased material immediately conveyed to the solvent extraction plant where it is treated.

Arguments in favour of such procedure, if referred to copra as distinct from low oil-containing seed would be :—

(1) The volume of the copra to be processed would be reduced from 200 tons to 75 tons.
(2) Due to the reduced volume to be processed in the extraction plant the losses of solvent would be smaller in the same proportion.
(3) As only slight pre-presssing will take place, the power consumption by the expellers and the wear and tear of the expellers will not be appreciable.
(4) The steam consumption in the solvent extraction will be smaller in proportion to the reduced quantity of the pre-pressed copra.
(5) No deterioration in the quality of the copra oil resulting from the extraction will take place, as the copra meal, after having been pre-pressed, will not be subject to any oxidation, as it will be immediately transported in closed conveyors into closed hoppers for solvent treatment.
(6) As smaller quantities of raw material will be processed, smaller quantities of solvent will be employed ; therefore the consumption of water for condensation of the solvent vapours for the solvent recovery from the miscella will be considerably lower.
(7) The capital investment due to the reduced size of the solvent extraction plant and partial elimination of some of the milling equipment will not be considerably increased by incorporating a pre-pressing equipment, &c.

Bearing in mind all our observations on solvent extraction plant and having considered very carefully the advantages of the various methods for the extraction of crude oil from copra, also not overlooking the fact that different types of material with a varying oil content will be processed, we submit that the following equipment should be incorporated in the scheme :—

(1) Pre-pressing plant capable of dealing with 200 tons of copra, with a continuous solvent extraction plant.
(2) A batch extraction plant consisting of two batteries, each capable of dealing with 50 tons of oilcontaining material.

The reason for our suggesting a continous solvent extraction plant in the first case is prompted by the fact that you will have at your disposal a homogenous material which is more adaptable for a continuous plant than in the second case, where the plant will be called upon to deal with poonac and possibly rapeseed and/or groundnuts.

The idea of breaking up the batch plant into two batteries is based on our envisaging that one battery might operate on poonac while the other might process groundnuts and/or rapeseed. Alternatively, it could treat 100 tons per day of any of the materials.

We are of the opinion that this arrangement would offer you the required flexibility, which is very important, bearing in mind our foregoing remarks.

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Refining.

On the understanding that the scope of the project will not be altered and will adhere fundamentally to the throughputs envisaged by Mr. Balfour, 130 tons of crude coconut oil will have to be pre-refined prior to being subjected to hydrogenation.

The crude oil produced by extraction or mechanical expression contains variable quantities of non-glyceride impurities. Besides free fatty acids which are objectionable in view of their instability to heat and oxidation, and which usually result from hydrolysis, there are present finely dispersed dissolved compounds, organic sulphur substances, oxy-fatty acids, &c.

All these affect the colour, taste and palatability of the product and interfere, if not removed, with the hydrogenation, exercising a toxic effect on the catalyst which renders it prematurely inactive.

There are also traces of albuminous and resinous substances which are to be eliminated. This is achieved by refining, a term which is usually referred to neutralizing, washing and drying, which is an essential part for the purifying of the oil. The term bleaching, which follows refining, is reserved for treatment designed solely to reduce the colour of the oil, whereas deodorization refers to the process for the removal of any odoriferous matter. All these operations will be described later.

The flow-sheet below gives you an indication of the various operations which the manufacture of refined, hardened coconut oil will entail. The same cycle of operations will apply for the refining, hardening and post-refining of groundnut and/or rapeseed oil, should it be decided to produce quantities of ghee for local consumption :—

Neutralizing
Washing
Drying
Bleaching
Filtering
Hardening (hardened oil for technical purposes)
Post-neutralizing
Post-washing
Post-bleaching
Post-filtering
Deodorizing

Cooling	Refined hardened deodorized coconut oil
Blending	
Ghee	

It can be stated that some of the operations mentioned above might be eliminated if the quality of the crude oil is of a very high grade. For instance, we might find that the neutralizing, with its somewhat expensive application of caustic soda, oil losses, &c., could be replaced by a simple desliming.

The same might apply to using considerable quantities of bleaching purposes.

It can also be said that we might find in the course of manufacture that the post refining of the hardened fat can be avoided.

For the purpose of this report we have accepted, however, that a coconut oil with a free fatty acid content of 2 per cent. will be processed, requiring all the operations indicated above and up to about 3 per cent. of earth for bleaching purposes.

By following this course we felt that we were increasing the safety margin of our calculations to a considerable extent.

Reverting to refining, there are a number of methods available which we have considered for your project, such as neutralizing by distillation, use of selective solvents, soda ash treatment (Glayton's method), continuous centrifugal separation (Sharples), &c. There is also a newly devised method of refining oils by continuous method, including continuous bleaching, suggested recently by the Girdler Corporation. All of them aim at the reduction of refining losses and deserve attention in countries where the oil is being imported, also where the aspect of saving as much as possible of the neutral oil from going into soap stock is of paramount importance.

These methods, however, involve complicated operation and equipment. They are, in our opinion, not to be recommended for your purpose at this stage, as the cost of oil in relation to the price which the final product commands is low and you have a ready outlet for your soap stock, the quantity of which, as already explained, increases in direct proportion with the refining losses.

By far the most important and generally practised method of refining is by means of alkali, a method which we propose to submit to you as meeting your requirements. This way of refining effects an almost complete removal of free fatty acids, which are converted into soap insoluble in oil, which forms the soap stock. It also coagulates most of the albuminous substances and has a bleaching effect on the oil.

As you will have observed, we have not discussed in detail in this memorandum the technology of neutralizing, which is concerned with the proper amount and concentration of alkali used to produce the desired purification without excessive saponification of neutral oil, nor have we mentioned all the methods for the efficient separation of the refined oil from soap stock.

The necessity of dealing with all these aspects of the scheme will only arise during the later stages, when your personnel will have to be proved regarding the most economical method for the refining of the fatty oils.

The neutralization with alkali completed, the soap stock is separated either by settling or, what we would recommend eventually as a more up-to-date method, by centrifuges. The oil is then subjected to washing with brine and hot water to remove any traces of soap or alkali in the oil. Drying under vacuum follows and the oil is then subjected to the bleaching operation.

The object of bleaching is to remove colour pigments relatively unaffected by the preceding refining. This treatment consists of bringing the oil into close contact with a solid absorbent, which has an affinity to the colour substances. Fuller's earth and activated carbon are usually used as effective bleaching agents.

There are other methods of bleaching available, such as treatment of the oil with an oxidizing agent capable of oxidizing these pigments to a colourless form. These methods, however, have a limited application and should not be used in connection with the manufacture of edible products.

Another reason for the bleaching, and this refers to oils which will be subjected to hydrogenation, which in itself exercises a bleaching effect, is that the bleaching earth tends to absorb traces of soap and other catalyst poisons which may have been left in the oil after refining. The bleached oil is separated from the bleaching agent by means of filter presses, and is ready either for deodorizing, if used as a liquid oil, or for hydrogenation.

As the hydrogenated oil in any case undergoes the same deodorizing procedure as the liquid oil, with very small variations of the conditions under which it takes place, we shall discuss the deodorizing of hard and liquid oils under one heading in a later part of the report, after having described the hardening procedure.

Hardening.

The main object of the scheme, as originally envisaged by Mr. Balfour is to submit a project whereby the maximum quantity of hydrogen can be employed for the hardening of coconut oil.

We have been advised by Dr. Underwood that the quantity of hydrogen which will be made available as a by-product from the caustic soda plant will be about 50,000 cubic feet per day. It was, moreover, indicated to us that for at least during the initial stage of the implementation of the project coconut oil should be regarded as the oil which will mainly be made available to the oil factory for the purpose of hardening.

It has already been pointed out to Mr. Balfour that coconut oil, due to its physical and chemical properties, the nature of which has already been referred to in the previous part of this report, cannot absorb large quantities of hydrogen.

Having accepted an average iodine value in the coconut oil of 8 (iodine value is a measure of unsaturation of the fatty oil and therefore predetermines the quantity of hydrogen which can be absorbed by the unsaturated portions of the fatty oil) and reducing it to 1·5, the quantity of hydrogen available would be sufficient to harden about 200 tons of coconut oil.

Inquiries which we have made lead us to conclude that, if the hydrogen were diverted for that purpose only difficulties might be encountered in disposing of the somewhat large tonnage of hardened coconut oil.

We therefore submit after due consideration and in order to be consistent not only with the marketing conditions but also with the quantities of copra which (according to Mr. Jayawardena) could be placed at the disposal of the industry that only 130 tons daily of pre-refined oil should be hardened. This would roughly account for 34,000 cubic feet of hydrogen leaving 16,000 cubic feet of hydrogen which could, for the time being either be used as a fuel, although its low thermic value is fully realised by us, or used for the hydrogenation of groundnut and/or rapeseed oil with a view to producing ghee.

Although the manufacture of ghee does not really fall, within the terms of reference of our investigation, as you will see later in the report, we have given some consideration to the production of ghee as, in our opinion, it would be worth your while to examine this aspect of the oil project.

The hydrogenation of fatty oils can be defined as a process whereby a part or, in some cases, nearly all unsaturated acids and glycerides in the oil are caused to combine under certain conditions with hydrogen in the presence of a substance referred to as " catalyst ". In this way the olein present as a liquid in the oil, by absorbing six atoms of hydrogen, produces stearin, a hardened substance. Only about 0·68 per cent. hydrogen is required to convert one unit of liquid olein into a hard stearin.

The degree of hydrogenation of the oil is directly related to its iodine value, the addition of one molecule of hydrogen corresponding to the absorption of one molecule of iodine. Theoretically approximately 34 cubic feet of hydrogen are required for each reduction of an iodine unit per ton of oil.

When studying the equipment for the hardening of oils, consideration was given to :—

(a) Continuous hardening with a stationary nickel catalyst, as manufactured by Technical Research Works, Ltd. (T.R.W.).

(b) Batch method with the use of a powder catalyst with or without " inert " support. This type of plant is manufactured by the Power-Gas Corporation, Messrs. Bamag, Ltd., and others.

Very recently the Girdler Corporation, U. S. A., put forward a claim for a continuously operating hydrogenation plant using a powder catalyst. As no proof of whether such a plant has yet been operated by them successfully has been obtained from the Corporation, we have decided for the time being to disregard their method of hydrogenation.

Continuous Method.

The fundamental principle underlying the T. R. W. continuous plant is that a soild stationery catalyst is placed in a battery of column usually made of drawn steel and provided with a jacket. The catalyst, commonly known as catalyst cage, cosists of monel metal gauze filled with activated pure nickel turnings. Oil and hydrogen pass through the catalyst under appropriate pressure and temperature, and the oil undergoes the hardening process while being forced through the system.

The important feature of this method, which differs considerably from the batch method, is the preparation of the catalyst and its reactivation after its catalytic potency has been spent as a result of its gradual poisoning in the course of hydrogenation.

The complete cycle of operations of the T. R. W. plant consists of :—

(1) Preparation of the catalyst by anodic oxidation in an electrolytic solution of a certain strength and at a specified amperage and voltage.

(2) Reduction of the nickel oxide formed during the oxidation by passing hydrogen gas under slight pressure through the catalyst cages at a temperature of about 25°C. Reaction follows the equation $Nio + H_2 = Ni — H_2O$.

(3) Actual hydrogenation, which occurs when the pre-heated oil and hydrogen are introduced under pressure varying between 50 and 150 lb. per square in. through the activated catalyst.

(4) Degreasing of the catalyst after the catalytic properties of the cages have been spent by pumping an appropriate solvent through the installation. The solvent is recovered by distillation in the usual way.

(5) Following the degreasing, the reactivation of the catalyst, in the manner described in (1) above for the purpose of restoring its activity.

To harden, say 65 tons of groundnut oil in twenty-four hours to a melting point of 40/42°C., the T. R. W. plant would consist of not less than 108 reaction tubes. These would necessarily have something like 700 to 800 valves essential for the operation of the plant. Each of the valves and flanges in the reactors offers a potential source of gas leakage, and, as hydrogen is a readily diffusible gas, the losses would inevitably be higher than in the batch process, which will be described later.

The catalyst require a month or two to reach a stage when they can produce the optimum results, as seven to ten reactivations and reductions are indispensable before the cages reach "maturity". Although the plant is continuous in the sense that the refined oil is fed into the system without any interruption and withdrawn as a hardered product continuously, the installation must nevertheless be closed down from time to time for the removal of the exhausted catalytic cages, degreasing of the plant and reactivation of the cages for further use. Thus, certain sections of the installation unavoidably remain inoperative for several days in turn every few weeks. This is not entirely satisfactory from an economic point of view and somewhat offsets the advantages which the principle of continuity of operation offers.

The catalyst cages are usually reduced in the T. R. W. plant by using superheated steam. As the heat transfer coefficient of superheated steam is poor, this does not offer a great attraction, bearing in mind that the steam valves, glands and packing are called upon to stand up to both wet and superheated steam, which leads to an increased cost of maintenance and is an additional strain on the technical staff. Mineral oil or diphenol as a heating medium would be more satisfactory, but the additional equipment would increase the cost of the plant.

As any form of oil hardening is influenced by factors such as mass of catalyst, thermic conditions, pressure, rate of agitation and state of " intimacy " between the catalyst, oil and hydrogen, one must bear in mind while assessing the relative advantages of the continuous plant, that the same catalyst remains in the plant from the commencement of the run until the time when the plant must be closed down in view of the drop in potency of the catalyst.

As the activity of this catalyst gradually decreases and cannot always be compensated by an increase in temperature of the oil and pressure of hydrogen and, as the structure of hardened fat depends greatly on its activity, the obtaining of a standard product is not always feasible.

We ourselves have operated a number of T. R. W. plants and have found them extremely satisfactory as long as their limitations are taken into account and the throughput within, say 10 to 20 tons per day.

The advantages of continuous hardening with a permanent catalyst are not to be overlooked, however, and might be considered by you at a later date should you decide to erect a small capacity plant elsewhere ; they are :—

(1) The catalysts are easily reactivated and reduced, thus making the plant entirely independent of the supply of the nickel salts required for the batch process. An analysis shows that the cost of reactivation of the catalyst is far less than the loss of nickel when, say, nicel formate is used as a catalystic agent.
(2) The oil hydrogenated by means of the T. R. W. plant does not necessarily require a subsequent filtration although it is preferable in our opinion.
(3) The principle of continuity of operation (even an interrupted one) is an advantage, as it does away with a fluctuating demand on steam and electric power.
(4) The time of contact between the catalyst and the oil under high temperature is limited to 20 to 30 minutes, which is an attractive feature, especially when oils of the semi-drying type are being processed.
(5) There are no moving parts, consequently the wear and tear is very slight.

Batch Method.

The theoretical considerations on which continuous hydrogenation are based are applicable to the batch method as well, with the difference that, instead of a stationary catalyst, a nickel salt, which is eventually reduced to metallic nickel, is used.

Although several developments have taken place since the first Norman's patent was granted, the general practice for the batch process remains the same. It consists of—

(1) The preparation of nickel salt, with or without support.
(2) Its reduction under certain thermic conditions to metallic nickel.
(3) Mechanical agitation between the finally divided catalyst in the oil through which hydrogen is being passed at temperatures varying between 140° and 200°C.
(4) Separation of the catalyst from the oil after the completion of hardening.

The question of catalyst is dealt with under a separate heading.

The advantages and disadvantages of the two methods of hardening of the oil in the light of your requirements can be summed up as follows.

The batch method differs from the continuous inasmuch as with the former there is a certain dependency in obtaining the catalyst, which must be procured or manufactured by yourselves. The reduction, wet or dry, of the catalyst required attention and is somewhat more complicated than the oxidation and reduction of the stationary catalyst. As the hardening operation itself is accomplished in about two hours, the resulting intermittent demand on hydrogen and steam fluctuates during the operational period and an ample reserve storage of the gas is required.

On the other hand, the standard and uniformity of quality of the pre-refined, oil need not necessarily be as high as it is in the case of the continuous method. Poorer quality can be offset by a slight increase in the quantity of catalyst used. The degree of saturation of the unsaturated portions of the oil (hardness) is easily controlled, as the reaction can be checked at any stage by stopping the agitation and closing the hydrogen inlet valve. If the oil is insufficiently hardened, the reaction can be recommended after the necessary tests have been carried out, and the desirable melting point obtained. This is more difficult to attain in a continuously operating unit.

The batch method offers greater flexibility if an increase in output with the same plant is required, as long as the necessary quantity of hydrogen is available.

By blending the spent and fresh catalyst in certain proportions, an even structure suitable for fixed blends of margarine, ghee and shortening can be obtained. The same applies if the hardened product is used for soapmaking, where a constant titer is essential, for the manufacture of a standard brand of soap.

The hydrogen losses are less, due to the fact that the plant operates at pressures considerably lower than those employed in the continuous plant, and has a lesser number of valves and glands.

We are of the opinion that, whilst the operation of the continuous plant offers a not inconsiderable saving in the cost of production, it has certain limitations which make the manufacture of a homogeneous hardened oil for universal use, namely, technical and edible, somewhat speculative. The same applies if, for some reason or another, the melting point of the fat must be raised, say, to 44/46°C. Such an increase in melting point would require a corresponding reduction in iodine value and would lead inevitably, if the T. R. W. method is used, to a very considerable decrease in the throughput of the plant. This would not be the case in a batch process, say, for instance, if a five-ton converter (auto clave) is used ; the time of actual hardening of an oil to a melting point of 36/38°C. should then not be more than an hour and a half ; to a melting point of 44/46°C., the hardening period could be extended by another hour if necessary, with a slight addition of fresh catalyst. The throughput could then be maintained irrespective of the melting point.

In view of the above we have decided not to consider a T. R. W. plant for your project.

Catalyst.

The catalyst employed in hydrogenation on a commercial scale invariably consists of nickel, although in some cases quantities of copper, aluminium and other metals are incorporated to form an alloy, usually referred to as " bi-metal " catalyst.

The catalyst decreases in activity with repeated use but its inactivation is relatively slow, and it can ordinarily be used a number of times.

As catalyst can be defined as " a substance which promotes the chemical reaction without affecting the energy factors of the reaction or being consumed during the course of reaction, " it possesses a regenerative nature. It might form temporary combinations with the reactants, but these are unstable and are broken down at the completion of the reaction to yield the catalyst in a practically unchanged form. Thus the catalyst enters into reaction over and over again, and this is why relatively small quantities of catalyst are capable of promoting the hardening of large amounts of material.

Since, however, the activity of a catalyst depends upon the presence of relatively few metallic atoms of a very high reactivity, these atoms display a marked avidity for many substances other than hydrogen and glycerides. If such substances are present in the form of impurities in the hydrogen or oil, they will gradually concentrate on the catalyst surface saturating the active atom and rendering the catalyst inactive. Such substances are termed catalyst poisons. Among them we could name sulphur compounds, carbon monoxide, sodium and other soaps, &c.

Hence, the emphasis which we endeavour to lay in this report on the necessity for pre-refining the oil and our preference for electrolytically produced hydrogen. The above also explains why, although the catalyst can be re-employed several times, it cannot last for ever.

The consumption of nickel in the hydrogen reaction is small and varies between ·05 and ·5%. Usually it is estimated in practice that one kilo of catalytic nickel metal is required for the hardening of one ton of oil, say, to a melting point of 38/40°C.

The catalyst can be used with or without so-called " inert " support. In the first case the catalyst is as it were attached to a support, generally kieselghur ; in the second the catalyst powder is free and so to speak suspended in the oil.

The preparation of a catalyst with a support entails the precipitate of nickel hydroxide or nickel carbonate on diatomaceous earth or other refractory support, drying and grinding the precipitate and reducing the resultant powder in a current of hydrogen at high temperature. It is during the reduction that the catalyst is activated (this being the so-called " dry " method.)

The preparation of catalyst without support is represented by the nickel formate method, or so-called " wet " method, and entails thermic decomposition of nickel formate suspended in oil, during which procedure it is reduced to an active metallic nickel.

In comparing the two methods, the following observations could be made :—

(1) The preparation of dry reduced catalyst differs fundamentally from that reduced by the wet method in that the activity of the former is determined during the precipitation, whereas the activity of the latter depends principally upon the conditions of reduction.

(2) As the precipitation procedure is in itself quite complex and, as the activity of the dry reduced catalyst depends upon a number of operating factors, such as temperature at which precipitation takes place, the rate at which the nickel salt and alkali are mixed, the excess of alkali, time of boiling to which the suspended precipitate is subjected, &c., it follows that the preparation of a standard quality catalyst is more complicated by the dry method than that prepared by the wet method, where the main determining factor is a relatively simple reduction in specially designed and easily controlled apparatus.

(3) Nickel catalyst prepared from nickel formate has good activity and, although it may be somewhat more expensive than catalyst prepared from a cheaper nickel carbonate, possesses desirable characteristics in respect of selectivity and formation of iso-oleic acids for hardening purposes.

(4) The catalyst can be made more uniform that that produced by the wet method.

(5) Since the nickel catalyst from nickel formate is activated while in contact with oil, the somewhat troublesome operation of transferring the catalyst to the oil without access to air is avoided. This is not the case with the dry method of reduction.

(6) The chief disadvantage of the wet reduced catalyst is that it contains nickel particles of colloidal or near colloidal dimensions, which are difficult to filter from the oil after hydrogenation is completed. This can, however, be minimised by the addition of some filtering medium to the hardened oil.

(7) The cost of nickel formate in this country is £250 free on board per ton of 2,240 lb. The content of nickel and the nickel salt is about 31 per cent. The dead loss of nickel due to filtration, &c., is usually estimated at 1 per cent. As said already, the nickel catalyst can be reused several times with the addition of freshly prepared catalyst. The completely exhausted catalyst is usually disposed of in this country at about £100 per ton, based on its Ni content.

A recently introduced method of catalyst preparation by electrolytic precipitation claims to yield a product of high catalystic activtic. This method involves corrosion of metallic sheets in an electrolytic solution by a direct current. The nickel is precipitated in the form of nickel hydrate on kieselguhr suspended in the electrolyte.

The method was introduced by Messrs. Sieck & Drucker in the United States and is now under investigation by us. As we so far possess no evidence as to whether their claims can be substantiated, we have refrained from recommending the method at this stage.

A product described as "hydrogenator's fluffy carbonate" is now being marketed by a United States manufacturer. This merely requires to be boiled in water with an equal weight of kieselguhr to produce what is claimed to be an active and uniform catalyst.

Unless difficulties are encountered in obtaining nickel formate, we do not propose to recommend you to resort to this.

We have not included in our proposals a plant for the manufacture of nickel formate or for the recovery of it. The cost of such an installation is not very great and, upon your reaching a decision to proceed with the scheme when final plans will be worked out, we shall suggest to you that such equipment should also be included.

Hydrogen Production.

Although one of the main objects of the scheme is to utilise the hydrogen resulting from the electrolysis of sodium chloride, we were asked by Mr. Balfour to regard the oil processing section as depending on its own hydrogen generation. This is in order to be able to assess the benefits which will accrue to the oil section by suing the hydrogen which will be derived as a by-product.

There are a number of methods for the generation of hydrogen, the economics of each of them are predetermined by local conditions. We will briefly describe all of them :—

1. *Hydro-carbon Steam Process.*—Whereby pure hydrogen is produced by reacting hydro-carbons with steam over catalysts at elevated temperatures (about 1500 F.) under conditions such that hydro-carbons are almost completely converted to carbon oxides and hydrogen. Carbon monoxide and steam are then converted catalytically to hydrogen and carbon dioxide, the latter being removed from the hydrogen by appropriate scrubbing. This method is known as Girdlers Hydro-Carbon Steam Process.

2. *Water Gas Process.*—This method produces relatively pure hydrogen be passing water, gas and steam over catalysts at elevated temperatures. The carbon monoxide reacts with steam to produce carbon dioxide and hydrogen. The gases are cooled and carbon dioxide is separated from the hydrogen by scrubbing with water under pressure.

3. *Steam Iron Process.*—In this process hydrogen is generated by passing steam over hot iron ore which has been previously reduced by water gas. At elevated temperatures iron and steam react to produce iron oxide and hydrogen. The characteristic feature of this process is that it is intermittent with alternative cycles of ore reduction and hydrogen production. Fairly high purity hydrogen may be obtained by a suitable purification of the gas.

4. *Methanol Steam Process.*—Methyl alcohol will react catalytically with steam at elevated temperatures and produce hydrogen and carbon dioxide. A fairly pure hydrogen is obtained by scrubbing carbon dioxide from the mixture. This process can only be considered on countries where methyl alcohol is relatively cheap.

5. *Electrolytic Process.*—Hydrogen and oxygen are produced by electrolysis of water. This process is extremely popular, but can only operate economically in countires where the cost of power is not excessive. Another outstanding feature of this process is the high degree of purity of the hydrogen which is entirely free from carbon compounds. The electrolytic method is in many respects the simplest way of making hydrogen.

There are two types of electrolyser being offered :—

(*a*) So-called " Knowles Cells ", manufactured by the International Electrolytic Plant, Ltd., in the United Kingdom, and

(*b*) Filter press type of electrolyser, manufactured by Messrs. Bamag, Ltd., in the United Kingdom, and Oerlikon, Ltd., in Switzerland.

The principal essentials of the two types are a motor generator combination, or any other source of supply of direct current, a number of electrolytic cells, supplemented by a hydrogen holder for receiving the hydrogen.

Normally, when electrolysis of caustic lye is employed, oxygen is a by-product of the process, and represents by volume 50 per cent. of the generated hydrogen and, where a market is available, equipment is usually provided for its receiving, compressing and bottling under pressure.

As to the merits of the open Knowles cells in comparison with the filter press type, since the passage of a definite quantity of current should always produce the same amount of hydrogen regardless of the type of equipment, it can be said that there is little variation in their respective efficiencies.

One ampere hour liberates 0·16 cubic feet of hydrogen measured at ordinary atmospheric pressure and temperature or stated in another way, approximately 125/135 KWh are required to produce 1,000 cubic feet of free hydrogen. For calculation purposes, however, we have accepted the figure of 150 KWh.

The purity of the hydrogen in the two types is extremely high and approaches 99·95%, while the purity of the oxygen is about 99·8%.

There are, however, several features in favour of the " filter press " type. The space required for the filter-press electrolyser is considerably less than that needed for the Knowles cells. The electrolytic solution does not come in contact with the air as is the case in the open type cells. This is of importance as the sodium or potassium hydroxide in the solution absorbes carbon dioxide from the air, and the resulting carbonates may lower the efficiency of the equipment. The electrolytic solution is continuously circulating in the filter-press type, thus maintaining an even concentration, while in the Knowles cells there is the constant necessity of making up the electrolyte, which varies in its concentration due to such possible causes as overflow, frothing and carbonisation.

In fairness to Knowles cells it can be stated that, notwithstanding the above, this type of equipment represents an efficient installation lasting for many years, although it needs more attention than the filter-press type and does not require any equipment to maintain lower temperatures of the electrolyte to give the most efficient working temperature of the battery when the ambient temperature is high.

It is highly unlikely that you will generate your own hydrogen but, bearing in mind that this aspect has only been investigated by us at the request of Mr. Balfour for illustration purposes, we have incorporated in the scheme the electrolytic method of hydrogen generation.

Should a situation arise when the implementation of the project will require an independent source of hydrogen (which we understand is highly improbable) other methods might be considered, but it can be said already that investigations carried out by us for similar projects have shown that the iron contact method, although producing hydrogen of lower purity, is considerably cheaper than the electrolytic method with the reservation, however, that not less than 3,000 cubic feet of hydrogen should be produced hourly.

The cost of hydrogen generated by the steam iron process was given to us some time ago by Messrs. Humphreys & Glasgow. The generation of the gas is based on coal, not on coke. Humphreys & Glasgow's calculations show that, with a depreciation rate of 15% which, considering the type of plant in our opinion is not too high and the cost of coal being 12/- per ton, the generation of 1,000 feet of hydrogen would cost 3/5*d*., whereas electrolytically produced gas would cost about 17/- based on a cost of power of 0·82*d* K Wh

The reason why we have suggested the electrolytic method for the generation of hydrogen in our calculations was influenced by the following factors :—

(1) Capital outlay.
(2) Purity of gas.
(3) Cost of generation of hydrogen bearing in mind the relatively small volume of gas to be produced.
(4) Space requirements.
(5) Cost of depreciation and maintenance.

Post-Refining

Having hardened the oil to the required melting point, the hardened oil, if it is desired to obtain a high quality product, undergoes an additional processing inasmuch as it is post-neutralised, washed, dried and, if necessary (this is not always the case), bleached.

The reason for this is that during the hardening operation a certain hydrolysis of the hardened fat might take place and an acidity develop.

Adoption of this procedure is sometimes avoidable but provision had to be made to deal with cases when the increase of the acidity warrants such post-processing.

We shall not describe the post treatment as it follows closely the procedure which crude oil is subjected to in its first stages of treatment already mentioned.

Deodorisation.

We have now reached the stage when the refined and bleached soft oil and, in some cases, post-refined hardened oil are available. The next process which the fat has to undergo is usually referred to as deodorisation. This treatment can be described as a process of steam distillation wherein volatile odoriferous substances are stripped from the relatively non-volatile oil or fat.

The operation is carried out at a high temperature to volatilise the odoriferous components. The application of reduced pressure during the operation protects the hot oil from atmospheric oxidation and also reduces the danger of any hydrolysis in the oil by the steam. The main reason for this is to lower the temperature below destruction point and to give a high partial pressure to the volatile substances. Moreover, the vacuum reduces the quantity of steam required to carry out the operation.

Only a few of the components responsible for the taste and odour of the oil have been identified. Certain ketones, aldehydes and substances related to them have been traced as sources of the odour.

It has been observed that the flavour and odour removal is generally parallel to the reduction of the content of free fatty acid in the oil. Thus, for example, if an oil has an initial free fatty acid content of 0·1 per cent., the disappearance of odour usually corresponds to a reduction of the free fatty acid content to 0·02 per cent. It is calculated therefore that the vapour pressures and molecular weights of the odoriferous substances are of the same order of magnitude as those of the common fatty acids of 12 to 18 carbon atoms.

In the case of hydrogenated fats, these usually acquire a specific smell known in the trade as "hydrogenated odour". Pinakolin (C_{22} $H_{44}O$) which has been traced in minute quantites in hydrogenated oils, is generally thought to be one of the agencies responsible for this odour.

The importance of this part of treatment of the oil cannot be over-emphasised as, not only does it contribute considerably towards the manufacture of a good product, but it has always a considerable bearing on the keeping property.

As far as equipment for deodorisation is concerned, this falls into two groups, batch and continuous.

For the purpose of this report we have based our calculations on the batch but when the project reaches a more advanced stage we shall suggest that tenders be called for in respect of continuous deodorisation equipment as well, as this offers certain attractions from the point of view of lower steam consumption, reduced time of contact between the oil and heat, even steam load, &c.

We should like to mention in this connection, however, that this type of plant is not so far manufactured in this country and, if the choice falls on continuous deodorisation, the orders will have to be placed in the United States.

Splitting of Coconut Oil derived from the Extraction of Poonac.

The preparation of fatty acids from glycerides was originally developed by the candle-makers, who used the fatty acids made from tallow and palm oil in their industry. The increasing demand for fatty acids has led to considerable improvement in the operational procedure involved.

There are a number of processes which we have considered before submitting to you our recommendations as to the type of equipment which should be incorporated in the scheme.

The fat splitting processes could be grouped under the following headings :—

(1) Lime saponification.
(2) Acidification.
(3) Enzyme process.
(4) Twitchell process.

All these are carried out at atmospheric pressure. Processes which are operated at pressures above the atmospheric can be divided into two classes :—

(1) Splitting at pressures between 8 and 12 atmospheres with a suitable catalyst.
(2) High pressure splitting (between 30 and 100 atmospheres) with or without catalyst.

At this stage we do not intend to submit to you in detail the reasons which prompted us to disregard the various processes enumerated above and recommend you to carry out your splitting in an autoclave under moderate pressures using zinc oxide as a catalyst. This method has the advantage over, say, the Twitchell process, inasmuch as it produces a fatty acid of high degree of splitting and of a colour very much superior to that in the Twitchell equipment, which uses a somewhat expensive reagent consisting of a sulphonated mixture of commercial oleic acid and benzene or naphthalene, although other and better reagents are employed by some of the firms in this country.

Bearing in mind the small throughput of the proposed installation, *i.e.*, about 5 tons of oil per 24 hours, it was felt by us that a low pressure equipment (which is considerably cheaper than one operating under high pressures) would meet the case.

As can be seen from our calculations, we have assumed that the oil content in the poonac will have an acidity of 5 per cent., and this will somewhat decrease the quantity of glycerine which can be obtained from splitting of a coconut oil with a lower free fatty acid content.

The glycerine water which will be obtained as a result of the splitting will be evaporated to a consistency of 80 per cent. glycerine and deliver daily something like 0·8 tons of that commodity.

The 1945 Review of the Oil Seed, Oil and Oil Cake Markets, by Frank Fehr, gives the price for glycerine outside the British controlled zone as varying between £95 and £220 per ton.

Manufacture of Artificial Ghee.

During the various discussions with Mr. Balfour and Mr. Jayawardena, an opinion was expressed that the manufacture of ghee should also eventually be considered as part of the proposed manufacturing programme under the scheme. We have therefore included in our calculations a rough summary of the cost of ghee should it eventually be decided to embark on its manufacture.

There is no set definition as to what an artificial ghee should represent with regard to its composition, method of manufacture, &c., except to aim at approaching as closely as possible the appearance, consistency and characteristics of the natural ghee.

We are aware of advances which have been made in India in the production of the substitute for natural ghee, the sale of which has been legalised by the Bombay Adulteration of Ghee Act. The Act required that all such products must be correctly described and that the presence of any fat not derived from the milk of buffalo, goat or sheep must be declared. We do not know if a similar legislation is being enforced in your Dominion.

Vegetable ghee in most cases consists of hydrógenated vegetable fats or mixtures thereof with vegetable oils. Recent legislation by the Vegetable Oil Products Control Order dated July 28, 1945, No. 5/VP/1/45, issued by the Government of India, prohibits the manufacture of any vegetable oil products which do not conform to a certain specification. A very high standard for the product is thus laid down, the manufacture of which, however, entails not only the employment of efficient machinery but also a great deal of skill and understanding of all the processes involved

As far as the nutritional value of such product is concerned it can only be said that consisting of almost 100 per cent. of fatty material, if manufactured under proper conditions and in conformity with the regulations laid down by the Indian Government, an extremely useful contribution towards national nutrition would be made ; this naturally if used in sufficient quantities by the population, thus preventing a number of diseases caused by internal disturbances due to non-consumption of fats.

You are aware that fats are the greatest energy producers ; they furnish weight for weight more than twice the amount of heat and energy obtained from carbohydrates, and can be looked upon primarily as a source of energy in the national diet. In fact, ghee is the main concentrated fat material, furnishing about 9·5 calories of energy per gramme as compared with 4 calories generated by proteins and carbohydrates.

We do not know the conditions prevailing in Ceylon with regard to national nutrition. Judging, however, by the information which we have had from India, the bulk of the population there is suffering from a diet deficient in high-grade fats. According to Professor Gangulee, lack of fats in maternal diet produces children of low birth weight, and it is undoubtedly one of the contributory reasons for the high infant mortality prevailing in India.

It has been observed that in cases when the population was deprived of sufficient fat intake the health standard has deteriorated considerably. This occurence has been partly explained by the fact that the addition of fats adds to the palatability of other foods whilst the absence of fats delays digestion and causes a premature sensation of hunger after eating.

It is interesting to observe that it appears there are other and more deep-seated reasons for the natural craving of the human organism for fats. Fats and their component fatty acids appear to perform quite a number of vital functions which are quite unrelated to their action as energy bearing substances, as it is assumed that fatty acids in combination with phosphatides are apparently essential constituents of many kinds of body cells. The deficiency of some of the unsaturated fatty acids leads to a form of dermatitis.

As you will notice from our calculations we have also allowed for the vitaminisation of the ghee, as most of the vegetable oils are deficient in oil-soluble vitamins and hydrogenated fats are completely lacking in vitamins, although it can be said that it is a generally accepted opinion that fats form an important accessory role in the absorption of carotene, thiamine and other equally important substances.

As to the digestibility of ghee, it can be said that it has been demonstrated through the work of Langworthy Holmes and others that there is no significant difference in the digestibility of different fats and oils except in the case of those which have melting points considerably above body temperature (about 50°C) and are digested somewhat less completely than lower melting point products. This aspect was taken into account by us when the composition of the ghee was considered.

Production of Fatty Alcohols.

We promised Mr. Balfour to make some brief reference to the possibility of production of fatty alcohols from coconut oil.

Alcohols of fatty acids such as lauryl alcohol, palmityl alcohol, &c., are at present in considerable demand for the manufacture of detergents and wetting agents. They are prepared on a large scale in this country and in the United States by catalytic hydrogenation of the corresponding acids, esters or glycerides. A variety of catalysts could be used for the reaction ; usually, however, they are of a bimetal type.

The hydrogenation can be carried out either by batch or continuous method at a temperature varying between 280°C. and 300°C. and at a pressure in the neighbourhood of 3,000 lb. per square inch.

In your case the coconut oil would offer a very interesting material for such conversion. We have not investigated the processing costs of the fatty alcohols in detail but give you below some information relating thereto.

The power consumption is about 2 KWh per kilo of alcohol produced ; the consumption of catalyst is about 1·5%. A very rough cost of production of one ton of lauryl alcohol could be estimated at about 1/6*d.* per lb., whilst today's price in this country has been given to us as something like 7/6*d.* per lb.

A plant of the capacity of, say, 3 tons of fatty alcohols per 24 hours would cost in the range of £35,000.

It is generally thought that the demand for fatty alcohols will be on an ever-increasing scale and the margin of profit at the price offered by the market is extremely high.

Conclusions and Recommendations.

In perusing this report it must be borne in mind that all our calculations were based on certain throughputs and any revision on your part of the ramifications of the scheme will inevitably necessitate a fresh examination.

It must also be borne in mind that the prices obtained for the various plants required are approximate and do not include the cost of shipping the machinery to Ceylon. Nor has provision been made for any possible duty which might be imposed on the import of the equipment, nor for the cost of buildings, preparation of site, sewage, cabling, instrumentation, laboratory, maintenance workshop or foundations.

You will also observe that we have omitted to provide you with an estimate of the profits to be anticipated should the scheme be implemented, but we thought it would be somewhat unwise to do this in view of the different prices prevailing in British controlled zones and the open market.

We trust, however, that the cost of processing shown by us, yields to be anticipated and the by-products to be obtained will enable you to assess the profits yourself as soon as you are able to ascertain the prices which your commodities can be expected to command.

Production of Crude Coconut Oil from 200 tons of copra.

As can be seen from our calculations and from the general part of the report setting out the various methods which were considered by us for the processing of copra for the purpose of production of crude coconut oil :—

(*a*) The cost of processing one ton of copra by using a continuous solvent extraction plant would be :—

£1. 5*s*. 2*d*. per ton.

The capital investment for the equipment which the application of this method entails is estimated as being about :—

£154,250.

(*b*) The cost of processing one ton of copra by using a mechanical pre-expelling, followed by continuous extraction is :—

19/10*d*.

The capital involved is :—

£119,700.

(*c*) The cost of processing one ton of copra by employing a mechanical expelling followed by batch solvent extraction would be :—

£1. 0*s*. 4*d*.

The capital involved is estimated as being approximately :—

£103,700.

We have eliminated the method under (*a*), which entails a larger capital investment and higher processing costs.

We have not submitted to you our calculations of the cost of processing copra by applying either hydraulic presses or double expelling. These costs, in the light of our own experience with that type of equipment, compare unfavourably with the cost of processing by any of the methods described above.

It is therefore our considered opinion that, although the method for the production of crude oil under (*b*) entails a larger capital outlay and offers on the face of our figures only a saving of 6*d*. per ton of copra treated under factory conditions, we have reason to believe that the claims of the makers of continuous solvent extraction plant that the solvent loss is in the range of 0·5 per cent. to 0·7 per cent., as compared with 1 per cent. in the batch extraction, will be borne out and therefore the saving should be greater than estimated by us.

We therefore recommend that the 200 tons of copra should be processed by subjecting the copra to a mechanical pre-pressing to be followed by continuous solvent extraction, the approximate cost of the plant involved being :—

£119,700.

Processing of Poonac.

We have discarded the mechanical method of extracting oil from poonac due to the low oil content of the material.

Owing to the comparatively low throughput, *i.e.*, 50 tons per day, we consider the employment of a continuous solvent extraction plant as uneconomical.

We therefore recommend a solvent batch extraction whereby the cost of processing per ton o poonac would be £1. 10*s*. 9*d*. per ton and the capital cost involved in the acquisition of the equipment would be :—

£36,800.

Processing of Groundnut and/or Rapeseed.

Our remarks referring to the processing of poonac apply.

We recommend a batch solvent extraction plant whereby the cost of processing of one ton of groundnut and/or rapeseed would be approximately £1. 10*s*. 9*d*. per ton of seed, and the cost of the plant would be :—

£38,500.

(The additional cost in comparison with the poonac plant is due to different pre-treatment of the seed prior to solvent extraction.)

3——J. N. 11725 (12/47)

This is on the understanding that you are confident of obtaining the required quantities of groundnut and/or rapeseed, or that a quantity of 100 tons of poonac could be made available to this section of the plant.

Processing of Crude Oil.

Although a number of methods different from the one on which we have based our calculations have been described, for reasons outlined in the general part of our report, we have based our costing on the conventional and usually accepted batch method of refining the oil by an alkali (caustic soda), washing, drying, bleaching, &c., and hardening by employing nickel formate as catalyst.

We have also gone into the cost of producing a post-refined and deodorised coconut oil, should the market offer better facilities for the disposal of such a commodity, *i.e.*, hardened, refined and deodorised coconut oil.

We have omitted from our calculations the cost of packing the manufactured product, as it was impossible for us under present conditions and the prevailing shortage of steel to assess this. We are, however, given to understand that, should the product be shipped in large containers as distinct from shipping in bulk, £5 or £6 per ton of fat shipped should be an adequate allowance.

Refining and Hardening of 130 tons of Crude Coconut Oil (with hydrogen to be derived from the caustic soda plant.)

The cost of processing is estimated by us as being £2.1*s*.10*d*. per ton of oil ; the capital cost would be :—

£65,000.

The revenue to be obtained from the by-products, *i.e.*, 5·2 tons of fatty matter from soap stock and 0·1287 tons of fat free nickel per day, has not been credited to the processing cost, as we are not aware of the prices which these commodities could command either internally or if exported to zones outside British control.

For your information, a coconut acid oil is quoted in this country at £58 per ton ex-factory, whilst the chemical manufacturers are prepared to accept a fat free nickel at approximately £100 per ton.

The additional cost of post-refining and deodorising of coconut oil has been estimated by us as 16/1*d*. per ton ; the capital cost involved by the necessary post-refining and deodorising equipment is about :—

£51,000.

Summing up this section, it appears that the processing cost of the manufacture of one ton of refined hardened post-refined coconut oil is £2.17*s*.11*d* per ton (naked at the factory) ; the total capital expenditure would be :—

£116,000.

The cost of hardening was based on the assumption that 50,000 cubic feet of free hydrogen would be made available to the oil section free of charges, the oil section bearing only the cost of compression. Should an independent source of hydrogen be deemed necessary, however, the cost of hydrogen for the hardening of one ton of coconut oil would be 4/5*d*. per ton of oil, 17/- per 1,000 cubic feet. The cost of plant for a hydrogen generating equipment for about 50,000 cubic feet of hydrogen per twenty-four hours, complete with motor generating sets, &c., would be approximately :—

£19,000.

On the assumption that a readier and more advantageous market would be found for a hardened refined and deodorised coconut oil, we recommend that a batch processing equipment, on the lines indicated above, should be considered by you.

Processing of Groundnuts and/or Rapeseed for the Manufacture of Ghee or other Fat Compounds.

Should it be found advisable to process quantities of groundnut and/or rapeseed by employing the same methods as we recommend for the production of crude coconut oil, it is estimated by us that the cost of processing one ton of groundnut and/or rapeseed would be the same as that of poonac, *i.e.*, £1.10*s*.9*d*. per ton.

In submitting our calculations to you we have borne in mind that the composition of the product to be placed on the market would necessitate a mixture of hardened and soft oils. For instance, ghee would consist of two-thirds hardened oil with a melting point of 40/42°C. and one-third soft oil (refined and deodorized).

In dealing with this section we have assumed that no extra equipment will be required for the production of the components of the fat and therefore the cost of processing would be the same as for coconut oil with the exception that, unless additional quantities of hydrogen could be made available, the capacity of the plant with regard to hardened coconut oil will be reduced. This, however, does not apply should additional quantities of hydrogen be made available or be generated by an independent unit.

The cost of ghee, consisting of 10 tons of soft, refined, deodorized oil and 20 tons of refined, hardened, post-refined, deodorized oil will then be made up as follows :—

	£	s.	d.	
Processing cost of 10 tons of refined deodorized soft oil ..	15	9	2	
Processing cost of 20 tons of refined hardened post-refined deodorized oil	57	18	4	
	73	7	6	
equivalent to a cost per ton of blended oil	2	8	11	
Cost of blending estimated at	0	7	4	per ton
PROC. Cost of ghee per ton (naked)	2	16	3	

Should the marketing of a vitaminized ghee ever be considered, the additional cost for vitaminization would be £1.12*s.* 6*d.* per ton.

The capital involved for the blending plant required to produce 30 tons per day involves a capital outlay of approximately £9,000.

The cost of production to be expected if the hydrogen is generated independently of any other project would amount to 17/7*d.* per 1,000 cubic feet or £1.14*s.* 6*d.* per ton of oil hardened.

We therefore submit that, after having ascertained the disposal facilities for ghee in your Dominion and the price to be expected, you consider seriously the acquisition of a suitable equipment. This, however, will naturally depend on whether or not quantities of groundnut and/or rapeseed oil can be made available for that purpose.

Manufacture of Fatty Acid and Glycerine.

For the splitting of the coconut oil derived from poonac we estimate that the cost of processing coconut fatty acids would be £1.18*s.* 1*d.* per ton and the capital cost involved for the purchase of plant :—

£8,000.

The cost of production of one ton of glycerine is estimated by us as being £10. 16*s.* 5*d.*, and the capital involved for the required equipment :—

£7,000.

We recommend that you should seriously consider the manufacture of fatty acid and production of glycerine, as it would enable you to place on the market material suitable for soap-making far superior to that which would normally be produced from poonac without subsequent processing by splitting and distillation.

(Sgd.) L. H. Manderstam, M.Sc., M.I.Chem. E.,
M.I.P., M.I.F., F.C.S.

December, 1946.

2.—Caustic Soda and Hydrogen.

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REPORT ON CAUSTIC SODA-CHLORINE PROJECT.

INTRODUCTION.

In this report approximate estimates are made of the capital cost and operating costs for a plant producing 5 tons per twenty-four hours of caustic soda and 4·4 tons per twenty-four hours of chlorine. It has been assumed that the caustic soda will be sold in the form of a 50 per cent. solution so that plant for converting it to solid form need not be installed. It is also assumed that the chlorine will be partly converted to liquid chlorine and partly to bleaching powder.

The estimates presented include plant for the production of 3 tons per twenty-four hours of liquid chlorine and plant for the production of 5 tons per twenty-four hours of bleaching powder, this latter requiring 2 tons per twenty-four hours of chlorine. It is understood that some of the chlorine may be used in other ways than those mentioned above, for instance in the manufacture of D. D. T. Pending a final decision on alternative uses for the chlorine, it has been thought best at the present stage to assume that it would be disposed of as liquid chlorine and bleaching powder.

Questions relating to the available and potential markets for caustic soda and chlorine or chlorine derivatives in Ceylon are not discussed in this report, as they can obviously be dealt with more satisfactorily in Ceylon where the necessary information is available. It may, however, be pointed out that both caustic soda and chlorine are basic industrial chemicals.

Some of the main uses of caustic soda are in soap manufacture, oil refining, cellulose manufacture, mercerization of cotton and there are, in addition, a large number of diverse uses. The main uses of chlorine, apart from those in the chemical industry, are for sterilization of water and bleaching. For these latter uses liquid chlorine, bleaching powder and sodium hypochlorite are to a certain extent interchangeable, the form of utilization depending largely on local conditions such as transport, convenience of handling, &c.

As an indication of the extent to which caustic soda and chlorine can be regarded as basic in industrial activity, it may be mentioned that the current rates of production in the U. S. A., according to the latest figures available, are 952,000 tons per year of caustic soda by the electrolytic process, 648,000 tons per year of caustic soda by the lime-soda process, and 986,000 tons per year of chlorine.

Combination of Caustic Soda-Chlorine Plant with other Plants.

As the basis for preparing the estimates it has been assumed that the caustic soda-chlorine plant is independent and selfcontained and includes steam and power plant for providing its requirements. The conbination of the caustic soda-chlorine plant with other plants located on the same site would obviously offer advantages. Among the general advantages that would result from such a combination of plants would be savings in the capital cost for site preparation, provision of services and communications. It should also be possible to effect economies in capital and operating costs by providing for the group of plants a common steam and power installation and common laboratories, offices and workshops.

In addition to these general advantages of locating a group of plants on the same site, there would be particular benefits from an oil refining and hardening plant or a D. D. T. plant on the same site. The former would provide a profitable outlet for utilizing the hydrogen from the electrolytic cells. This hydrogen would otherwise have to be burnt as boiler fuel, for which purpose its value is very much less. The location of a D. D. T. plant on the same site should permit of a substantial amount of chlorine being sent to it in gaseous form, thus saving the cost of liquefaction or conversion to bleaching powder.

At the present stage no attempt has been made to evaluate quantitatively the advantages that would result from locating an oil refining and hardening plant and a D. D. T. plant on the same site as the caustic soda-chlorine plant. When detailed information about these other projects is available it should be possible to estimate approximately the magnitude of the economies that would be achieved by locating these other plants on the same site as the caustic soda-chlorine plant.

Capital Cost.

In preparing the estimate of capital cost, the capital cost of the various sections comprising the caustic soda and chlorine plant proper is based on the preliminary quotation submitted by the Power Gas Corporation, Limited, and on various discussions with that firm. To provide the necessary power and steam it has been assumed that power would be generated by Diesel engines and that a boiler would be installed to produce process steam. It has been assumed that three-phase alternating current would be generated and that a motor-generator would be used for converting to direct current the power required by the electrolytic cells. On the basis of figures submitted to them for the size of the power and steam plant required, the Crown Agents for the Colonies provided an approximate estimate of capital cost based on their experience with similar plant.

It has not been considered necessary to investigate at the present stage alternative types of steam and power plant such as steam turbines, &c., which might ultimately be found more economical. Nor have the relative merits of a mercury rectifier against a motor generator been considered in detail. A number of alternatives would, in any case, have to be examined if other plants were to be located at the same site and a common steam and power installation were to be provided.

The cost of buildings has been based on a figure of £1 per square foot of ground area, which was supplied by Mr. D. H. Balfour. The items for freight and erection are naturally rough estimates. An item for contingencies of 15 per cent. has been included, and this includes some provision for possible increases in cost of plant arising during the period of manufacture. In view of the impossibility of foreseeing the trend of costs of labour and materials during the next year or two the allowance to be made for contingencies obviously is very much a matter of opinion.

Table I. shows the estimated approximate capital cost of the caustic soda-chlorine plant.

TABLE I.

Approximate Capital Cost.

	Cost (f.o.b., U. K. port.) £.	£.
Salt solution and brine purification plant	6,800	
Electrolysis plant	17,000	
Concentration plant	12,200	
Chlorine liquefaction plant	11,600	
Bleaching powder plant	21,000	
		68,600
Boiler	3,000	
Diesel engines	20,000	
Motor-generators (including stand by)	6,000	
Auxiliary equipment for power house	4,500	
		33,500
		102,100
Carriage, insurance, freight (estimated at 10 per cent.) ..		10,200
Erection (estimated at 10 per cent.)		10,200
		122,500
Buildings		28,000
Ancillary equipment—workshops, fire-fighting, &c. ..		5,000
		155,500
Allowance for contingencies, including possible increases in cost (15 per cent.)		23,500
Licence fee for electrolysis and bleaching powder plants ..		4,400
Overhead expenses during construction		7,000
Interest during construction		4,000
Total ..		194,400

It is to be noted that the items shown in Table I. do not include the cost of the site and its preparation, the provision of services and communications, sewerage, housing, working capital, &c. Additional sums will have to be included for these items to obtain a figure for the total capital required for the project. It is understood that these items will be estimated in Ceylon, where the necessary data are available.

In Table I. an item of £4,000 is included to cover interest on capital during the construction period. Whether such an item should be included or not depends on the particular basis of financing such a project which will ultimately be adopted by the Government of Ceylon. For the time being it has been thought appropriate to prepare estimates on the same basis that would be taken for a normal commercial project.

Production Cost.

In the electrolysis stage caustic soda solution and chlorine are produced simultaneously. The allocation of the total cost of this stage to the two products must necessarily be somewhat arbitrary. The procedure adopted has been to allocate half the total cost to the caustic soda produced and half to the chlorine produced. The amount of caustic soda produced is slightly larger than the amount of chlorine produced and this method shows a slightly higher cost of production for the chlorine than for the caustic soda from this stage.

As the chlorine is to be converted into liquid chlorine and bleaching powder and the relative amounts of these products may vary, the allocation of capital charges to the various products would normally be varied according to their relative amounts. In order to simplify the presentation of figures, the capital charges on all the plant and buildings, including the steam and power plant, have been charged to the electrolysis stage and no other capital charges are introduced in the subsequent process stages.

In estimating the capital charges, interest on capital has been taken at 3 per cent. per annum and an average rate of depreciation over the whole of the plant and buildings has been taken at 6 per cent. per annum. This average rate of depreciation corresponds to a rate of 7 per cent. per annum on plant and 2½ per cent. on buildings.

On this basis the annual capital charges for depreciation and interest amount to £17,500. These charges have to be carried by some 3,900 tons of products, namely, 1,500 tons of caustic soda, 900 tons of liquid chlorine and 1,500 tons of bleaching powder. If distributed equally over all the products, these capital charges would amount to £4.10*s*.0*d*. per ton of product. From this rough calculation and from the more detailed cost figures given later in this report, it is evident that the production costs will be very materially affected by the policy which is ultimately decided on for determining the incidence of capital charges.

Overhead charges for the whole plant have been dealt with in the same way as capital charges, that is, the total amount has been allocated to the electrolysis stage. A figure of £4,550 per annum has been taken for overhead charges and this covers the salaries of one technical manager, three chemists, three laboratory assistants, one office manager and two clerks.

The following basic prices have been assumed :

Salt (96–97 per cent. purity) ..	£1 10*s*. per ton
Skilled labour	10*s*. per 8-hour shift
Unskilled labour ..	5*s*. per 8-hour shift
Fuel oil	5*d*. per Imperial gallon
Diesel oil	7*d*. per Imperial gallon

Table II. shows the cost of producing one ton of caustic soda as cell liquor with the simultaneous production of 0·88 ton of chlorine as wet gas.

TABLE II.

Cost of Producing 1 ton Caustic Soda as Cell Liquor together with 0·88 ton Chlorine as Wet Gas.

		£
Salt		2·55
Chemicals for purification		0·65
Power		7·31
Steam		0·48
Labour		0·91
Salaries (total plant)		3·00
Electrode and disphragm renewals		0·63
Repairs and maintenance		1·00
		16·53
	£	
Credit for hydrogen based on fuel value ..	0·33	
Total cost excluding capital charges	..	16·20
Depreciation (total plant and buildings) ..	7·80	
Interest on capital (total plant and buildings) ..	3·90	11·70
Total cost including capital charges	..	27·90

When half the total cost of production is allocated to the caustic soda and half is allocated to the chlorine—

		Excluding Capital Charges. £
Cost of 1 ton caustic soda as cell liquor ..	..	8·10
Cost of 1 ton chlorine as wet gas ..	$\frac{8 \cdot 10}{0 \cdot 88}$	9·20

		Including Capital Charges. £
Cost of 1 ton caustic soda as cell liquor ..	..	13·95
Cost of 1 ton chlorine as wet gas ..	$\frac{13 \cdot 95}{0 \cdot 88}$	15·85

Excluding capital charges the total cost of producing one ton of caustic soda as cell liquor together with 0·88 ton of chlorine as wet gas is £16·20, corresponding to £8·10 per ton of caustic soda and £9·20 per ton of chlorine when half the total cost is allocated to each of the two products.

When the capital charges on the whole of the plant and buildings are included the cost of producing one ton of caustic soda as cell liquor together with 0·88 ton chlorine as wet gas is £27·90 corresponding to £13·95 per ton for caustic soda and £15·85 per ton of chlorine.

The credit for hydrogen on the basis of its fuel value is quite small. With fuel oil at 5*d*. per gallon, hydrogen is worth 8*d*. per 1,000 cubic feet on its thermal equivalent. The cost of generating hydrogen independently for an oil hardening plant would be of the order of 10*s*. per 1,000 cubic feet more than the above figure. The caustic soda-chlorine plant would produce 50,000 cubic feet of hydrogen per twenty-four hours and the additional value of this hydrogen, if used for oil hardening, would thus be about £25. The credit for hydrogen in Table II. would then be £5 instead of £0·33.

It will be seen from Table II. that the biggest item of cost, apart from capital charges, is the cost of power. Any reduction in the cost of power due to a common power installation for a number of plants would obviously have an important effect.

Table III. shows the cost of producing one ton of caustic soda in the form of the 50 per cent. solution in which it would be marketed. Excluding capital charges the cost per ton of caustic soda is £14·98. When capital charges are included the cost per ton is £20·83.

TABLE III.

Cost of producing 1 ton Caustic Soda as 50 per cent. Solution.

		Excluding Capital Charges.	Including Capital Charges.
	£	£	£
Cost of 1 ton NaOH as cell liquor ..	..	8·10 ..	13·95
Steam ..	5·28		
Power ..	0·20		
Cooling water ..	0·27		
Labour ..	0·60		
Repairs and maintenance ..	0·53	6·88 ..	6·88
Total ..		14·98	20·83

From Table III. it will be seen that the major item, apart from capital charges, in the cost of converting the cell liquor to marketable caustic soda solution is the cost of steam. Here again any reduction in the cost of steam due to a common installation supplying a number of plants would have an important effect on the cost of the product.

The marketing of caustic soda in the form of a 50 per cent. solution saves the cost of further concentration to the solid state. Freight on the product is naturally somewhat higher. Most consumers who use caustic soda in solution prefer to buy it in this form instead of in the solid form as the handling is simpler and the somewhat disagreeable task of dissolving the solid caustic soda is eliminated.

The cost of drums or other containers for shipment of the 50 per cent. caustic soda solution is not included in Table III.

Table IV. shows the cost of producing one ton of chlorine in liquid form. The cost of liquid chlorine is £12·77 per ton, if capital charges are excluded, and £19·42 per ton when these charges are included.

TABLE IV.

Cost of producing 1 ton Liquid Chlorine.

		Excluding Capital Charges.	Including Capital Charges.
	£	£	£
Cost of 1 ton chlorine from cells ..	..	9·20 ..	15·85
Power ..	0·52		
Cooling water ..	0·15		
Sulphuric acid for drying ..	1·50		
Labour ..	0·50		
Repairs and maintenance ..	0·90	3·57 ..	3·57
Total ..		12·77	19·42

The cost of cylinders for the shipment of liquid chlorine has not been included in Table IV., as data are not available regarding the number and sizes of cylinders that would be used. The cost of cylinders would, of course, be an item which would have to be included in estimating the price of liquid chlorine to the buyer.

A certain quantity of concentrated sulphuric acid is used for drying the chlorine before liquefaction. For the purpose of the estimate it has been assumed that this sulphuric acid would be discarded when its concentration was no longer high enough for it to be used in the drying process. It should, however, be possible to find some local use for the dilute sulphuric acid, and this would effect some reduction in the cost of producing liquid chlorine.

Table V. shows the cost of producing one ton of bleaching powder.

TABLE V.

Cost of producing 1 ton Bleaching Powder.

		Excluding Capital Charges. £		Including Capital Charges. £
Chlorine	£	3·68	..	6·34
Lime	1·05			
Power	0·54			
Steam	0·24			
Labour (operating)	0·38			
Labour (handling lime and product) ..	0·38			
Repairs and maintenance	1·00	3·59	..	3·59
Total ..		7·27		9·93

It has been assumed that the bleaching powder would be filled into drums and the cost of this filling operation has been included. The cost of the drums themselves has, however, not been included. If it should be desired to market bleaching powder in packages smaller than drums, this would obviously involve additional costs, but the price charges for the product in smaller packages would be correspondingly higher.

In estimating the cost of producing bleaching powder it has been assumed that lime of reasonable quality would be available at a price of £1.10.0 per ton. If lime of the quality required is not available locally it would be necessary to instal a small lime kiln to provide the requirements of the bleaching powder plant. An approximate estimate of £4,000 has been obtained for an oil-fired lime kiln for this purpose. Including freight, erection, &c., the final cost of such a kiln would probably be £5,000—£6,000.

November 14, 1946. (Sgd.) A. J. V. UNDERWOOD.

3.—Textile Manufacture.

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January 18, 1947.

REPORT ON PROPOSED COTTON TEXTILE INDUSTRY IN CEYLON.

Before he left England for Ceylon in November, 1946, after some months spent in Industrial investigations, Mr. D. H. Balfour, Director of Commerce and Industries for the Government of Ceylon, requested me to take over the enquiries he had already instituted with reference to Cotton Textile Machinery, and to formulate in general outline for submission to his Government a scheme for the development of a factory industry on modern lines for production in Ceylon of Cotton and Rayon Textiles needed in that country which has hitherto relied for these supplies, so essential in a tropical climate, almost wholly upon Imports.

I learned that war-time experience has shown that such complete dependence on external sources can lead to shortage in supply of clothing textiles amounting to serious hardship for the Ceylon people.

Climate.—Until comparatively recent years tropical and sub-tropical countries in which cotton is the principal textile requirement—including countries which are the world's largest growers of cotton—were dependent for woven cotton cloth upon imports from temperate countries.

The original location of cotton spinning and weaving in certain districts of England and other early industrialized countries has been ascribed to climatic reasons. It was long the accepted view that the Cotton industry could only be carried on successfully in places having a particular kind of climate—the typical example being the cool rainy climate of Lancashire. Climate was certainly important but associated with it were many other factors of industrial history which helped to decide the location of the Cotton Industry. Such were the pioneer inventions of Crompton, Arkwright and Kay ; the presence of coal and development of steam power ; the growth of engineering specialisation ; and the progress in skill and knowledge of the workers and technicians.

These various advantages have gradually become available to all, and the climatic factor itself has become less dominant. The conditions necessary for processing cotton are now more fully understood and controllable and today it is practicable to spin and weave cotton successfully in hotter countries. Even in America where cotton manufacture was long established in the temperate New England states of the north, there has been a considerable migration of the industry to the hotter cotton growing (and incidentally cotton using) Southern states.

During the last quarter of the hundred year history of the cotton industry, India, Japan, China and Egypt have each become largely self sufficient in cotton manufacture and capable of exporting cotton cloth. Many countries of South America now have well established cotton industries, and development is in progress in several tropical West African territories.

It would appear that Ceylon has fallen behind in these developments rather because of the relatively high prosperity of her existing chief occupations, the cultivation of important primary products and not owing to any unsuitability for cotton manufacture of her climate or her people.

There is certainly no technical reason why cotton yarn and cloth should not be manufactured and finished in Ceylon of good marketable qualities suitable for the daily needs of the Ceylon people.

Cotton Industry Organisation.—After about a century of continuous development the Cotton Textile Industry has become a very complex and highly specialised series of processes and in these countries and districts longest concerned with cotton manufacture—notably in Lancashire—certain of these processes have become the whole concern of particular firms who obtain their material from other firms specialised for earlier processes of the series and who in turn supply their product to firms carrying on later stages.

Briefly, these stages of manufacture may be listed as follows, (major stages in italics) :—

(*a*) Raw Cotton import, marketing, grading and selection for various uses.

(*b*) *Spinning.*—*I.e.*, Making of Yarn.

Includes many preparatory processes auxiliary to " Spinning " proper.

" Fine Spinning " is a distinct trade with which may be grouped " Doubling ", *i.e.*, making of yarns with two or more threads twisted into one.

(*c*) *Winding.*—Forming yarn into various forms of package for processing and into Pirns for use in the weaver's shuttles.

Warping.—Forming yarn into a sheet of parallel threads for use in the weaver's loom.

These intermediate processes may be associated in the same factories with either Spinning or Weaving.

(*d*) *Weaving.*—*I.e.*, Making of Cloth.

Coarse, fine and " fancy " weaving form distinct trades.

(*e*) *Finishing* or after loom process.

Comprising Bleaching.

Dyeing, *i.e.*, Colouring the whole fabric.

Printing, *i.e.*, Colouring in pattern.

" Finishing " in the narrower sense. (The industrial edition of laundering.)

Dyeing of yarn before weaving, falls technically into this group.

It should be noted that this "Horizontal" specialization of the cotton industry is by no means a defect of organization—as superficial observers and critics have sometimes suggested—but is, on the contrary, a result and a condition of very advanced technical and economic development.

There are of course in England and America many firms who are concerned in several or all of these main stages of manufacture. In those countries in which the Cotton Industry has been more recently established and particularly those in which it has been installed under Government encouragement, there has naturally been an effort to cover the whole course of manufacture from raw fibre to finished goods and "Vertically" organised firms have arisen and have proved suitable for those conditions.

For Ceylon such vertical organization would seem to be appropriate at least for the initial units.

Machinery Makers.—"Horizontal" organization of Textile manufacture has caused corresponding specialization by the engineering firms making machinery for the Textile Trades. No firm today makes both spinning and printing machinery.

Spinning Machinery.—English makers of machines for the spinning and related processes have become organised into a group headed by Platt Bros., Ltd., which controls the manufacture of a large proportion of such machinery.

Weaving Machinery.—Makers of Looms and Auxiliary machines are not so closely combined. Automatic looms are a speciality of certain firms, notably the British Northrop Co.

Finishing Machinery.—For after-loom processes—is made by several independent firms, some of them covering only portions of the requirements. The most inclusive in range of machines is Mather and Platt Ltd., with which firm the writer has long been associated as Consultant—more precisely as interpreter of the requirements, ideas and difficulties of the users of such machinery.

Enquiries in England by the Director of Commerce and Industries had already brought him into touch with the firms mentioned above.

Whether, in the event of the Textile scheme being proceeded with, these firms are to undertake the work or whether tenders should be invited more generally is a matter of policy for consideration by the authorities concerned. Meantime, I have, with Mr. Balfour's approval, utilized the services of these firms to prepare provisional estimates for the machinery required in each section of the industry.

Provision of Boilers, Electrical Power Plant and the general engineering work necessary for the installation of such a factory is outside the scope of any of these textile machinery making firms and it is unlikely that any of them would be prepared to become general contractors for the whole installation, although each would be able and willing to contribute much from their wide experience to assist the Department of Commerce and Industries and the Crown Agents or their Architects and constructional engineers in relation to the requirements of the respective sections.

Foreign Machinery.—I have dealt only with the position of machinery supplies from England. Textile machinery for most sections is manufactured also in America, but this is not a field in which America excels ; and there is reason to believe that the delivery probabilities, although more optimistically quoted, are in fact not more favourable than from England, whilst prices are definitely higher.

Switzerland makes excellent machinery for the finer sections of Textile Industries—Real silks, fine woollens, cottons and rayons, but this does not come into consideration for Ceylon at the present stage. Prices are very high.

Technical Advice.—From the foregoing it will be appreciated that each of the main stages of Textile manufacture offers an ample field for study and experience to the technical personnel engaged in it and it would be difficult, at any rate in England, to obtain the services of one person really competent to advise upon the detailed processes and equipment of all stages, although an expert in one stage must have much knowledge of those stages which precede and follow his own.

My own field is that of the "After-loom" processes which my experience has covered fairly widely in England and abroad. In this most complex section I will prepare the detailed specification and organization of the equipment and processes required and I have undertaken the task proposed to me by Mr. Balfour of formulating the general scheme as I can readily obtain and co-ordinate the required information and specialist guidance in relation to the other sections which at the outset will call for relatively standardized installations.

For this purpose I have been fortunate in obtaining the co-operation with particular reference to Spinning of Mr. Harold Bromiley, F.T.I., head of the Textile College, Bolton, Lancashire, and in respect of Weaving of Mr. John Read, F.T.I., of the Royal Technical College, Salford, Manchester. Those gentlemen are recognized authorities in these fields in the Lancashire Cotton Textile Industry

Ceylon's Requirements.—In undertaking the formulation of the general scheme, I accepted and endorsed the opinion formed by Mr. Balfour, during his preliminary inquiries, that in the present instance, where it is proposed to foster an industry to supply an existing market with very special established traditions and with progressive interest in more general textiles, planning must logically begin by determining first the requirements of the market (present and potential) for finished goods, from which may then be decided the kinds and quantities of cloths and from these of yarns and ultimately of raw cotton required.

I have proceeded by a careful study—qualitative and quantitative—of Ceylon's pre-war and present supplies, immediate demands and probable longer term interests in Cotton Textiles. Records and statistics for this investigation are naturally not very complete, nor very fully itemized for the particular purpose, but with the cordial and very capable co-operation of Mr. Dolapihilla, Textile Technologist to the Department of Commerce and Industries, and that of the Textile Controller's officers and through them of the principals of a number of the larger importing firms, it has been possible to obtain a very useful general view of the past and present position of Cotton Textiles in Ceylon.

Available statistics indicate that for Ceylon's population of 6½ millions, mostly dressing entirely in Cotton, pre-war imports of totton textiles amounted to some 63 million yards per year (10 yards per person) of which some 20 million yards came from U. K. and the remainder from India and Japan. War conditions interrupted supplies disastrously. Post-war imports from all sources are still much below requirements (1946—31 million yards) and there must be a substantial "replenishment" demand owing to prolonged scarcity.

It is probable that the requirements of the Ceylon market for current consumption now amounts at a very conservative computation, to at least 75 million yards of Cotton goods yearly (12 yards per person) and is likely to increase.

The hand loom industry has contributed 3 million yards per year and when freely supplied with yarns may reach 6 million yards, but this would be only 10 per cent. of total requirements (or 1 yard per person).

Target.—I have drawn up a scheme for development, taking as a reasonable target for, say, five years, one half of the Island's yearly requirements of cotton textiles, which half I have taken as 30 million yards of cloth. This will require the importation of some 4,000 tons of cotton for the spinning of 8 million pounds of yarn.

Economic Size.—These are quantities large enough to permit the establishment of spinning; power loom weaving; bleaching; dyeing; printing and finishing on most up-to-date and economical principles.

The target quantities are not, however, large enough to make distribution of the plant advantageous.

Spinning will require 100,000 spindles which is suitable for one or two large factories with sections for coarser and finer yarns.

72 per cent. of Lancashire's yarn output comes from firms of 100,000 spindles or more, and the recent proposals of the British Board of Trade are designed to encourage such large concerns.

Weaving calls for some 2,000 looms and these must include sections of various types and widths to make the variety of cloths the market requires.

Only about 20 per cent. of Lancashire's cloth comes from factories with 2,000 looms, but 60 per cent. comes from sheds of 1,000 looms and over. Economic reasons would place the weaving in not more than two factories of about 1,000 looms each, one adapted for bulk production of a limited range of standard makes and the other for somewhat more varied qualities.

However, Weaving could be further subdivided without much loss of economy—apart from transport costs—if there were reasons for so doing.

Bleaching and Finishing of goods to be sold white should form a unit distinct from the equipment for *Bleaching, Dyeing, Printing and Finishing* of coloured goods with which latter would be included departments for Yarn dyeing and for finishing of Coloured-woven cloths. The target quantities of coloured goods of all types do not call for more than one factory.

Subject to availability of labour, power and water, economic considerations would favour placing all these sectional factories in one vicinity, so minimizing inter-process transport and enabling certain services to be centralized, *e.g.*, Steam and Power generation, repair workshop, warehousing, packing and sales.

Whether any distribution of power-loom weaving in several centres of population is advisable will depend on consideration of other than rigorously economic factors.

Raw Material.—As regards the supply prospect for such an industry, although Ceylon is not at present growing cotton, there is no prospect of difficulty in obtaining supplies, for few commodities enjoy such a world market from which cotton of any required quality can be obtained by any country at world price.

The project for a Factory Cotton Industry is in no way dependent upon prospects of Cotton cultivation in the Island.

"*Rayon*" is of many kinds. The one of immediate interest in connection with the proposed development is the "Viscose" type, made usually from would pulp by a series of chemical processes. It is now manufactured in many countries, suitable pulp coming from Canada, Scandinavia and Russia. Subsequent to making of the filament, Rayon manufacture is closely parallel to that of Cotton outlined above. It is very largely used in combination with cotton.

The Ceylonese hand-loom weaving industry might make much use of Rayon to diversify and embellish its products.

Steam and Power–Fuel.—All sections of this Industry require substantial power supplies. The Bleaching, Dyeing and Finishing section needs much steam for process purposes.

As there is no early prospect of hydro-electric supply, the power required can best be obtained from suitably proportioned Pass-out or Back-pressure Turbines taking Steam from Boilers at a relatively high pressure and delivering it at a lower pressure suitable for process purposes. For the latter some steam at 100 lb. per square inch is required (air heaters), but for many purposes steam at 15-30 lb. per square inch suffices.

The total installed Horse Power (in many relatively small motors) for textile machinery only—Target quantity will approximate to :—

		H.P.
	Spinning	4,000
	Weaving	2,500
	Finishing	1,000
Allow for	Lighting, Ventilation, Humidification, Auxiliaries	500
	Installed Total	8,000

The maximum demand is unlikely to exceed 3,000 K.W.

For the initial installation (proposed below) one fifth of these figures is applicable. Steam for process purposes—target quantities—some 50,000 lb. per hour.

Colours.—Dyestuffs are the products of a highly specialized chemical industry in which fortunately the U. K. now holds a leading position. Ceylon can obtain all needed supplies from that country.

Technicians.—Specialists fully experienced in each of the branches of this very complex series of processes are available to assist in establishing the industry and in training its personnel.

Foremen.—A suitable staff of skilled foremen to act under the managerial and scientific chiefs, will have to be engaged from England. Inquiries indicated that there are at present available a few such men who after training in England have had experience in India or South America and, having returned home after prolonged spells abroad due to war conditions, are now open for new engagements.

Workers.—The requirement of *greatest importance* to which I must refer is that of sufficient numbers of really capable, intelligent and diligent workers, prepared to learn and become skillful in the many operations of the cotton industry. Upon this matter those responsible in Ceylon can judge better than a short time visitor. I can only say that my observations have produced a very favourable impression partic- ularly as regards intelligence and capacity to develop a high degree of skill.

Number of Operatives.—The number of workers required when the factories are in running order, depends greatly upon the influence of climatic conditions and the diligence and stamina of the workers available. Previous experience of Ceylonese workers under factory conditions is very limited, and at the present stage it may be best to indicate the numbers of experienced workers in established mills in England per shift of 8 hours daily.

		Workers.
Spinning—100,000 spindles require some		450
Weaving— 2,000 looms, if non-automatic, require some..	750	
If automatic	300	
Both types will be required and workers may be computed at..		550
Bleaching—The machinery proposed requires some		250
Power—Maintenance, &c.		100
Total ..		1,350

With administrative and clerical staffs, say, some 1,500 persons per shift.

In India more than twice this number would be employed.

It will be for Ceylonese workers to establish their own economic value which must inevitably control the wage level at which the factories can employ them.

Training School.—To hasten the starting up of production when machinery is delivered, it is desirable to establish in advance a Training School for Operatives. I have obtained proposals from Messrs.Samuel Dodd & Sons of Oldham to supply a limited range of reconditioned spinning machinery to equip such a school at a com- paratively early date. A few Reconditioned Power Looms could also be obtained for use in training weavers.

Mechanization.—In view of climatic conditions as well as in accordance with the whole trend of modern development throughout the world, I am proposing an advance degree of mechanization and the use of automatic machinery and controls wherever economically justifiable.

Spinning.—Of the total yarn requirements some 60 per cent. to 70 per cent. will be of counts below 30s and some 20 per cent. to 30 per cent. between 30s and 50s, with not more than 10 per cent. over 60s count.

Few of the factory-made samples purchased in Ceylon contain doubled yarn, but of the hand-loom products many have doubled warp yarns, which greatly facilitate hand weaving and improve its quality and output.

Weaving.—From information gathered and from the styles of fabric, it appears probable that the great bulk of cloths required can be made on looms of 48″ reed space.

The majority of the cloths represented by these samples can be woven on plain or Tappet looms, but the Sarong will require a proportion of looms with Dobbies—additional mechanism which can be fitted to standard looms as required.

Some looms will require multiple shuttle boxes for check weaving.

Some wide looms for sheetings will be needed.

Finishing.—There is obviously a considerable call for grey cloths in loom state, and most of the coloured-woven goods are unbleached, but of the total projected output of 30 million yards yearly or 600,000 yards per week, at least two-thirds will require bleaching, viz., 400,000 yards or some 35 tons per week (9 tons per day).

Probably half of this will be sold in white state and that remainder dyed and/or printed, say :—

	Yards per Week.	Yards per 8 Hour Shifts.	Yards per Hour.
Finished unbleached	200,000	20,000	2,500
Finished white	200,000	20,000	2,500
Finished dyed	80,000	8,000	1,000
Finished printed	120,000	12,000	1,500
	600,000	60,000	7,500

These allocations are only tentative. But some assumptions are necessary to arrive at a general view of the scale of the project and of plant required, also with respect to its location in the Country and to the question of centralization or dispersal of the factories.

Yarn Dyeing.—A considerable proportion of yarn Dyeing will be needed for the woven checks which appear to be an important, requirement here, at present supplied from South India (hand looms).

Stage I.—It is not possible to obtain early delivery of machinery to the extent required for the five-year target and for many reasons it is best to start such an installation in successive stages. I have recommended, as Stage I., about two tenths of the target machinery for spinning—one tenth (10,000 spindles) to spin heavier and one tenth to spin finer yarns. And for weaving also two tenths of the target number of looms, one tenth (200 looms) for quantity production of standard cloths and one tenth for more varied qualities.

These one-tenth units comprise suitable numbers of spindles and of looms to form convenient groups within the larger factory.

Stage I. represents the largest quantity of machinery which it is practicable to obtain for earliest delivery—(say two years).

Much preparatory work on site and buildings can be proceeding meantime.

Initial Installation for Spinning.—Proposals from Messrs. Platt Bros. have been obtained for one unit (10,000 spindles) of machinery for spinning yarns of 10's to 30's counts from India or America cotton. In view of the preponderance of yarns under 30's count in the cotton goods required by Ceylon, and also of the advantage of coarse spinning for the first training of novice workers, it is desirable that this should be the first unit to be installed.

In view of the need for some finer yarns for variety of fabrics and for supply to the handlooms weavers, the second unit estimated by Messrs. Platt Bros. is 10,000 spindles for spinning yarn of 30's to 50's from America and Egyptian cotton. This machinery should be ordered at the same date, but with priority for the coarser spinning.

Each of these units includes a suitable proportion of machinery for doubling yarns.

Initial Installation for Weaving. Automatic Looms.

These are unquestionably successful under suitable conditions, as, *e.g.* for production in long runs of standard cloths from yarns of reliable regularity.

The cost of installation is very much higher. Its justification depends upon the amount of labour cost which can be saved and this in turn upon the wage level and supply of suitable workers.

In America automatic looms were economic before the war.

In Britian they are becoming more advantageous with steeply advancing wages and scarcity of workers.

Whether automatic weaving is rational in Ceylon or likely to become so in the near future remains for consideration.

For the first power loom installation, however, automatic looms would be quite unsuitable since for reasonable success they require highly trained and experienced operatives and it has been found necessary to begin the training of operatives intended for automatics upon simpler looms in the first stages.

Furthermore, although automatic looms are capable of producing other than plain cloths when equipped with tappet motions, dobbies and shuttle changing boxes,.

this is hardly their proper role where, as in Ceylon, a wide range of different fabrics in moderate quantities is called for.

For these reasons the quotation of the Northrop Company for Automatic looms has been supplemented by one from Henry Livesay, Ltd., for non-automatics and it is advisable that the first installation should be of the latter type. As more than one such weaving unit will be included in the initial orders, the second might well be Automatic, enabling the suitability of this type for Ceylon's conditions to be given actual trial.

Whichever the eventual main type selected, there will be need for some non-automatic looms for smaller lots and special fabrics. In case automatic looms prove not suitable for general adoption, this first unit of automatics can be advantageously kept on standard plain cloths.

Initial Installation for Finishing.—Some items of machinery in the after-loom sections are of much larger capacity than those in the earlier sections and in view of the eventual Target requirement it would be uneconomic to instal for these processes a first plant smaller than four or five tenths of Target capacity.

This is a further reason for making the initial Spinning and Weaving sections each two-tenths of the target capacity instead of one-tenth as previously proposed.

The estimates so far obtained will be subject to considerable revision after the actual proportions of Textile requirements have been ascertained. At the present stage they can serve only as guides to the approximate costs of installation and for this purpose can be tabulated and computed roundly, thus :—

	Initial Installation.		For Target Production.	
Spinning—				
Unit SA.—10,000 spindles 10s to 30s yarn, Platt Bros. Quotation ..	97,500			
Platt Bros. Extras ..	19,000			
Holt.—Estimate ..	1,500			
		118,000 ..	4 Units	472,000
Unit SB.—10,000 spindles 30s to 50s yarn, Platt Bros. Quotation ..	77,600			
Platt Bros. Extras ..	16,400			
		94,000 ..	3 Units	282,000
Unit SC.—10,000 spindles 50s to 100s yarn, No. Quotation. (Approx. 100,000)	—	..	2 Units	200,000
Humidifiers and Sprinklers ..		7,000 ..		23,000
		219,000		977,000
Weaving—				
Unit WA.—250 looms non-antomatic				
Livesey's quotation ..	20,300			
Livesey's 125 tappets ..	1,500			
Livesey's winding, Beaming, sizing	3,200			
Motors approx. ..	2,500			
Spares	2,500			
		30,000 ..	5 Units	150,000
Unit WB.—192 looms automatic				
Northrop quotation ..	39,200		assuming half to be automatic	
(approx.) 100 tappets ..	1,500			
(approx.) winding, Beaming, sizing	4,000			
Motors (including) spares ..	5,300			
		50,000 ..	5 Units	250,000
Humidifiers and Sprinklers ..		5,000		15,000
		85,000		415,000
Finishing—				
Unit FA.—Piece bleaching, dyeing, printing and finishing, Mather's quotation A. ..		58,700 ..	Quotation. A & B	112,600
Unit FC.—Yarn dyeing, approx. ..		9,300 ..	approx.	22,400
Sprinklers, approx.		4,000 ..	approx.	10,000
		72,000		145,000

Summary—	Initial Installation.	For Target Production.
Totals : Spinning	219,000	977,000
Weaving	85,000	415,000
Finishing	72,000	145,000
	376,000	1,537,000
These prices are f.o.b. British Port		
Landed in Ceylon, *add* say, 15 per cent.	56,000	242,000
Erection in Ceylon, *add* say, 15 per cent.	56,000	242,000
	488,000	2,021,000
Plus contingencies, say.	500,000	2,250,000

These very approximate figures are for Textile Machinery and Motors only and exclusive of Steam Boilers, Power distribution, Water supply, Buildings and Sites.

Capital Cost.—It is not necessary to remind Ceylon authorities that prices are at a very high level. As regards machinery there are no present indications of decline.

For the Target, machinery *and plant* will cost some two and a half million sterling. This is some 2¼ times the 1938 cost.

Land, buildings, road, rail, water and similar requirements are not my special field, but from figures supplied by the Department of Commerce and Industries, these items will probably require a similar sum making a total capital cost of some five millions sterling.

Stage I. will cost for machinery more than one-fifth of the target and in respect of other items, expenditure will be proportionately larger at the outset and the Stage I. total should not be put lower than one and a quarter million sterling.

Production Cost.—Having regard to the rapid price changes still occurring in Textile materials and products, and in view of the fact that two years must elapse before production begins, no useful purpose would be served by computing costs in terms of cash per unit of output, selecting arbitrarily some typical cloth from the wide variety required.

It is apparent that the decision of the Government of Ceylon whether to proceed with Cotton manufacture must be based upon broader considerations than any such forecast in cents per yard which could have no serious validity for the date when production is achieved.

Decision must be based on such considerations as the need for diversified industries to balance the predominantly agricultural economy of Ceylon, the special importance of cotton clothing for Ceylon's climate and customs, the world market security of raw cotton supply and prices, the favourable oil fuel position and the close inter-dependence between Ceylon's cost of labour and its market's capacity to pay corresponding prices for its clothing.

Hand Loom Weaving.—My principal concern is with the project for a powered factory Cotton Industry and I have left to the last any comment upon the hand loom weaving industry which has been fostered in Ceylon by groups of people working for social betterment and education and has during the war been greatly expanded under the auspices of the Department of Commerce and Industries.

Although under modern conditions the main bulk of textiles must be produced on power looms, there remain certain fields in which the hand loom can find a place, a notable example of particular interest in Ceylon is for weaving a large variety of coloured checks such as are so largely used here for sarongs and are in fact made in Southern India for this market upon hand looms. A further field available is the making of higher grade fabrics, including sarees of finer cotton and rayon yarns.

During the war the hand loom weavers have served a valuable purpose in weaving simple cloths for immediate use, but in these qualities they are unlikely to hold their place in the market, although some section of simpler cloths such as towels might well be left to the handloom weavers for training beginners and as material for people only intermittently engaged in weaving.

The provisions of suitable yarns for the hand loom weavers should be a first call upon the Spinning section, which has been planned to have a surplus output over the requirements of the power looms.

(Signed) THOS. L. MORT.

4 ——J. N. 11725 (12/47)

4—Steel.

John Miles & Partners (London), Ltd.,
Consulting Engineers,
Successors to H. A. Brassert & Co., Ltd.,
Cannon street,
London, E.C. 4.

September 2, 1946.

DEVELOPMENT OF AN IRON AND STEEL INDUSTRY IN CEYLON.

It is understood that a programme of industrialization has already been started in Ceylon with a view to a general raising of the standard of living. This programme will undoubtedly be intensified. A small steel re-rolling plant has already been operating and was brought into being by the exigencies of war conditions. The present consumption of steel in Ceylon is of the order of 30,000 tons per annum, but this must increase with an intensification of the policy of industrialization.

Ceylon possesses deposits of iron ore but coal has to be imported. There are, however, considerable water power potentialities and it is possible to develop on these resources an iron and steel industry on an economic basis. The same conditions exist in Scandinavia, Italy and also in Switzerland, where flourishing iron and steel industries have been developed.

The establishment of a steel industry has been found to be one of the first essential steps in the industrialization of any country and with certain exceptions the consumption of steel per head of population is a fair measure of the standard of living. Both for the manufacture of all consumer and capital goods steel is used in some form or another. The following table gives the production of the principal iron and steel manufacturing countries and also the production and consumption per head of the population :—

Steel Production and Consumption in 1939.

Country.	Population. (Millions).	Steel Production (Millions of Tons).	Production in lb. per Head of Population.	Consumption in lb. per Head of Population.*
U. S. A.	137	70	1,140	762
U. S. S. R.	175	23	300	201
Germany (Old Reich)	68	20	660	587
U. K.	47	12·5	600	550
France	42	7·9	400	285
Japan	98	7	160	125
Belgium, Luxemburg	8·3	6·2	1730	537
Italy	44	5	250	123
Canada	10·5	2	418	408
Australia	7	1·8	180	198
India	389	1·4	6·5	6·5

* Average 1936/1937.

It will be seen from the table that America is far ahead as regards consumption per head of the population, but from the point of view of production per capita Belgium (with Luxemburg) is considerably in advance of the United States. This is due to the proximate location of coking coal and iron ore, making for the cheap production of steel which formed the basis of a large export trade.

The position in 1946 is that there is a considerable world shortage and this is likely to continue for sometime to come. In the first place, it is proposed to limit Germany's steel production to somewhere between 6 and 8 million tons per annum, whilst the production in other European countries such as France, Holland, Belgium, Czecho-Slovakia, Poland, is still only a fraction of what it was in 1939. This is due to coal shortage and the fact that many of the plants in these countries whilst not having been destroyed by enemy action are either out of date or require considerable overhaul and maintenance to put them into full scale production. On the other side of the picture there is a five-year world shortage of consumer goods, and this is further accentuated by the fact that in Europe especially there has been an enormous amount of destruction of buildings, railways, shipping, bridges and other civil works all of which will require huge quantities of steel for their reconstruction.

All these facts point to a steel shortage in Europe alone of upwards of 15,000,000 tons per annum. Many countries are considering increasing their steel-making capacity in view of this estimated shortage, and the following increases are foreshadowed :—

Great Britain	3,000,000 tons/annum
France	2,000,000 ,,
Holland	500,000 ,,
Spain	1,000,000 ,,
Scandinavia	800,000 ,,
India	1,000,000 ,,
South Africa	500,000 ,,

Such schemes will take between three and eight years to be completed and even if they are all realized there will still be a considerable shortage after that period.

There are two methods of starting a basic steel industry in any locality. The first is to base the industry on iron ore and some carbonaceous fuel producing pig iron which is subsequently converted to steel or secondly the industry can be based upon indigenous or imported scrap. There are, of course, various combinations of these two methods in use such as in Great Britain, where the industry is based upon supplies of both pig iron and scrap. If an industry of considerable size were contemplated, say, over 150,000 tons per annum then it is essential to be independent of the scrap market. On the other hand, for an initial small production where indigenous scrap is available there are certain advantages in basing a steel industry on a small plant remelting and refining scrap. In the first place a steel industry is initiated with a minimum capital outlay, and secondly, it provides an opportunity of training from small beginnings a personnel—both staff and operatives—in the science of steelmaking, the handling of molten metal, the casting of ingots and the hot rolling of steel. It is far easier to expand from a nucleus of trained work people than to start a large industry from virgin ground.

The idea of making engineering products as well as finished steel sections is a sound one in so far as the profit margin is higher on this merchandise, and this will assist in amortizing the complete plant in a much shorter period.

Raw Materials.

We understand that there is sufficient indigenous scrap collected in Ceylon to provide annually a quantity of some 11,000 tons. Part of this scrap can be cast iron.; at least it is advantageous that up to 20 per cent. of the charge should be cast iron. This will eliminate the necessity for purchasing pig iron, the cost of which at the moment is £8 per ton. Alternatively, if no cast iron scrap is used graphite can be employed for recarburizing the steel scrap which is essential in the open hearth process. Approximately 2 per cent. of the charge will be required as graphite (in the absence of cast iron scrap) which will mean about 200 tons per annum.

The steel scrap should be sorted so as to eliminate all contamination with non-ferrous metals, especially copper and nickel alloys, whilst only a small proportion of alloy steels, such as shell steel, &c., will be permissible. This is due to the danger of contamination with chromium in particular which will render the rolled product air hardening. The scrap should be cut up so that it is of a suitable size for the charging boxes but quite large pieces, say, from 500 lb. to 1,000 lb., can be readily melted as well as a certain proportion of turnings and light scrap.

The other raw materials required include ironore and mill scale for " boiling down " the open hearth bath. Approximately 200 tons of lumpore will be needed per annum and 100 tons of mill scale collected from the rolling mills.

Limestone is also an ingredient of the slag and approximately 900 tons of limestone will be required. There are sundry other materials, such as fluorspar, but these are only required in small quantities.

For deoxidation of the steel ferro-alloys and aluminium have to be added and the following annual tonnages will have to be purchased, probably in India :—

Ferro-Manganese (70-80 per cent.) ..	40 tons
Ferro-Silicon (50 per cent.) ..	20 ,,
Aluminium	2 ,,

The fuel oil requirements will be of the order of 600,000 gallons per annum and this oil should have a maximum sulphur content of 2 per cent., and its calorific value has been assumed as 18,000 B. T. U's per lb.

The only other major item is refractories. These will consist principally of firebrick for ladles, silica bricks for the steel furnace roofs chrome magnesite bricks for certain vital sections for the open hearth furnace and calcined dolomite for the installation of the furnace hearth and for repairs. It is recommended that the firebricks, silica and chrome magnesite bricks should be imported. The requirements are relatively small and the material can be easily stocked. For instance, the annual requirements of these bricks will be—

Firebricks	60 tons
Silica bricks	130 ,,
Chrome magnesite bricks ..	20 ,,

Dolomite will have to be freshly calcined *in situ* as it perishes on exposure and a small kiln is envisaged in our report. This is similar to a small cupola and is preferably operated with coke. The annual tonnage of calcined dolomite needed is 500 to 600 tons.

General Metallurgical Considerations.

In the first place we recommend that only mild steels are made. It would not be advisable to consider the manufacture of medium or high carbon steel or of any alloy steels. It is not merely a question of adding the correct amount of carbon or the appropriate quantity of alloys to make such products, but these steels require specialized treatment from the casting of the ingot right down to the finished product of the ingot whilst it is not anticipated that the demand is likely to be such as to warrant the manufacture of such grades in any quantity. The steels to be made, therefore, will fall within the specification of 0·12 to 0·30 per cent C. for merchant bar wire rod and small structural sections of the standard type. Using local scrap which will vary widely in composition and origin, we recommend it should be melted and refined by the basic open hearth process which (excluding the basic electric furnace) is the only process whereby both phosphorous and sulphur can be removed. If an acid-lined open hearth furnace were installed, as has been suggested, there would be no control over the phosphorous and sulphur contents of the steel. With the basic open hearth furnace where phosphorous and sulphur can be removed a cheaper source of scrap would be available.

It will be noted that we have recommended a 20-ton oil-fired open hearth furnace which with a shallow hearth will run heats of 15 tons from cold scrap in 7 to 8 hours tap to tap. This unit, as you will note, would produce 45 tons of steel per day, which is approximately 50 per cent. more than your requirements. We have recommended this as it will allow of a stock of ingots to be made in case of shut-downs for repairs and maintenance whilst the larger unit would operate far more efficiently than two smaller units which would be necessary in order to have one unit as a standby.

In order to avoid the high capital costs of blooming mill it is recommended that billet-size ingots are cast approximately 5 inches to 6 inches square, and bottom pouring is preferred from the point of view of obtaining the best surface finish on the ingots. A number of ingots are cast at a time and the advantage of pouring small ingots is the high yield which is obtainable, the proportion of cropped ingots to open hearth charge being of the order of 90 per cent.

Products Recommended.

The rolling mill which is described in a following section of this report will be suitable for rolling merchant bar and small sections as well as narrow strip or hoop iron for baling purposes. The following range of rolled products can be made :—

	16″ Mill.	12″ and 10″ Mills.
R. S. J's	4″ to 3″	—
Channels	4″ to 3″	—
Angles	3″ to 1½″	1½″ to ⅞″
Tees	2½″ to 1½″	1½″ to 1″
Flats	4½″ to 2½″	2½″ downwards
Squares	3″ to 2″	2″ downwards
Rounds	3″ to 2″	2″ downwards
Wire rod	—	Down to 5 BG (·22″ dia.)
Hoop iron	—	3″ down to ½″ × 20 BG (·0392″)

This will cover rod for drawing into wire products, concrete reinforcing bar and for nut bolt and rivet manufacture ; hoop strip for baling and packing and small structural sections.

It is not recommended that a sheet mill should be installed at present as it would not be justified by the small output.

The manufacture of steel castings would probably be worth while at some later stage, but we do not favour the idea of using the same steel melting plant for making castings as that intended for the manufacture of ingots. Open hearth furnaces are commonly used for steel castings, but they are mainly employed in large foundries making the heavier type of castings, generally for castings weighing from 5 cwt. up to several tons in capacity. It is thought that the biggest demand in Ceylon would be for small castings, say, from 20 lb. up to 224 lb. in capacity and for this purpose a small Tropenas converter plant or an electric furnace would be far more suitable This should be borne in mind as a possible development in the near future.

We have considered the possibility of manufacturing forgings and drop stampings, but we can see little justification for such a development. The presses and hammers required are expensive in first cost and the demand for such products would be so varied and would necessitate the manufacture of so many grades of both carbon and alloy steels that such a project cannot at this stage be recommended. The manufacture of drop stampings is essentially suited to mass production, and unless this was allied to the large scale manufacture of agricultural implements or other similar engineering project it is essential to await the demand or the prospect of a demand for such products before embarking upon a scheme for the manufacture of articles which are essentially mass-produced.

In effect, we recommend in the first stage concentration on the manufacture of rolled products from essentially one grade of steel together with manufactured products made from these rolled sections. This is in our opinion preferable to branching out laterally into castings, forgings, stampings and like products, the manufacture of which requires an altogether different technique.

We recommend that careful consideration should be given to the manufacture of certain wire products, and we have included in our estimates for a wire drawing plant and a plant for small wire products.

Steelworks.

In order to provide the necessary steel ingots of the required quality, for rolling into finished, or semi-finished, products, it is proposed to instal an open hearth furnace plant.

We recommend that a small open hearth basic furnace, of 15/25 tons capacity, of the fixed type and designed for oil firing should be installed. The operations of this furnace can be so arranged as to give the tonnage of steel ingots now proposed, and its production can be increased reasonably to give further additional tonnages when required.

We propose this, as the difference in cost between a furnace of 15 tons capacity and 25 tons is not great and in the future, when the industry is established an additional steel tonnage is required, the larger furnace will prove decidedly advantageous.

As will be seen from our arrangement drawing, the furnace is located towards one end of the furnace bay, the other end being available for scrap and other materials storage. The railway is indicated running along one side of the shop for bringing in materials.

The whole shop is spanned by an electric overhead travelling crane of 5 tons capacity, which will be equipped with magnet and lifting hook, and would be used for unloading and loading materials into charging boxes, afterwards lifting these and depositing them on the bench on the furnace platform.

The furnace will be surrounded by a platform at charging floor level and on this will operate an electrically driven railless type furnace charging machine. This unit will take the loaded boxes from the stocking bench and, after charging them into the furnace, will return them to the bench for removal by the overhead crane for re-filling.

The furnace will be complete with all regenerators, flues, valves, air fan, oil burning equipment, oil storage and chimney.

Slag will be tapped into ladles, which will be lifted out by the casting shop crane and deposited on carriages on the railroad at the end of the shop for disposal.

The casting shop will be situated as shown parallel to the furnace bay and will contain a straight sunken pit in which the ingots are cast also suitably placed will be an ingot mould cooling bench, ladle and stopper drying apparatus, and a space for ladle repairing and stopper making.

The steel ladles will be held in the casting crane for casting into moulds, which would be set up in groups of about 18. These will be bottom poured through a central tundis common to each group the moulds being seated on casting plates grooved to contain the fire bricks runners.

The ingots will be stripped by means of an auxiliary hoist on the casting crane and the ingots then transferred to the end of the casting shop nearest the ingot reheating furnace. The casting shop is of the same span as the reheating furnace bay, but is higher than the latter, the crane gantry of which can therefore also cover the last bay of the casting shop, thus allowing the ingots to be transferred to the reheating furnace by a lighter crane serving them.

The casting crane will have a main hoist capacity of 40 tons and will be equipped with an auxiliary hoist of 10 tons capacity. It will span the whole width and will travel the length of the shop.

Additional equipment necessary for the steel plant, which will be supplied, will be a grinding mill for dolomite, a small crusher and heating furnace for ferro manganese, and a dolomite kiln for burning the raw magnesian limestone.

In order to produce 7,500 tons per annum of finished products of a varied nature, ranging from small sections, through the usual sizes of merchant bars down to hoop and strip for baling purposes, we have specially designed the rolling mills for this purpose, and these are described in the following pages. We have also provided for the manufacture of wire products of approximately 2,000 tons per annum, including a small tonnage of wire nails.

As previously stated, the output visualized at present is relatively small, and on the plant we recommend this production can be made working on a single shift. We are of the opinion, however, that the demand will increase in a relatively short while, and for this reason we have carefully studied the problem from the point of view of the capital cost necessary during the initial stages of operation, and little additional capital cost will be necessary to meet the future increase in demand. We have designed the plant in such a manner, therefore, that it will give low production costs with the minimum amount of labour required in the first stages. When the market enlarges the additional capital cost to meet this new demand will be relatively small, and consequently the production costs will be reduced and the margin between the production costs and selling prices considerably increased.

Under these conditions we recommend that it is undesirable to simplify the equipment unduly to cover the needs of the first stages of operation, as this would prejudice the installation of good modern labour saving equipment wherever practicable at this stage.

In preparing our layout, therefore, we have made a reasonable compromise and are putting forward a sound modern plant of medium capacity, which will give satisfactory and economical results over its useful life.

Open Hearth Plant.

Estimated Net Manufacture Cost of Steel Ingots.

Steel Production—15 tons Open Hearth, Oil Fired

Production—10,000 tons Ingots per annum

Casting—6″ × 6″ × 4′ 0″ ingots in clusters.

	Amount per Ton.	Price.	Cost per Ton of Ingots.
	Tons.	Shillings.	Shillings.
Mill scrap / Steel and iron scrap purchased	1·01	50·0	55·0
Pit scrap	0·045	40·0	1·80
Ingot moulds	0·0125	50·0	0·625
Scale and ore	0·03	20·0	0·6
Ferro manganese	0·004	say 450·0	1·8
Ferro silicon	0·002	say 500·0	1·0
Ferro alloys sundries	0·002	say 400·0	0·8
Aluminium	0·0002	1,600·0	0·32
			61·945
Less			
Pit scrap	0·045	40·0	1·8
		Net Metal	60·145
Limestone	0·09	40·0	3·6
Fluorspar	0·006	say 100·0	0·6
Dolomite	0·06	say 60·0	3·6
Coke for dolomite burning	0·01	say 80·0	0·8
Labour and supervision			12·5
Repairs and maintenance materials			2·0
Tools, lubricants, supplies and refractories			4·0
Fuel	37 gals. at 5*d*.		15·4
Electrical energy	5 KWH	0·04	0·20
Water	0·3	0·2	0·06
Traffic			3·0
Laboratory			2·0
Provision for furnace lining			5·0
Provision for moulds and plates	0·0126	400·0	5·0
General works expense and administration			8·0
	Cost above net metal		65·76
	Net cost per ton of ingot		125·905
		say	126·0

Rolling Mills.

16″ Mill.

Production :—Joists under 4″, angles from 3″ down to 1″–1½″ and 1¾″ billets for 12″ Mill

Production per annum :—4,300 tons small sections
4,000 tons billets for 12″ Mill

Total .. 8,300 tons

No. of shifts operated : 1 per day

	Total Quantity.	Amount per Ton.	Price.	Cost per Ton of Rolled Product.
	Tons.	Tons.	Shillings.	Shillings.
Ingots 6″ × 6″ × 4′ 0″ ..	10,000 ..	1·20 ..	126·0 ..	151·2
Less				
Scrap	..	0·17 ..	50·0 ..	8·5
Scale	..	0·025 ..	20·0 ..	0·5
				9·0
			Net Metal ..	142·2
Ingot reheating fuel ..	..	16 gals. ..	0·42 ..	6·72
Supervision and labour ..	..	..	..	11·0
Repairs and maintenance materials	..	..	..	1·0
Tools, lubricants and supplies	..	..	..	1·5
Laboratory and test house	..	..	..	2·0
Water	..	0·5 m³ ..	0·2 ..	0·1
Electrical energy ..	..	85 KWH ..	0·040 ..	3·4
Traffic	..	..	..	1·0
Provision for furnace ..	..	..	..	1·0
Provision for rolls ..	..	..	..	5·0
General works expense and administration		..	..	8·0
			Cost above net metal ..	40·72
			Net cost per ton of rolled product ..	182·92
			say	183·0

Rolling Mills.

12″ Mill.

Production—Small Sections under 1″-1½″ }
Wire Rod 3/8ths } Assumed 3,700 tons per annum
Hoop Strip }

No. of shifts operated : 1 per day

	Total Quantity.	Amount per Ton.	Price.	Cost per Ton of Rolled Product.
	Tons.	Tons.	Shillings.	Shillings.
Billets from 16″ mill ..	4,000 ..	1·08 ..	183·0 ..	197·64
Less				
Scrap	..	0·055 ..	50·0 ..	2·75
Scale	..	0·025 ..	20·0 ..	0·5
				3·25
			Net Metal ..	194·39
Billet heating fuel ..	..	18 gals. ..	0·42 ..	7·56
Supervision and labour ..	..	..	..	15·5
Repairs and maintenance materials	..	..	..	1·0
Tools, lubricants and supplies	..	..	..	1·25
Laboratory and test house	..	..	..	2·0
Water	..	0·6 m³ ..	0·2 ..	0·12
Electrical energy ..	..	115 KWH ..	0·04 ..	4·6
Traffic	..	..	..	1·0
Provision for furnaces ..	..	..	..	1·0
Provision for rolls ..	..	..	..	4·0
General works expense and administration		..	..	8·0
			Cost above net metal ..	46·03
			Net cost per ton of rolled product ..	240·42
			say	241·0

5.—Paper.

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REPORT ON ESTABLISHMENT OF PAPER INDUSTRY IN CEYLON.

Suitability of Raw Materials for Paper Making.

A presentable sheet of paper can be made from almost any vegetable fibre, but the number of fibres utilized commercially are relatively few. The question to be considered in connection with raw materials which preferably, should be waste products or by-products of some other industry, are the quantity and concentration of the available supply, the conditions of cropping and the cost of transport from the field of the factory.

Technical questions are, the uniformity and quality of the fibre for paper making, the yield of pulp from it and the expenditure of chemicals, fuel and labour in its treatment. These are, of course, also prime economic factors. This section deals with these questions, as fully as facilities to hand permit, and refers to the following materials :—

(*a*) Illuk Grass—(Imperata Arundanacea).
(*b*) Mana Grass—(Andropogon Nardus).
(*c*) Citronella Grass—(Cymbopogon Nardus), Distillation residue.
(*d*) Paddy Straw—(Oriza Sativa).

Illuk Grass.

Experiments were conducted some years ago by paper makers in England who found this grass well suited for paper making. They stated that it gave a reasonably good yield of pulp and bleached readily. As a raw material it resembles African Esparto grass, but it requires a more drastic treatment for the manufacture of bleached paper.

The Imperial Institute has experimented with Illuk grass grown in Ceylon. It reports that the grass furnishes a fairly good yield of pulp by normal caustic soda process from which white papers can be made. The yield is somewhat lower than that obtained from African Esparto and the fibres are harder and less bulky. The pulp produced an opaque, well closed sheet of greyish cream colour and possessed satisfactory strength. It bleaches easily to a good white shade. There are reports of Imperata Arundanacea having been used for making pulp and paper on a commercial scale in Queensland and Indo-China.

After conducting a series of pulping experiments at the Industrial Research Laboratories of this Department the writer can confirm that the foregoing opinions are substantially correct. In these experiments the grass was chopped into lengths of about two inches and digested by the normal caustic soda process. At first the single stage method of cooking was used, the conditions and results are shown in Table No. 1.

Table No. 1.

ILLUK GRASS.

Ref.	Caustic Soda used.		Cooking Conditions.		Yield.	Remarks.
	Parts/100 Parts Grass.	Parts/100 Parts Solution.	Time. Hours.	Steam Press LBS/O ″		
a	16	2	3½	60	—	Large quantity unresolved fibre, dark brown in colour
b	18	3	4	60	—	Little improvement
c	20	2·5	4½	65	—	Resolution and colour improved but not satisfactory
d	22	2·45	5	65	—	Still not good enough for bleaching

These experiments carried a single-stage digestion to a point where the consumption of caustic soda was excessive and the fibres still not sufficiently resolved. The feature mostly militating against good results was the bulky nature of the grass which necessitated a large volume of relatively weak caustic solution. The effect of this will be much less pronounced in a commercial size digester as the solution is circulated in the digester while the grass is filled into it. By the time the desired amount is filled into the digester the bulk is considerably reduced and a smaller volume of more highly concentrated and therefore more effective solution can be used. To overcome this difficulty two-stage or fractional digestion was introduced with improved results. The following indicate how this method was used.

The conditions shown in Table No. 2, Ref. c., produced satisfactory results. The first stage removed most of the ligneous matter and reduced the bulk of the grass to such an extent that a smaller volume of strong solution could be used in the second stage. This produced a soft well boiled pulp of good colour, the yield was reasonably high and it bleached to a good white shade with 12 per cent. bleaching powder on the original weight of fibre. It is reasonable to expect a modification of these conditions resulting in a slight saving in one or other of the three factors, namely, caustic soda, steam or time, in a commercial digester fitted with circulating equipment. In fact it may not be necessary to cook Illuk grass fractionally but if it is, it should be noted that the spent caustic soda solution from the second stage in one cook can be used in the first stage in the next one. This is an important feature of economic importance of this process.

Table No. 2.

ILLUK GRASS.

	1st Stage.				2nd Stage.					
	Caustic Soda used.		Cooking Conditions.		Caustic Soda used.		Cooking Conditions.			
Ref.	Parts/100 Parts Grass.	Parts/100 Parts Solution.	Time. Hours.	Steam Press LBS/O″	Parts/100 Parts Grass.	Parts/100 Parts Solution.	Time. Hours.	Steam Press LBS/O″	Yield.	Remarks.
a	12	1·5	1½	60	12	3	3½	60	39	Some unresolved fibre, very good colour
b	16	2	1½	20	12	3	3½	60	41	Resolution same as above, colour good
c	16	2	1½	60	16	4	3½	60	38·8	Satisfactory pulp ready for bleaching
d	14	2·1	1½	60	16	4·8	3	60	42	Satisfactory pulp ready for bleaching

It will be seen from the foregoing that Illuk Grass yields to a moderate treatment, produces an economic yield of pulp and bleaches readily. A variety of writing and printing papers can be made from it, while in the unbleached form the pulp can be used for cheap wrapping papers.

Mana Grass.

So far as can be ascertained this grass has never been used as a raw material for making paper. A series of digestion experiments were carried out with Mana at the Industrial Research Laboratories. The grass had been cut close to the stolan, and the whole plant was digested by the caustic soda process after it had been cut into pieces about 2 inches long. The cooking conditions and results are shown in Table No. 3.

Table No. 3.

MANA GRASS.

	1st Stage.				2nd Stage.					
	Caustic Soda used.		Cooking Conditions.		Caustic Soda used.		Cooking Conditions.			
Ref.	Parts/100 Parts Grass.	Parts/100 Parts Solution.	Time. Hours.	Steam Press LBS/O″	Parts/100 Parts Grass.	Parts/100 Parts Solution.	Time. Hours.	Steam Press LBS/O″	Yield.	Remarks.
a	14	1·75	1½	60	14	3·5	3	60	38·2	Some unresolved fibres, poor colour
b	16	2	1½	60	16	4	3½	60	33·6	Resolution and colour improved
c	14	2·1	1½	60	16	4·2	3½	60	34	Good resolution and colour
d	16	2·4	1½	60	16	4·8	3½	60	—	Ready for bleaching

As will be seen from the above, Mana yields to a moderate treatment in the digester. The fractional method was employed for the same reason it was used in digesting Illuk Grass. The pulp produced was at least as good as from Illuk in regard to length and strength of fibre and the yield of cellulose was only slightly less. It bleached white with 12 per cent. bleaching powder on the original weight of fibre.

Its chief characteristics compares closely with Illuk grass and it will therefore, produce a similar variety and quality of paper. It is in all respects a very useful material for making paper, but as it is only found in any quantity on hilly ground remote from roads and railways the cost of cutting, extracting and transporting it to the mill precludes its utilization profitably.

Citronella Grass (*Distillation Residue*).

As far as is known this grass has never been commercially used as a raw material for making paper. The Imperial Institute has experimented with spent Citronella Grass from Ceylon and states that it cannot be recommended as an economic source of paper pulp. The culms are difficult to reduce, the yield of cellulose is very low and the treatment required is too drastic to be profitable. The Imperial Institute further states that the leaves entirely freed from culms would be more easily reduced to pulp, but it is presumed it would not be feasible to ensure that the material would be in such a condition. In regard to the last remark the grass has been digested in the laboratory here after the culm below the leaves has been cut off but without appreciable improvement in the appearance of the pulp.

A series of digestion tests with caustic soda were carried out in the Industrial Research Laboratory. The grass was dried out to approximately an air dry condition and prepared in the usual manner by cutting it into short lengths. At first the single stage method was employed, the conditions and results are shown in Table No. 4.

Table No. 4.

CITRONELLA GRASS.

Ref.	Caustic Soda used. Parts/100 Parts Grass.	Caustic Soda used. Parts/100 Parts Solution.	Cooking Conditions. Time. Hours.	Cooking Conditions. Steam Press LBS/O ″.	Yield. Per Cent.	Remarks.
a	12	2	3	60	—	Pulp very raw and contained much unresolved, dark green colour

The results were very unsatisfactory for although the leafy portion of the material responded on the whole to the treatment the pulp was rendered of little value through the presence of undisintegrated pieces of the culms most of which was only slightly attacked by the caustic soda. Also, the pulp was in a highly pigmented condition, its colour was dark green. It was apparent that single stage cooking, especially in in regard to the pigmentation, would be unsatisfactory under almost any conditions. Fractional digestion was, therefore, resorted to particulars of which are set out in Table No. 5.

Table No. 5.

CITRONELLA GRASS.

Ref.	1st Stage. Caustic Soda used. Parts/100 Parts Grass.	1st Stage. Caustic Soda used. Parts/100 Parts Solution.	1st Stage. Cooking Conditions. Time. Hours.	1st Stage. Cooking Conditions. Steam Press LBS/O ″.	2nd Stage. Caustic Soda used. Parts/100 Parts Grass.	2nd Stage. Caustic Soda used. Parts/100 Parts Solution.	2nd Stage. Cooking Conditions. Time. Hours.	2nd Stage. Cooking Conditions. Steam Press LBS/O ″.	Yield.	Remarks.
a	12	1·75	1½	20	12	4	2½	60	27·8	Much unresolved fibre; Light green colour
b	12	2	1½	60	12	4	2½	60	26·5	Still too much unresolved fibre; pale green colour
c	14	2	1½	60	14	4·5	2½	60	26·4	Resolution slightly better; very pale green colour

The results show a considerable improvement. Resolution was better although there was incompletely digested culm and the colour was improved. Most of the pigment was removed in the first stage thus enabling resolution to be carried further in the 2nd stage with the caustic solution in a much cleaner condition. The worst feature however was the very low yield, it is too low to be economic even with the grass at a very low price. There appears to be a considerable quantity of organic and inorganic matter in the grass which is dissolved in the cooking process and charged with the spent caustic solution.

Citronella Grass is, because of the drastic treatment required in the digester and the low yield of pulp obtained from it, uneconomic as a raw material. Also there is not sufficient of it to meet the requirements of the mill within an economic radius as the oil distilleries use most of it as boiler fuel.

Paddy Straw.

Straw of several varieties has been used for making paper. In Britain during the last war when supplies of Esparto Grass were cut off it came into general use. Wheu used alone it produces medium grade papers having trans-lucency and rattle as their chief characteristics. It is not so suitable for making bulky, soft and opaque papers but the writer is of opinion that this can be counteracted to a large extent by mixing it with Illuk Grass. This will enable it to be used for a much wider variety of papers than when used alone. Paddy Straw or Illuk Grass will when used by themselves or mixed together produce all but the highest quality of paper, used in Ceylon. The high quality papers represent a comparatively small proportion of the total quantity consumed but even these can be produced from straw or Illuk with the addition of a certain percentage of rags or wood pulp.

It was found by experiment that paddy straw can be reduced to pulp by a comparatively mild treatment with caustic soda. There is no necessity for fractional digestion as it does not bulk so large and can be resolved with a weaker solution of caustic soda than the grasses experimented with. The nodes are naturally, the most difficult part of the plant structure to resolve and optimum digesting conditions have to be obtained where the fibres in the internodal parts are resolved without deterioration while the nodes which have not broken down are left to be dealt with in the subsequent straining process. A satisfactory yield of cellulose, similar to that from Illuk Grass was obtained from the straw and the pulp bleached to good white shade. The bleaching powder consumption on a commercial scale will not exceed 12 per cent. of the original weight of fibre.

In preparing the straw for experimental digestion it was cut into pieces about 2 inches long. The results of these experiments are shown in Table No. 6.

Table No. 6.

PADDY STRAW.

Ref.	Caustic Soda used. Parts/100 Parts Straw.	Parts/100 Parts Solution.	Cooking Conditions. Time Hours.	Steam Press. LBS/O ″.	Yield.	Remarks.
a	8	1	3	60	40·5	Pulp raw much unresolved matter
b	10	1·25	3	60	59·8	Resolution improved, pulp cream colour
c	12	1·5	3½	60	30	Resolution good, some shive from nodes can be removed by straining, satisfactory for bleaching
d	14	2·1	3½	60	37·5	Slight improvement still some shive from nodes, good enough for bleaching

Table No. 6, Ref. c, indicates the conditions under which straw can be reduced to pulp suitable for bleaching. The remarks referring to the cooking of Illuk Grass in a commercial digester adopted for circulation of the cooking solution apply here also to some extent. A reduction in caustic soda or steam consumption is not expected as these are already on a low level but there may be some improvement in the resolution of the nodal parts.

Paddy Straw is, next to Illuk Grass, the best now under consideration as a raw material. It yields to a mild treatment, produces a satisfactory yield and bleaches easily. It is suitable for making papers similar to those derived from Illuk Grass but slightly inferior in bulk, opacity and softness. Straw because of its capacity for hydration is particularly suited for thin papers. When mixed with a strong fibre such as rags or chemical wood pulp it will produce typewriting and air mail paper.

Dry Digestion.

Mention should be made here of the new method of digestion introduced experimentally at the Research Laboratory of the Department of Commerce and Industries before the writer came to Ceylon. It consists of soaking the raw materials in a caustic soda solution, pressing the excess solution out of or allowing it to drain from the raw material, then steaming it in a digester. It might be described as a dry method for there is no solution in the digester other than what the raw material has absorbed.

The result of this method with Paddy Straw is quite remarkable. The fibres have absorbed the caustic solution before entering the digester and there being no mass of free solution to heat up the pressure and temperature rises quickly after the steam is applied to the digester and resolution starts early and proceeds rapidly. The cooking time is consequently shorter than in conventional digestion.

As there are no facilities for proving the dry method on a commercial basis it will be necessary to design the projected mill on conventional lines. The new method can however, be experimented with after the mill is constructed and there are good reasons for believing that, possibly with some modification to either the process or the mill equipment it can be put into successful operation. The savings it will introduce will be considerable.

Conclusion.

It will be seen from the foregoing that Illuk Grass and Paddy Straw are the only two materials which can be utilised economically. It is therefore, these two which will form the basic materials for producing paper. It is stated earlier in this section of report that the pulp derived from them will, when bleached, produce a wide variety of printing and writing papers. In the unbleached condition it will produce cheap wrapping papers. It should be noted that neither of these raw materials are suitable for making very strong papers such as kraft. Newsprint made from them will be more costly then the imported variety as it is made from mechanical wood pulp.

The following figures obtained from the Assistant Paper Controller show the average yearly imports of paper to Ceylon, based on the period from January 1, 1937, to June, 1939, which these raw materials will produce—

(*a*) Writing Paper, 1,560 tons,
(*b*) Printing Paper, 1,926 tons.
(*c*) Wrapping Paper, 815 tons.

Note.—2,028 tons of wrapping paper were imported but 815 is the estimated tonnage which can be made from local material.

It will be observed that the printings and writings together are more than the proposed initial production of the mill and that with the wrappings added the tonnage is nearly half as much again. There is also the growing demand to take into consideration due to the improved educational facilities and a higher standard of living ; nor should the possibility of making papers to meet other internal demands be excluded.

The average c.i.f. price in Ceylon for these papers in 1947 was—

(*a*) Writings—£79 or Rs. 1,050 per ton.
(*b*) Printings—£77 or Rs. 1,024 per ton.
(*c*) Wrappings—No figures obtainable for paper comparable with that to be produced from local raw materials.

It is estimated that these papers can, at the prevailing price of materials, be produced in in Ceylon for—

(*a*) Writings } Average Rs. 802 per ton
(*b*) Printings }
(*c*) Wrappings Rs. 728 per ton

Description of Power and Paper Making Plant for the Production of 3,000 Tons of Bleached Paper Per Annum from Paddy Straw and Illuk Grass.

The plant herein described embodies the most modern methods and equipment for the type and size of mill under consideration. Having in mind that fully mechanized paper-making will be a new industry in Ceylon, the processing method and machinery will be as simple as possible so that the operatives will be able to adapt themselves to it and learn the technique of its manipulation as quickly as possible. This description follows the natural sequence of the process.

Power Plant.

(*a*) *Boilers.*—These will consist essentially of two water tube boilers each digested for a steam pressure of 250 lb. per sq. inch and a normal evaporative capacity of 22,000 lb. of steam per hour. They will be equipped for oil firing and be fitted with a superheater for a total temperature of 500° F also an economiser which will raise the temperature of the feed water to boiling point before entering the boiler. Only one boiler will be necessary at a time the other will act as a standby.

The auxiliary equipment will include induced draught fan, feed water softener, feed tank, two feed pumps, a duplicate oil fuel heating and pumping set and fuel storage tank.

(*b*) *Turbo-alternator.*—The power generator will have a normal rated capacity of 900 K.W. at 440 volts. The turbine will be of the passout steam type which means that the process heating steam will first go through the turbine and be passed out at a point where the pressure has been reduced to 30 lb. by the steam producing power. The remainder of the steam will pass on to a surface condenser in the usual way. There will be an automatic regulator for controlling the pressure and quantity of the passout steam. The unit will be equipped with the necessary cooling water, condensate and oil pumps. This type of prime mover is highly economical in steam and is eminently suited for a paper mill. The turbine will drive the alternator through a speed reduction gear.

A switchboard will be provided which will include panels for the alternators a voltage regulator and the necessary number of distribution panels. There will also be a panel and voltage transformer for the lighting circuits

If power for use when the main power unit is stopped at the week-end cannot be purchased from an outside supply a diesel-alternator having a normal rating of 90 K.W. will be installed. This unit will be equipped with the necessary auxiliary equipment, namely,air compressor, starting air bottles and fuel tank.

A panel will be provided for it on the main switchboard.

Water Supply.

There will be two electric pumps each capable of delivering approximately 2,000,000 gallons of water per 24 hours to the mill. Only one will be required at a time, the other will act as a standby.

Tanks for coagulating and settling sedimentary matter in the process water will be required. It will also be treated in a rapid gravity sand filter. The process water amounts to about one-fourth of the total required. It will be delivered to the various departments of the mill at a pressure of 25 lb. per sq. inch.

The remainder of the water which is required for the turbine and soda recovery plant condensers will only be screened.

Collection, Transport and Storage of Raw Materials.

It is recommended that collection centres be established in the paddy and grass growing areas selected, they should be on a motor road or railway. The paddy farmers and contractors entrusted with the cutting and collection of the grass will deliver the materials to these centres. It is assumed that Government representatives will take delivery at these centres where the straw and grass will be baled to reduce the bulk to suitable proportions for handling, transport and storage. The baling presses will be operated by petrol motors and be portable.

On arrival at the mill either by road or rail the bales should be weighed and samples obtained from representative bales for moisture determination. This is necessary so that payment can be made and all accounting carried out on an air-dry basis.

It will be advisable to store the bales in sheds to avoid deterioration of the straw and grass between cropping seasons. The sheds should be large enough to accommodate, say, 4,500 tons whcih is roughly 6 months' supply. These sheds should equipped with electric transporter cranes to facilitate unloading, stacking and conveyance of the bales to the processing plant.

Straw and Grass Duster, Elevator and Conveyor.

The raw material will be fed to a rotary duster which removes soil and dirt adhering to it. A dust extraction and collecting unit connected with the duster will bag the düst ready for disposal. An elevator and conveyor removes the raw material from the duster and feeds it direct into the digesters as required.

Digesters.

The raw materials are "cooked" in a solution of caustic soda under steam pressure. This operation is carried out in vertical stationary digesters fitted with solution circulating equipment. Three digesters each capable of holding 5 tons of air dry material are required.

While the grass or straw is being fed into the digester the solution is circulated in it. The volume of raw material is thereby reduced and the maximum digester charge obtained. The digester equipment wi!l be arranged for both single stage and two stage or fractional digestion.

When digestion is complete pressure is reduced and the solution run off to the recovery plant where the remaining soda is recovered for further use. The pulp in the digester is then washed with hot water to remove as much of the spent caustic solution containing ligneous matter as possible. The pulp is washed out of the digester with a high pressure water jet and flows by gravity to the next stage in the process.

Washing and Breaking Machine.

The function of this equipment is to open out the small bundles of fibres so that they can be effectively washed free of the remaining spent caustic solution. The potcher, as it is usually referred to, is a very large tub or vat with semi-circular ends and a division down the centre but which does not extend to the ends. The pulp is circulated in this tub at about 3½ per cent. density by a roller on one side of the division which has paddles on its periphery, the fibre bundles are broken up by the action of these paddles.

A drum with a fine wire cloth around it and buckets inside is partially submerged in the pulp and removes the objectionable solution; fresh water is added till the pulp is quite clean. The pulp is then thickened to about 5 per cent. density, the drum lifted clear of it and the first-stage hypochlorite bleaching solution run in. The pulp is circulated till bleaching solution is thoroughly mixed and is then pumped to the tower bleaching plant.

Bleaching Plant.

A tower bleaching plant derives its name from the fact that it consists of a number of cylindrical tower-shaped vessels. These towers have conical bottoms and each is fitted with a pump for circulating the pulp or for transferring it from one tower to another. In this case there will be four towers.

The first tower is equipped with dewatering drums or concentrator and when the bleaching solution which has been added to the pulp in the potcher is exhausted the pulp is washed with water just before passing into the concentrator for thickening. On being concentrated to about 6 per cent. the pulp is delivered into the next tower where the solution for the second stage bleaching is added.

The bleaching action is accelerated by circulating the pulp at intervals. It is passed on to the third and fouth towers as bleaching proceeds and as space becomes necessary for more pulp coming forward in the process. By the time the pulp reaches the last tower the chlorine should be exhausted and bleaching complete. It is pumped from the last tower to the straining plant.

Straining Plant.

The purposes of this equipment is to receive all adventitious material from the pulp. Firstly the pulp, in a highly dilute condition (about 1 per cent. fibre) flows over a sand trap which is a trough with a series of baffles interposed across the flow. Dirt particles settle out behind these baffles and are eventually removed. From the sand trap the pulp passes into rotary drum strainers which reject all fibrous matter over a pre-determined size. They also reject a considerable amount of extraneous matter not settled out in the sand trap. An auxiliary strainer deals with the fibrous matter which the drum strainers have rejected so that it can be recovered for further treatment. After straining the pulp is again dewatered in a concentrator so as to bring it into the most suitable density for treatment in the beaters which is about 5 per cent. fibre. The concentrator delivers the thickened pulp into a storage chest which is situated below it.

Beaters.

The object of these machines is to bring about a hydration and fibrilation of the pulp so that it can eventually be formed into a homogenous product bearing the physical characteristics desired in the paper. The pulp is pumped from the storage chest referred to above to the four beaters which in this case, are necessary. These. beaters will be of the Hollander type each having a capacity for 1,000 lb. dry stock. They consist of a tub or vat as described for the potcher ; they have a somewhat similar roll but no water extractor. Steel bars are fixed in the bottom of the tub immediately under the roll and it is between these bars and the rotating bars of the roller that the fibres are reduced to the requisite dimensions. The roll is adjustable in relation to the stationary bars so that the cutting action can be regulated to the desired degree. The beater is emptied through a valve which directs the pulp into a pump for transferring it to a storage chest which is fitted with an agitator to prevent the stock settling. Beating to produce the best results for various grades of paper requires considerable skill which can only be gained by experience.

The sizing agent, loading material which will be China clay or kaolin, and dyes when they are necessary, are all added and mixed in the pulp in the beater.

Paper Making Equipment.

This heading includes the machine stock chests, sand traps, strainer and the paper machine which forms the fibres into a sheet, extracts and dries out the water in which the fibres have been suspended, calendars and cools the sheet, and finally winds it on a reel.

The storage chest containing the beaten stock supplies the machine chests by gravity as required. These chests are also provided with agitators to maintain the density of the stock in a uniform condition. The stock at about 3 per cent. density is pumped from these chests to a service tank which maintains a constant pressure head and from thence it flows by gravity to a mixing box where it is diluted with water to 1 per cent. or less. From this box the stock flows over a sand trap similar to that described for the straining plant and into a drum strainer. The effect of which has also been previously mentioned. In this case however, it is strained to a finer degree.

From the strainer the stock flows, still by gravity, through a sepcially designed box which spreads it over the endless travelling and shaking wire cloth of the paper machine. The water drains through the fine meshes of the wire cloth leaving the fibres in a felted condition on it and at a point when drainage becomes too slow a suction is applied to the underside of the wire; this extracts more water and the sheet is then consolidated between two couch rollers. At this point the sheet is strong enough to be transferred by hand to the wire cloth on to endless travelling felt which carries the sheet through a pair of press rollers. Here the sheet is subjected to considerable pressure and much water is squeezed out. It is then run through two more sets of press rollers the third time the direction is reversed so that the bottom side which has been in contact with the carrying felts is now uppermost and the impression of the felt is smoothed out by coming in contact with the polished surface of the top roller.

The paper still contains about 60 per cent. of moisture and as about as much water as possible has been squeezed out, steam drying is resorted to. The sheet is led around, over and under a double tier of steam heated cylinders. Before quite dry it is passed between a pair of smoothing rollers. From the last cylinder the sheet is led through two sets of calendar rolls where any irregularity in thickness is corrected and the surface glazed to the desired extent. The paper making process now being completed and as the sheet is in a hot condition it is passed over two cooling cylinders before being wound up on a reel.

The machine herein described will produce a sheet of paper 92 inches wide at speeds up to about 400 feet per minute. It will be driven by a variable speed electric motor. The various sections of the machine will be driven independent of one another by means of a line shaft and cone pulleys so that the speed can be adjusted to suit the stretch of the paper.

Sheet Cutter.

A rotary duplex sheet cutter will slit the sheet from the parent reel into widths and cut them off at the desired length. This machine will have a wide range of adjustment both in regard to width and length of sheet. It will be provided with an automatic layer for catching and piling the cut sheets.

Slitter and Winder.

This machine will slit the sheet from the parent reel and rewind it in any required width except very narrow reels.

Guillotine.

A guillotine is provided for trimming off-cuts or for reducing the size of paper that has already been cut.

Finishing Department.

The work in this Department consists of examining the better grades of sheeted papers and counting the sheets into reams. All dirty, creased or badly cut sheets are rejected for repulping. Coloured and tinted papers are also examined for shade.

The stock warehouse, packing and despatch sections are usually part of the finishing department.

Chemical Department.

The equipment in this department are as follows—

(*a*) *Hypochlorite Bleach-making.*—If bleaching powder is used three mixing tanks will be required. The tanks are fitted with stirrers for mixing the bleaching powder in the water, and cocks are provided at suitable levels for decanting the solution after the residual matter has settled out. After decanting the solution is stored in tanks till it is required. If liquid chlorine and lime is used a deep tank is necessary to contain the water and lime. The chlorine is supplied in cylinders under pressure and when released is bubbled into the lime formation which is in a state of suspension in the tank. It becomes absorbed by the lime and after settling, the solution is decanted into a storage tank.

(*b*) *China clay* (*Kaolin*).—Used as a filler in paper. This is mixed with water in a tank fitted with stirrers and kept in a state of agitation till required when it is filtered and centrifuged to remove grit and dirt.

5——J. N. 11725 (12/47)

(c) *Resin Size.*—The size is prepared in an open steam-jacketted pan in which the resin is boiled in a solution of soda ash. It is stored in a tank till required and is filtered before adding to the beater.

(d) *Alum.*—This is used for precipitating the size on the pulp fibres. It is usually dissolved in a wooden tank lined with lead. The slabs of alum are placed in it and a constant flow of water through the tank dissolves the slabs and produces a solution. It is stored in a separate tank till required.

Recovery Plant.—The object of this equipment is to recover the soda remaining in the solution which has been used for digesting the raw materials. With a plant in good condition and efficiently operated 92 per cent. of the soda in the spent solution can be recovered. The solution is first evaporated to dryness in a multiple effect evaporator. In this condition it is fed into a revolving furnace or kiln where the organic matter, principally lignin from the raw material, is burned off. A coal, wood, or oil fire is required to start combustion but the calorific value of the organic matter is considerable and sufficient to maintain combustion without any external heat. When the combustible matter has been burned off the remaining soda ash is discharged from the furnace and dumped into lixivating tanks. The next stage in the recovery process is to convert the sodium carbonate in the soda into caustic soda and this consists in heating a solution of the soda with burnt lime. This operation is carried out in causticising tanks which are cylindrical vessels fitted with stirrers.

The lime in lumps is contained in an iron basket at the side of the tank and it gradually disappears in the solution under the action of the stirrers. When causticisation is complete, the sedimentary matter is allowed to settle after which the solution is decanted and the spent lime discharged. Losses in the digesting and recovery processes are made up by adding fresh soda ash to the causticisers.

Modern plants are equipped with waste heat boilers which utilise the heat from the rotary furnace for producing the process steam required.

Engineer's Workshop.

This shop will be equipped with the necessary machine and tools to effect all but major repairs to the plant and machinery. A section will be set a side for the electricians and joiners.

Plan of Mill.

Estimate of Executive and Office Staff, Superintendents and Operatives.

A.	Executives :	Manager, Engineer	Paper- maker Chemist	(Assistant Manager) Accountant
B.	Office and Stores :	Four Seniors,	Four Juniors,	Three Peons
C.	Superintendents and Foremen :	Three Superintendents,		Three Foremen
D.	Operatives :—			

(a) Shift workers, skilled ..	45	Semi-skilled ..	57	Un-skilled ..	75
(b) Day workers, skilled ..	9	Semi-skilled ..	33	Un-skilled ..	25
Total skilled ..	54	Semi-skilled ..	90	Un-skilled ..	100

Total in Category A	5
Total in Category B	11
Total in Category C	6
Total in Category D	244
Grand total	266

European Specialists for Supervising the Construction of the Mill and putting it into Production.

So far as the writer is aware there are no firms of purely consulting engineers in the U. K. specialising in complete paper mill plants. Projects are usually developed by the manufacturing engineers in collaboration with the mill staff. It will be necessary therefore, to engage a specialist who can draw up specifications, examine tenders and advise Government on same. He will co-ordinate the work of the suppliers and contractors and be responsible for the construction of the entire mill. Finally the plant will be put in production under his supervision. Under present conditions the mill cannot be put into operation in less than 2½ to 3 years after the major items have been ordered. The services of this specialist will therefore be required over a period of three or four years.

A fully qualified paper-maker will also be required. He should be engaged to start work some months before the mill is ready for going into production. He will be responsible for the manufacture of the paper until the permanent mill staff is sufficiently conversant with the process to take over from him. The length of time required for this depends largely on the aptitude of the permanent staff to adopt themselves to the process. It can be expedited by sending the future manager and paper maker abroad for a period of training before construction starts. Assuming this suggestion is carried out the services of the European paper maker will be required from two to three years.

The engineers who supply the paper making machinery should send one erector who is thoroughly experienced in the equipment which they make. His services will be required for about one year provided there is no delay in the delivery of the machinery and there is no serious interruption in construction.

Synopsis of Report on the Establishment of a Paper Factory by Mr. R. Grierson.

This report, the result of widespread and through investigation, has as its main subject the elucidation of the following main points which are decisive in considering whether a paper industry can be established in Ceylon on a sound economic basis.

(*a*) Are there suitable indigenous raw materials in sufficient quantity to maintain a paper industry of economic proportions ?

(*b*) Can these raw materials be procured and transported to the manufactory at an economic cost ?

(*c*) Can these materials be converted into paper economically and what varieties of paper will they produce ?

(*d*) Location of mill in relation to source of raw material supply, transport facilities for fuel, chemicals, general stores and paper, availability of water and labour.

(*e*) Is there sufficient demand for the papers which can be produced to warrant the establishment of a paper industry ?

(*f*) Will the manufacturing cost of these papers enable them to be sold at a price which will compete favourably with the c.i.f. value of imported papers of similar quality and yield a satisfactory return on the capital invested in the industry ?

The foregoing have been dealt with at considerable length in the text of the report. The following answer to these questions in a condensed form and provide a general view of the possibilities of the project.

(*a*) There are sufficient raw materials existing or potential to support a paper industry of economic proportions. The most suitable are Paddy Straw and Illuk Grass. Sufficient of the former is now available to supply the industry but the growth of the latter will have to be developed to produce an adequate supply. These materials can be used separately or mixed together so that manufacture is not entirely dependent on one or the other.

(*b*) Paddy Straw and Illuk Grass can be purchased and transported to the manufacturing centre at an economic cost but the latter will have to be conserved and developed to ensure an adequate and continuous supply under intensive cutting conditions. If measures for this purpose are put in hand in the near future the grass will have developed a long way to ensuring an adequate supply by the time the mill is ready to produce paper.

(*c*) Both Paddy Straw and Illuk Grass can be converted into paper satisfactorily and economically by the caustic soda process. Separately or mixed together they will produce a wide variety of good quality writing, printing and book papers. Each will however, produce paper of slightly different characteristics. In an unbleached condition the pulp can be made into wrapping paper possessing moderate strength.

(*d*) It is logical to think that the mill should be situated as near to the source of raw material supply as possible but due to the position of Ceylon's only commercial seaport in relation to the paddy and grass growing areas and the inadequacy of transport facilities this is apparently, not so. The schedule of comparative transport costs in Section 1 of the report indicates that it will be more economical to construct the mill near Colombo. This circumstance is influenced by the fact that all fuel, chemicals and other stores have to be imported through that port and most of the paper made will be disposed in Colombo. As a result of the foregoing the Kelaniya area has been taken as a basic for the economic section of the report. It possesses almost all the essential requirements of paper mill site but there are various other factors to take into account in a national undertaking of this description. The location of the mill is therefore, open to further consideration.

(*e*) Pre-war imports of paper similar to these which can be made from indigenous raw materials were in excess of the proposed initial production of the mill and it is reasonable to assume that these imports would have increased considerably but for the intervention of the war. Current import figures are no criterion of the demand for the paper as consumption is restricted by the supply. There is adequate scope for a paper industry in Ceylon and improved educational facilities, a higher standard of living and the possibility of an export trade enhances its prospects.

(*f*) Using estimated costs of raw materials, price quotations for fuel, chemicals and freight rates and current wage rates as a basis for calculation it is found that the total manufacturing cost will be approximately 80 per cent. of the current c.i.f. value of imported papers similar to these which can be made locally. This percentage is not unduly high considering the delivered cost of materials and can be reduced if railway freight rates are modified to more reasonable proportions and long term contracts are arranged for bulk supplies of oil fuel and chemicals. The interest on capital invested is relatively low, namely, 5½ per cent. This is to some extent due to the present high cost of paper mill equipment and in this respect is not an exceptional case. The return on capital invested will of course, increase as the manufacturing cost is reduced.

May 21, 1947. R. GRIERSON.

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SUPPLEMENT TO REPORT ON THE ESTABLISHMENT OF PAPER INDUSTRY IN CEYLON—REFERRING TO THE POSSIBILITY OF PRODUCING PAPER FOR MAKING CEMENT SACKS.

With a cement factory being constructed at Kankesanturai there is no need to enlarge on the advantages of producing cement sacks in Ceylon. The possibility of manufacturing paper for making them is however, a matter for careful consideration as there are no suitable indigenous raw materials for producing the very strong paper normally used for this purpose. The following is the number of 112 lbs. sacks which will be required—

(*a*) Designed output of cement factory 100,000 tons per year ;
(*b*) Number of sacks required for above 2 millions.

The raw materials recommended for the projected paper mill are Paddy Straw and Illuk Grass. These are the only two which can be obtained in sufficient quantity and at economic cost but neither are capable of producing paper possessing strength characteristics comparable with the Kraft paper which cement sacks are usually made of. Kraft paper is made of wood pulp which has been specially treated to obtain maximum strength conditions. Fibres such as manilla, hemp, jute and flex produce very strong papers but as indicated above they are either non-existent or unobtainable in sufficient quantity in Ceylon.

There are two suggestions for overcoming this difficulty—

(*a*) A cement sack being made of several plies of paper the number of plies can be increased to compensate for the lack of strength in the paper. There is however, an economic limit to this for if the plies have to be incresed beyond a certain point it will be cheaper to import sacks. This has still to be investigated and a decision can only be arrived at by comparing the bursting strain of paper similar to that which can be made locally with that of Kraft paper. There are no facilities for doing this in Ceylon but the writer hopes to be able to come to a decision on this point after he has returned to the U. K. where the necessary information can be obtained.

(*b*) To import a cheap quality of open textured gunny or similar fabric and sandwich it between sheets of locally made paper, The sack will depend largely on the gunny for strength and the paper will contain the cement and provide a suitable surface for any printing that may be necessary. This form of sack like the all-paper one, can be seamed down one side with an adhesive and closed at the ends with wire staples. Enquiries are being made in India regarding a suitable fabric.

The price of Kraft paper sacks—apparently French made-quoted in a recent tender from the U. K. is—

Five-ply sacks ·41 cents each f.o.b. Marseilles—say ·49 c.i.f. Colombo
Six-ply sacks ·50 cents each f.o.b. Marseilles—say ·60 c.i.f. Colombo

Presumably the first mentioned would be suitable for local use and the other for export purposes.

It is estimated that sacks having the same number of plies of paper as above but made from Paddy Straw or Illuk Grass can be produced in Ceylon for—

Five-ply sacks ·32 cents each
Six-ply sacks ·39 cents each

Assuming the number of plies are increased to 7 and 9 respectively to compensate for the deficiency in strength of the paper the estimates cost is—

Seven-ply sacks ·45 cents each
Nine-ply sacks ·58 cents each

It is apparent that the above increases in the number of plies are the maximum permissible without raising the manufacturing cost of the sack above the c.i.f. value of the imported article. The above-mentioned investigations will determine whether these increases will be sufficient.

It is not possible to estimate the cost of the fabric reinforced paper sacks till the price of the fabric has been ascertained.

The paper for these sacks whether made in accordance with suggestions (*a*) or (*b*) can be produced in the mill described in the report so that there is no need to have a separate unit for the sack paper. The only difference in the process is that the raw material will be digested for maximum strength rather than quality as applied to writing and printing papers and of course, the pulp will not be bleached.

The estimated weight of paper required to produce the 2 million sacks mentioned in suggestions (*a*) and (*b*) and the percentage of the annual total production (3,000 tons) of the projected mill is—

Seven-ply sacks 1,020 tons—34 per cent. of total production ;
Nine-ply sacks 1,320 tons—44 per cent. of total production ;
fabric reinforced paper sacks 300 tons 10 per cent. of total production.

It should be noted that this supplement is of an interim nature and that a full report will be submitted when the investigations in the U. K. have been completed.

June 25, 1947. R. GRIERSON,