"THE DEVELOPMENT OF CANAL FALLS FOR THE PRODUCTION OF ARTIFICIAL FERTILIZERS."*

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Synopsis,—Introduction—Need of manure in Indian agriculture—Sources of Manure in India—Types of manures produced by electric power—Cost of production of Calcium Nitrate by water power—The cost of large power developments—The indirect consequences resulting from the development of canal falls primarily for chemical purposes—Conclusion.

Introduction.

"There is a real awakening in the recent years as to the value of oil-cakes amongst the cultivators of India. Year by year, the prices have gone up in certain localities, up to a point at which they actually exceed the cost per unit of nitrogen of imported manures, such as, Chili saltpetre. Recent processes of obtaining nitrogen from the atmosphere open up great possibilities, and we should be prepared for future developments".

The above remarks were made by Dr. Leather at the Board of Agriculture held at Cawnpore in February 1907, almost exactly seven years ago.

In December 1908, Messrs. Cramp and Hoyle read a paper in London before the Institute of Electrical Engineers, on research work carried out by themselves on the oxidation of nitrogen in the electric discharge.

Meanwhile a plant for 120,000 H. P. was being constructed in Norway for the production of nitrates by the process invented by Messrs. Birkland and Eyde and described in the paper.

Since that date immense advances have been made in connection with these processes and at the present time there are no less than 750,000 water horse power employed in this industry in Norway alone, and plants in contemplation aggregating 1½ million H. P.

Two extracts from the *Times Engineering Supplement* of October 15th last and from *La Nature* are given in Appendix A. These show the enormous strides that have been made in this industry within the last five years and give some idea of its gigantic future.

* Note.—Those interested in this subject are recommended to study Drysdale's paper referred to in the footnote on page 19 in conjunction with this paper.

It is instructive to note, that, while Scandinavia has made such enormous strides in the development of this industry, the progress in India has been absolutely nil.

The Irrigation Branch of the Public Works Department have for years past been considering the possibility of utilising some of the large quantities of power going to waste on the various canal falls in the north of India and elsewhere, and some attempts have been made, from time to time, to develop these falls on a small scale, but up to the present no means have been devised for overcoming the two hitherto insuperable difficulties connected with (*i*) the necessity of canal closures, and (*ii*) the lack of suitable markets for power within a reasonable distance of the falls.

At this Congress last year, reference was made to the possible employment of power available at the proposed storage dams in the foot-hills, for pumping sub-soil water, and other industrial purposes, while at the recent Engineering Conference in Simla, a most instructive paper was read and discussed regarding the development of two small falls on the Ganges canal for use during construction work ; and after several years' discussion between the Irrigation Branch and the Government of India, a small scheme for utilising a canal fall near Amritsar has been sanctioned for pumping out sub-soil water.

With the exception of the above, no progress has been made in India within the last ten years in the development either of existing falls on canals already constructed, or of some of the larger falls which will become available on completion of two or three projects now under construction, nor, I believe, has any provision been made in the existing designs to facilitate the development of power at a later date.

India is at present one of the largest agricultural countries in the world, and the most advanced in the science of irrigation, but, in spite of the excellent work being done by the Government Agricultural Departments, it is generally recognised to be the most backward in scientific agriculture. In this connection, it has been said that the most urgent necessity of agricultural progression in India is water and manure and that just as the former has been, and is still being, provided for so must attention be given to the supply of manure, and that the necessity for this latter commodity is enormous and the supply of it exceedingly inadequate.

It is the business of the Engineers of the Public Works Department to provide the water here referred to and in

doing so they have constructed some of the finest monuments of engineering skill to be found anywhere in the world.

Could anything be more appropriate than that the same Department should undertake the supply of the second commodity by means of the very canals constructed to supply the first, and in doing so not only completely solve the agricultural problem referred to above, but also the more technical one of how to overcome the two hitherto insuperable difficulties in the economic development of canal falls, and at the same time provide an adequate supply of cheap power to all towns and cantonments within a radius of fifty miles or so of the fall.

The purpose of this paper is to show how this may be done, and as the problem is essentially an economic one from the engineers' point of view, it will be advisable to deal with the agricultural side of the question first.

Need of manure in Indian agriculture.

The chief obstacle in the improvement of Indian agriculture generally is the need of manure, while for the scientific cultivation of certain crops, it is an absolute necessity.

The vexed problem of how to obtain the necessary supply of manure at rates within the reach of the ordinary Indian cultivator has exercised the Government Agricultural Departments for years past.

The need for manure falls roughly into two main classes :—

(1). That required for manuring ordinary cereal crops which form the bulk of the agricultural produce of the country.

(2). That manure which is an absolute necessity for the proper scientific development of special garden crops such as, sugarcane, cotton, rice, tea, etc.

For the former, no artificial fertilizers are of any use whatever, owing to their excessively high price and ordinary farm-yard manure is the only article available for this purpose. Owing, however, to the great scarcity of fuel throughout large tracts of the agricultural districts of India, this commodity which should by right be employed upon the ground, is generally burnt up as fuel, leaving little or no natural farm-yard manure available for the soil, so that one of the most urgent necessities of Indian agriculture at present is a system of fuel and fodder reserve calculated to release the supply of farm-yard manure for its more legitimate

purpose that of a soil fertilizer. This custom of burning up as fuel, the farm-yard litter, which should by right be used as manure, constitutes one of the greatest sources of waste throughout the whole of India and has for years past received the special attention of Government, but is outside the scope of this paper.

For the second class an artificial fertilizer is a necessity, and it is safe to say that, until a cheap one is procurable, the further development of these crops on scientific lines is impossible.

Sources of Manure in India.

The present sources of supply in India are three as follows :—

(1). Nitrate of potash, of which there are considerable quantities already deposited in the soil of Northern India

(2). Phosphates in the form of bones, in which there is an enormous export trade.

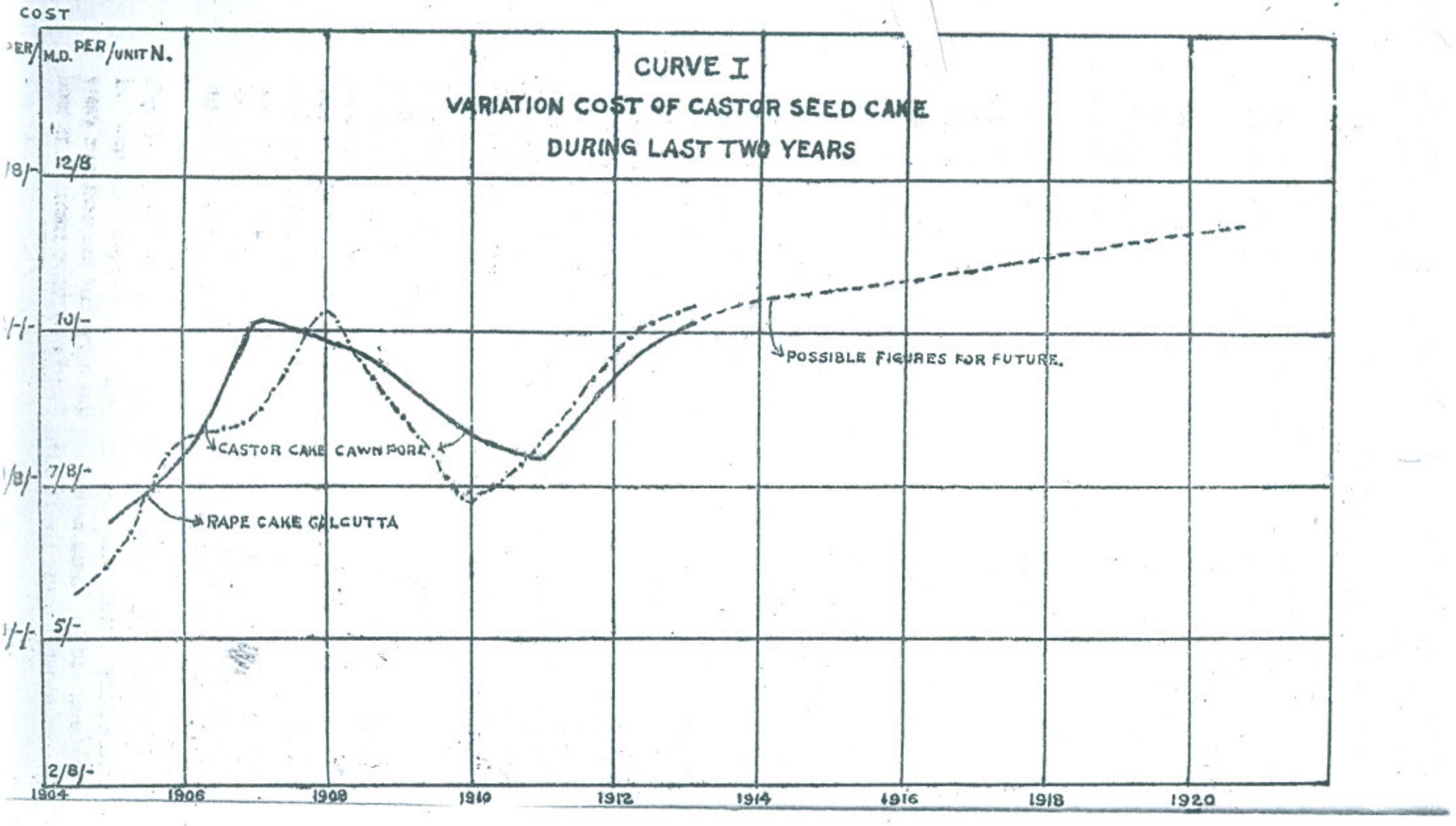
(3). Oil seed cakes manufactured in the country from various oil seeds grown and crushed locally.

The first source is practically unexploited and is generally considered of little use as the soil of Northern India already contains sufficient quantities of natural potash.

The phosphates in bones are of very little use for practical agriculture until reduced to a soluble form by the application of sulphuric acid. Owing to the absence of any natural deposits of sulphur in India and to the consequent absence of any sulphuric acid industry, all required for the purpose has to be imported at high cost, with the result that 90 per cent. of the bones which would otherwise, apart from caste prejudices, be used for manure throughout India, are exported for reduction into soluble phosphates in other countries where sulphuric acid is more readily obtainable.

The third and last source of supply constitutes the only available supply of artificial manure in bulk in the country and is therefore the one with which this paper is chiefly concerned.

Before considering the question of oil-cake manufacture, it is advisable to mention, however, that a plant for the recovery of ammonium sulphate as a bi-product has, I understand, been installed at the Tata Iron Works. The import of ammonium sulphate into Java, Mauritius, and Japan, in connection with the sugarcane industry, is enormous and amounts to some two millions sterling in value per annum for these three countries alone, the


COST
PER/M.D. PER/UNIT N.
CURVE I
VARIATION COST OF CASTOR SEED CAKE
DURING LAST TWO YEARS
12/8
10/-
7/8/-
5/-
2/8/-
CASTOR CAKE CAWNPORE
RAPE CAKE CALCUTTA
POSSIBLE FIGURES FOR FUTURE.
1904
1906
1908
1910
1912
1914
1916
1918
1920

bulk of which is manufactured in, and exported from, Great Britain and Germany, so that there would appear to be a future for this industry in the coal mining districts of Bengal.

The low price at which oil seed can be grown and crushed locally has placed this commodity in the forefront of all artificial fertilizers in India, so much so that there is a considerable export trade in this material in addition to the amount actually consumed within the country.

The gradually increasing enlightenment of the more educated agriculturists has resulted in a growing demand for this material, especially for irrigated crops, such as sugarcane and rice, and the whole future of the sugar industry of India now largely depends upon the supply of a cheap oil-cake or other suitable manure. For instance, most of the ammonium sulphate imported into Mauritius is used in the cultivation of sugarcane, the bulk of which is afterwards imported into India as sugar. This country is one of the largest sugar consuming countries in the world, importing no less than some £. 000,000 sterling worth of sugar annually. The bulk of this would all be grown and manufactured locally, but for the unscientific methods of cultivation and manufacture at present employed. Now, next to the preparation of the land and supply of water, manuring is the most important operation in the scientific cultivation of sugarcane and accounts for no less than 18 per cent. of the whole cost of cultivation in some districts, while the two materials regarded as essential in the most advanced sugar growing countries are a good supply of well rotted cattle manure and artificial fertilizers. Neither of these sources of manuring is available in the desired quantity in India at present.

Owing to the increased demand for oil-cakes, combined with the limited facilities for its manufacture at present existing, the price of this commodity has fluctuated considerably during the last ten years, and, as stated by Dr. Leather, has actually reached a price per unit of nitrogen greater than some of the more expensive forms of imported manures, thereby checking the further extension of its use, which would otherwise follow. Should the use of oil-cakes on a large scale extend, the supply will soon be exhausted, the question of cheap artificials is, therefore, already acute.

Curve I illustrates the fluctuations in the price of this commodity within the last few years and also per "ton-unit" of nitrogen and a continuation of this curve for the next five years shows to what figure the price in 1918 may have risen. It is well

here to explain that the value of all manures is reckoned by the percentage of nitrogen they contain and that a "unit" of nitrogen is the total weight of nitrogen contained in one per cent. of the weight unit adopted. The ordinary commercial castor seed oil-cake contains a very variable percentage of nitrogen, but the general average may be taken at $5\frac{1}{2}$ per cent. which, at Rs. 2 per maund, amounts to Rs. 10 per ton unit.

It now remains to be seen what other sources of manure exist as a possible addition to the oil seed industry. The intention is not to compete with the oil seed industry, but rather to supplement it, since the experiments of the Agricultural Departments tend to show that the best manure for Indian soils is a combination of organic oil seed manures, such as castor cake, with an inorganic artificial manure, and also by increasing the supply of manure in the country to thereby keep the price down within the reach of the ordinary cultivator, which may be considered as equal to, say, Rs. 10 per "ton-unit" as a maximum.

Types of manures produced by electric power.

Two entirely different types of manure are at present being produced by means of water power and the employment of electricity fulfils an entirely different function in both processes.

The two manures manufactured at present are :—

(1) Calcium cyanamide, *i.e.*, $CaCN^2$ in which calcium carbide is manufactured in the electric arc by the union at a high temperature of free carbon, in the form of anthracite, with burnt lime, and the eventual combination with this calcium carbide, of free nitrogen, separated from the air by the Linde process of liquification of the air, under extreme high pressure and low temperature and its subsequent boiling, during which the nitrogen and oxygen are boiled off at different temperatures, resulting in the supply of free oxygen as a valuable bi-product.

(2) Calcium nitrate, *i.e.*, $CaNO_3$, in which the nitrogen of the air is burnt in a high tension electric arc, to form oxides of nitrogen which are then immediately cooled and passed over burnt lime forming calcium nitrate.

The adoption of the first process would necessitate a supply of anthracite as well as lime near the site of the factory, and owing to the complicated nature of the re-action would in all probability necessitate the services of a highly paid chemical expert.

In addition to this, the original plant required is considerably more costly and the whole operation involves three entirely separate processes, while the oxygen obtained as a bi-product, although extremely valuable in Europe, would only have a very limited sale in India. It is not proposed to study this process further, but to proceed at once with the second.

For a full description of this process, the above-mentioned paper by Messrs. Cramp and Hoyle should be studied, together with the more recent literature on the subject.* The plant orginally developed by the Badische Anilin and Soda Fabrik in conjunction with the Birkeland Eyde Co. is known as the Schönerr furnace and as described by Mr. Weiss in the discussion on the above paper, consists of a long metallic tube, or tube of fire clay with a spiral metallic line about sixteen feet in length with one electrode entering at the bottom end and insulated from the sides of the tube, consisting of an iron rod which is water-cooled and can be screwed in or out, thereby adjusting the length of the arc. The other electrode at the top of the tube is connected to the tube itself. The arc is started between the bottom electrode and the side of the tube, the space between the electrode and the side of the tube being small. Air is then blown in at the bottom of the tube behind this electrode with a whirling motion, which blows the arc out along the whole length of the tube to a length of ten or fifteen feet. The arc burns steadily along the axis of the tube for weeks at a time without having to be re-started and gives great concentration of gases. The furnaces most recently installed have a capacity of 3,500 kilowatts each, and employ alternating current at a pressure of about 10,000 volts at a frequency of fifty cycles per second. In practice the tubes are jacketed and the air before entering the tube is heated in the jacket and enters at a temperature of 500° cent. The air, when issuing from the tube, emerges with a large percentage of the nitrogen converted into oxides which are then cooled as rapidly as possible to prevent dissociation. The whole process is an extremely simple one and has the outstanding advantage that it is only necessary to have a supply of lime available at the site of the factory, a question of considerable importance in a country where distances are so great. The chemical re-action also is an extremely simple one and consists merely of two parts, the first of which is an extremely common-place one well known to every Indian engineer, while the second one involves no special

* NOTE.—See Dr. Drysdale's recent address to the students of the I. E. E, given since this paper was drafted, published in I. E. E. Proceedings, Vol. 52, p. 268, No. 227, dated 2nd February 1914 and other papers mentioned by him, which give much further and more up-to-date information on both processes.

technical knowledge beyond that usually possessed by any ordinary fully qualified electrician.

It would, therefore, be possible to arrange for the whole management of the factory to be carried out by the same staff as would in any case be required for the operation of the Power House and would, if anything be simpler than that carried out daily by every public works engineer when manufacturing lime and surkhi mortar.

Cost of production of calcium nitrate by water power.

It has already been shown that any artificial manure to be of any real value in this country must be salable in the centre of the agricultural district, where used, at a price not exceeding Rs. 10 per unit of nitrogen. It now remains to be seen whether it would be possible to manufacture calcium nitrate and supply it at anything like this figure.

The cost of manufacture and supply of manure falls under four main sub-heads as follows :—

(1) Cost of power required for the production of the necessary oxides of nitrogen from the air by means of the electric arc.

(2) Cost of excavating, burning and supplying the necessary quicklime.

(3) Cost of management, salaries and wages for carrying out the above operations and the interest and depreciation on the factory equipment.

(4) Cost of carriage charges from the factory to centre of sale districts.

The first which forms the main subject of this paper will be dealt with last under a separate heading.

The cost of manufacturing lime is a matter well-known to every Public Works Engineer and when carried out on a large scale with up-to-date machinery may be taken as not exceeding Rs. 30 per cent. c.ft., *i.e.*, Rs. 15 per ton which may be compared with the cost of manufacturing cement in a modern and up-to-date factory in England, *i.e.*, 30s. per ton, which, of course, includes a much higher temperature for conversion, expensive grinding, and also the carriage, etc., of the necessary clay. When carried out in conjunction with the operation of a large power station, the extra labour and standing charges on the factory equipment required would be a comparatively small item and may be taken as 10 per cent. of the whole cost of production. The cost of interest and depreciation on the factory equipment may be taken at 10 per cent. per annum.

The cost of carriage depends, of course, upon the relative position of the factory with the centre of the sale area, which is dealt with in detail later on. This may, however, be taken as six pies per ton mile, inclusive of all terminal charges and assuming North-Western Railway charges.

The amount of power required for the production of oxides of nitrogen from the air on the process originally invented by Messrs. Birkeland and Eyde and now employed in a modified form on a large scale by the Badische Anilin and Soda Fabrik may be safely taken as* 700 kilogrammes of nitric acid per kilowatt year. Nine hundred kilogrammes has been reached, but the original installation put up in 1908 was based on 600 and was considered at the time a safe and conservative figure. 700 may therefore be considered a safe figure for the latest type of plant operated on a large scale in the year 1918. In these figures a kilowatt year is taken as approximately 8,500 units instead of the theoretical 8,760 units, as 8,500 units per annum is found to be the average running time of each machine in any well designed electro-chemical installation.

The total weight of nitric acid required per ton of calcium nitrate is 1,434 lbs. and it will therefore be seen that power must be available at rates in the neighbourhood of Rs. 50 per kilowatt year before any figure approaching Rs. 10 per unit of nitrogen can be obtained—*vide* Appendix K.

It now remains to be seen at what rates power could be produced from canal falls, with this object in view.

The cost of large Power Developments.

The cost of power per kilowatt year for chemical processes depends, of course, entirely upon the original capital cost of the development and this is a figure which depends so much upon the local conditions, nature of the country and the circumstances under which the plant has to be constructed, that the preparation of general estimates for such works is a matter of the greatest difficulty and can only be arrived at by a careful investigation into the cost of a large number of schemes already carried out with due regard to the peculiar conditions of each.

All water power development, whether high or low pressure, consist of three parts as follows :—

Part A.—Works for manufacturing or artificially producing the fall which in most cases does not already exist.

Part B.—Means for conveying the water pressure from the top of the fall, to the machines in the Power House.

* NOTE.—Later information just received from Prof. Birkeland shews that more than 600 kilograms per k. w. year should not be relied upon.

Part C.—The actual Power Station buildings and equipment itself.

The cost of Part A is the one most affected by local conditions and consists either, in a high pressure scheme of a small diverting weir, flume, and as large a balancing reservoir or fore-bay as possible at the top of the pipe, and in low pressure schemes of a watertight dam with overflow weir and arrangements for diverting the flow through the turbines and tailrace.

The cost of this portion of the plant, other considerations being equal, generally varies directly with the quantity of water handled and the distance to which it has to be conveyed, which of course, has no direct connection whatever with the actual power thereby made available.

The investigation with which this paper deals is greatly simplified by the fact that in most irrigation developments, such as those with which this paper is concerned, the bulk of this portion of the scheme has already been provided for under the irrigation project and can, therefore, except in special cases, be left out of the calculations.

Although this is true generally, there are cases of course where a relatively small, but by no means negligible, sum would have to be expended on this part of the project and to enable some idea of the amount which might be spent under varying conditions to be formed, a statement of the different cost of this part of the project on a few well known schemes is given in Appendix B. and it will be seen from this table that the rate varies tremendously and may be anything from Rs. 150 to Rs. 300 per k. w. depending entirely upon the general circumstances governing the scheme.

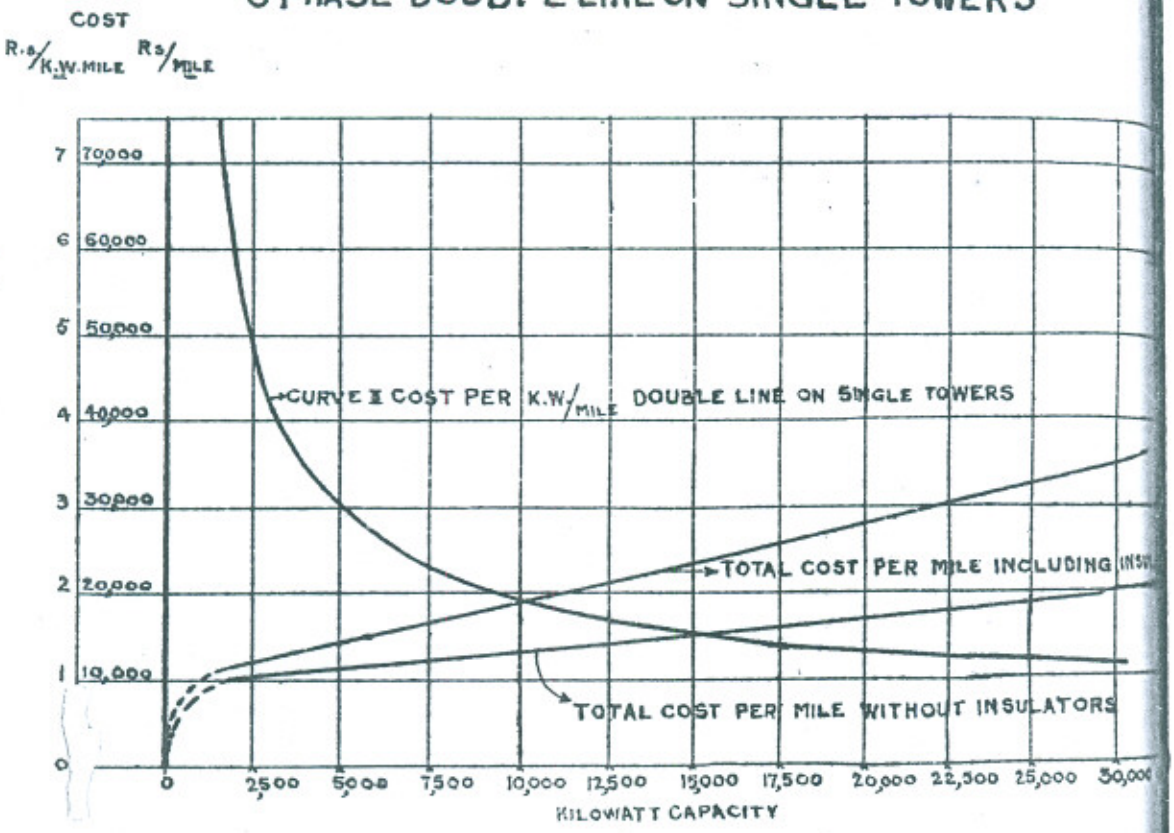
Turning to Part B, namely, means for conveying water from the top of the fall to the machines. In all high pressure schemes this varies regularly as the product of the cusecs and the length of the pipe-track. As in most schemes, the slope of the pipe-track is somewhere in the neighbourhood of one in three and is not a factor which varies very largely, the cost of this portion may be considered as varying directly with the product of the cusecs and the head and is therefore a constant per k.w. for all sizes of plant subject to a percentage of variation in large plants on account of the smaller proportion of supervision charges, cheaper controlling arrangements at both ends and variation in slope and normal full load velocity.

Turning now to part C, the Power House equipment itself, it is necessary to sub-divide this into its various constituent parts

CURVE II

COSTS OF TRANSMISSION LINES PER KILOWATT-MILE

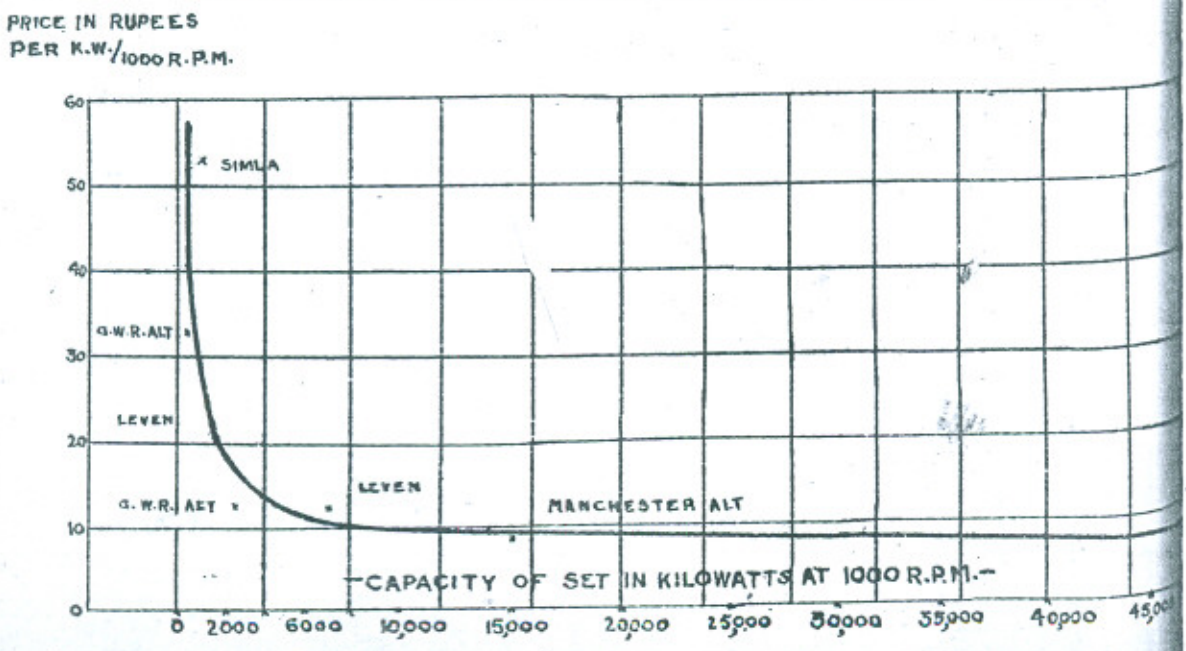
3 PHASE DOUBLE LINE ON SINGLE TOWERS



CURVE III

COST OF WATER DRIVEN GENERATING SETS PER KILOWATT/1000

ERECTED-TESTED AND SET TO WORK IN INDIA



before it is possible to arrive at a practical system of rates. Part C can be divided up into four separate parts as follows :—

(1) Generating sets.

(2) Switchgear, telephones, etc.

(3) Buildings, crane and workshop, etc.

(4) Roads and quarters for st. ff.

The cost per k.w. of generating sets varies inversely with the k.w. capacity of each unit and its speed. The larger the machine, the lower the rate per k.w. : this however is partially compensated for by the fact that larger machines, as a rule, run at lower speeds. The rates per k.w. per thousand r.p.m. of generators varies pretty evenly and inversely with the size of the machine in accordance with well-known laws. Much the same remarks apply to water turbines, so long as one class and type of machine is under consideration. The combined "cost size" curve for the whole generating set complete would, therefore, vary with the class of turbine employed. There are many varying factors to be considered for turbines however, for instance, when considering the cost of Pelton wheels, the necessity of deciding upon the speed and the number of nozzles together, owing to the efficiency of these machines being so much reduced if the ratio of wheel to jet diameter is less than ten.

As such "cost-size" curves for works costs are usually considered as confidential by manufacturing firms, no such figures are available for publication and the curve in this paper is based on the actual expenditure incurred on a few typical schemes.

The rate for switchgear is only slightly variable and increases inversely with the output and directly with the number of subsidiary and auxiliary panels required and may be considered to vary between Rs. 15 and Rs. 30 per k.w.

The cost per k.w. of buildings, cranes, workshop, etc., is of course entirely dependent upon the number of machines housed and with a given total output is therefore inversely proportion to their size and therefore varies with much the same consideration as the generating sets themselves, the workshop plant being, of course, a constant.

Before going further, it might be advisable to consider the actual cost of the Simla hydro-electric scheme which is the first Government scheme of this nature constructed by the Public Works Department in British India. The scheme is designed for a full capacity of 2,000 k. w. installed when finally completed and capable of meeting a maximum demand of 1,500 k. w.

The bulk of the hydraulic equipment forming Part A of the scheme has been installed from the start for the full final capacity of the plant, but Parts B and C have only been completed to the extent of 750 k. w. up-to-date with careful provision for extensions to the full capacity at a later date, while the fourth section Part C, consisting of roads, quarters, etc., have, of course been completed for the full capacity of the plant

It will be seen that the scheme, even when completed to its full capacity, is a small one, the average size of the units now installed being only 250 k. w., and even when completed of four 250 k. w. and two 500 k. w.

The total cost of the whole scheme, including all establishment and direction charges, has amounted to Rs. 15,25,464. Of this Rs. 1,04,303 may be considered as extraordinary expenditure due to administrative considerations in no way connected with the actual design of the scheme itself and not directly chargeable thereto. Allowing for a reduction by this amount, the actual cost of the scheme amounts to Rs. 14,21,161. The exact distribution of this sum is shown in Appendix D. As certain portions of the plant, such as the flume, etc., will require some additional expenditure to make them correctly capable of dealing with the full output of the plant when completed, and other portions such as the pipe-track, power house buildings, etc., have of necessity involved a certain amount of additional expenditure to provide for extensions economically at a later date, corrections have been made in the prices of such portions of the plant to enable a fair rate per k. w. to be arrived at. These are clearly indicated on the table in brackets and noted as corrected figures.

A perusal of this appendix shows that the cost of Part A amounts to Rs. 258 per k. w. installed. Owing to the many descriptions of the scheme already published in the Press, it is unnecessary to give a detailed account of the works covered by this portion. The whole of this portion of the scheme has, however, been carried out in masonry and concrete construction, with a considerable amount of re-inforced concrete and cement work and is absolutely permanent throughout, *e.g.*, there are no such things as wooden flumes and timber baffles, gates, etc., and since the scheme was put into operation last summer, no expenditure has been incurred upon repairs. The scheme was carried out with imported labour throughout, in exceptionally difficult country and without the assistance of any modern appliances. There is little doubt that some saving might have been made on this portion of the plant, particularly on the tunnels, by the in-

stallation of an auxiliary water power plant at the commencement of operations. The figures may, however, be considered as average cost of construction under similar circumstances elsewhere

The cost of Part B amounts to Rs. 123·4 per k.w. and this figure will not be appreciably altered for the whole scheme when finally completed. Of this 9 per cent. consists of hand carriage from Simla to site over 21 miles of hill road.

The cost of Part C amounts to Rs. 203½ per k. w. made up as follows :—

		Rs.	
1.	Generating sets	... 104	per k. w.
2.	Switchgear ...	... 29½	,,
3.	Buildings, etc.	... 45	,,
4.	Roads and quarters	... 25	,,

An appreciable percentage of the cost of No. 3 is due to the necessity of some very heavy excavation in quartzite rock, a feature which might not occur in all schemes.

Part D only affects the present investigation in the event of the power having to be transmitted to a more suitable site for the factory and is fully dealt with in Appendix H., while Part E (distribution) is outside the scope of this paper.

The remaining items, *i. e.*, contingencies, tools and plant and establishment have had to be slightly modified to make them applicable to the scheme when finally completed and amount to Rs. 122 per k. w. or 11·6 per cent. of the whole of the remaining items. The corrections made are based on the fact that only a very small additional establishment, contingencies and tools, etc., would have been necessary to enable the plant to be completed up to its full capacity of 2,000 k. w. as the bulk of these were expended in connection with the construction of Part A and the transmission and distribution system.

It is interesting at this stage to run out the actual cost of Parts B and C in this scheme, with all contingent items, *i.e.*, omitting Part A as would occur in most Irrigation developments. This amounts to Rs. 377, allowing 12 per cent. for contingent items, as follows :—

	Rs.
Part B	... 123½
Part C	... 203½
Contingent items, 12 per cent.	... 40½
Total	... 367½

So much for a comparatively small scheme of 2,000 k. w. capacity.

It is interesting to compare this with another and a much larger scheme recently completed in Scotland with total capacity of 21,100 k. w. installed, *i.e.*, The British Aluminium Company's works at Kinlock-Leven completed in 1909, on which the writer spent some months while on deputation in 1908. A very interesting description of the works is contained in two papers read by Messrs. Roberts and Sonnenchein before the Institute of Civil Engineers in London in 1911. The total cost of the scheme amounted to £660,000 of which approximately £320,000 was the cost of Part A constructed for 24,250 k. w. Unfortunately, figures showing the correct distribution of costs over the whole scheme are not to hand, but the pipes for this scheme were a very large item owing to the unusually flat slope of $\frac{1}{7 \cdot 1}$, and amounted to some £180,000 in cost, or about £$8\frac{1}{2}$, *i.e.*, Rs. 128 per k w.

The cost of Part C totalled about £97,000 and was made up approximately as follows:—

	£	
Part 1	... 2·37	per k. w.
Part 2	... ·25	per k. w. only (There was practically no switchgear for the main sets).
Parts 3 and 4	... 1·67	(This figure is only approximate).

Contingent items about 10 per cent.

The total of Parts B and C with, say, 10 per cent. for contingent items amounts, therefore, to £14·12, *i.e.*, Rs. 212 per k. w.

A direct comparison of the two schemes is given in Appendix B.

At Kinloch-Leven 9 D. C. units of 2,000 k. w. each were installed and the generators were made in two parts to facilitate design.

We are now in a position to form an estimate of the cost of developing large canal falls such as would be required for chemical purposes and to enable this to be done a statement has been drawn up in Appendix E showing the variation in cost per k. w. of three or four different types of schemes at a glance.

There are at present two projects nearing completion in the Punjab alone which would, if developed, yield approximately

40,000 and 20,000 k. w. respectively each. I refer to the Upper Swat River Canal with a discharge of 2,100 cusecs and a total fall of 300 feet, and the Lower Jhelum Canal with a discharge of 4 or 5,000 cusecs and a possible fall of 80 feet.

The latter scheme cannot unfortunately be carried out in full with the canals as actually constructed. If however the sum originally spent eighteen years ago on the construction of the head works of the Lower Jhelum Canal had been available now for constructing a slightly larger upper canal, as far as Rasul, so as to carry an additional 4,000 cusecs, the whole of this could have been discharged through eighty foot head into the lower canal. The shortage of water in winter may even yet perhaps be made up by the construction of a storage dam, which may be found a necessity in any case, at the outlet of the Wular Lake.

The whole of these considerations may and in all probability have been fully investigated already and the above remarks are not in any way intended as a criticism of the works as carried out.

It is interesting however to consider what might have been possible had such provision been made for power development in the original designs and may for that matter even yet be found possible either by increasing the discharge of the upper canal above Rasul or reducing the quantity required to be carried by the Upper Jhelum Canal as a result of storage dams on the Ravi or Chenab, without raising the cost of development beyond practical limits.

The two schemes are entirely different, the former being a high and the latter a low fall scheme. Estimates for both schemes and also for an ordinary nine feet canal fall, have been worked out and are given in Appendices F and G and included in Appendix E, based on the following assumptions :—

Maximum demands of 40,000, 20,000 and 3,000 k. w. each.

No spare plant.

Modern water driven generators are so reliable in operation that it has been found more economical to run the whole station at the full available output continuously and to shut down some of the furnaces for a day or two in the event of repairs being necessary on the generating plant, than to pay the standing charges necessary on spare sets. In all such schemes also, only as few and as large sets as possible should be installed, say three or four at most, otherwise the capital charges on the idle stand-by set would form an exceedingly heavy burden on the undertaking.

This system of shutting down the furnaces for repairs on the generating equipment of course assumes a central control of the factory by the generating staff and it may not be out of place here to make a digression on this point.

In all large electro-chemical undertakings, the control of the factory and generating equipment is invariably under one management. In fact dual control of these two portions of the plant would be absolutely out of the question and the writer believes that there are no large modern electro-chemical industries carrying on such processes on a large scale where dual control is in operation. This idea is of course carrying out to its logical conclusion the principle of "controlled loads" which is the ideal of all electric supply engineers. The only extent to which this is usually put in public undertakings is such as exists in the Simla scheme where both the supply undertaking and the municipal pumping are under one management. Such a state of affairs is generally considered to be ideal from the point of view of the generating station staff.

This at once disposes of any suggestions that might be made for developing these falls with a view to selling current to subsidiary undertakings who would carry out the manufacture of the actual manure. For much the same reason, it is absolutely essential from the irrigation point of view that the management of the Power Station should also be in the hands of the Irrigation Branch and in fact it may be emphatically stated once for all that the control of the whole system from the intake on the canal to the sale of the manure must be carried out entirely by the Irrigation Branch or not at all.

Objections of course are sure to be raised in certain quarters that this is liable to interfere with private enterprise. It is however high time that this bogey of interference with private enterprise should be definitely abolished once for all. There is little doubt that should a Government Department take up the development of three or four of its water powers in the manner indicated in this paper, and carry the projects through to a successful conclusion, private enterprise would be immensely stimulated and it is probable that several similar plants would be constructed all over the country.

The estimates are therefore based on the whole available power being used continuously and also on the following assumption :— Units of 8,000 and 5,000 k.w. respectively, being installed, *i. e.*, five of 8,000 k. w. each at the Malakand and four of 5,000 k w. each on the Lower Jhelum Canal.

An ample supply of lime being available within the vicinity of the fall enabling the factory to be located on the same site as the Power House and adjacent thereto, as was done at Kinloch-Leven.

Interest at 3½ per cent. and depreciation at 4 per cent. which is the figure adopted by the British Aluminium Coy. for Parts B and C of their works at Kinloch-Leven.

Working expenses at 1 per cent. which is considerably more than that obtained at Kinloch-Leven with highly paid British labour. This makes a total of all standing charges of 8½ per cent.

The modifications in the above estimates which would have to be carried out in the event of a suitable lime-stone not being available within a twenty-five mile radius of the fall is given in Appendix H and results in an increase of 16½ per cent. in the cost of manufactured manure, *i.e.*, an increase of Rs. ·6 only per unit of nitrogen delivered at the centre of the district.

A perusal of these estimates show that the cost per kilowatt year would be Rs. 25 and Rs. 18½ for the two schemes respectively, and Rs. 36 say for any ordinary nine foot canal fall.

Cases have occurred in Norway where power developments including the whole of Part A, and not only a portion as in the case of irrigation developments, have been carried out complete for £14 only per k. w. installed. Experience shows that the extra cost of such schemes in India on account of freight, etc., is not much more than 10 to 20 per cent. at most so that those figures may be considered as safe for works of this nature.

Taking the lower figure as the scheme which would most likely have been taken up first had the canals been designed to facilitate power development, we can now prepare an estimate for the cost of production. This is worked out in full detail in Appendix K and amounts to Rs. 50 per ton delivered at a point approximately 200 miles from the site of the fall which is equivalent to Rs. 3·65 per unit. The cost of manufacture on the Swat Canal, would be about Rs. 60 per ton delivered 200 miles from the fall.

This is equivalent to being able to manufacture calcium nitrate, which is 2½ times as valuable a manure as castor cake, at the same price, *i. e.*, Rs. 2 a maund or taking the value as proportional to the nitrogen contents at 40 per cent. of the market price.

Having shown that two large canal falls now coming into existence, can be economically utilised for the production of

manure on a large scale at remunerative rates. It now remains to consider the last and most interesting side of the whole question, namely :—

The indirect consequences resulting from the development of Canal falls primarily for chemical purposes.

The usual policy hitherto adopted in considering the development of water powers has been to develop such falls for the sale of power in the following order of importance :—

1. For private, public and municipal lighting,
2. For the supply of motive power for industrial purposes,
3. Occasionally for railway purposes,
4. Finally and last of all, for chemical purposes considered mainly as a bi-product.

Now, owing to the very small quantities of power required by towns and cantonments in India and the present undeveloped state of industrial enterprise, the amount of power actually required for these purposes is so insignificant, that with one or two marked exceptions it has never been found commercially or financially practicable to develop any natural sources of power for such purposes on a large scale, and there is little doubt that unless the conditions are exceptionally favourable to hydraulic development (and such cases are by no means unusual in a country possessing few fuel resources), the development of water powers is seldom financially feasible unless carried out on a large scale.

By however completely reversing the above policy the situation is entirely changed and instead of supplying power for chemical purposes as a bi-product, it is now proposed to treat this as the main purpose of the development and the supply of power to public and municipal lighting and industrial purposes as the bi-product. By so doing it is possible to supply these comparatively small quantities of power at such exceedingly low rates, that it is found feasible not only to transmit to long distances and yet compete with steam and other fuel-driven plants located at the centre of demand, but also to install a fuel reserve to tide over closures, where such are unavoidable, and thereby solve both the hitherto insuperable difficulties connected with the development of canal falls described above.

Most ordinary standard electrical generators take about six hours to reach their normal maximum temperature and owing to inherent qualities in design are capable of carrying 25 per cent. overload for two hours at any time without suffering any

dangerous or harmful heating. In consequence of this, it is now standard practice to specify an overload capacity of 25 per cent. on all generating sets for two hours. Similarly all high pressure schemes with up-to-date governor gear can run at 25 per cent. increase of speed on the pipes without fear of damage. In a station of 30,000 k. w. capacity the total overload capacity of the whole station would be not less than 7,500 k. w. for two hours or say 3,000 k. w. for four hours, and this additional short hour capacity has cost absolutely nothing to install, assuming of course that the 25 per cent. additional water is available for such short periods at the top of the pipes, which is a perfectly reasonable assumption in the case of comparatively low falls in which the whole of the Part A of the scheme has been carried out under the irrigation project.

Assuming this to be the case; as the maximum demands for public and municipal lighting and other such purposes usually last for only about four hours a day and the actual peak for only two hours, it would be possible to supply all the small towns and cantonments within a radius of about fifty miles of the power station from the overload capacity of the plant alone, *i. e.*, entirely as a bi-product. Now where part A of the scheme has already been provided under another project as in the case of the Upper Jhelum Canal the supply of this additional 7,500 k. w. costs absolutely nothing and can therefore be legitimately treated as a true bi-product of the concern.

When however the additional water is not available at the top of the pipes owing to the flume not having been constructed to carry more than the exact full load supply, as might be the case at the Malakand, or owing to there not being any additional water whatever available owing to the whole discharge of the canal being taken through the station, it would be necessary either to install a slightly larger flume at the commencement, the whole additional cost of which would have to be borne by the extra units sold for the public and municipal lighting, or in the second case to shut down some of the furnaces daily every evening to enable the power used by them in the day time to be diverted for lighting and other purposes in the evening. In either case, the maximum cost of the power sold for lighting would not exceed that used for chemical purposes, *i. e.*, about 1-21th to 1-28th of an anna per unit.

Since this is the actual generating cost at the station bus-bars, a very much larger sum than usual is available for expenditure on transmission and on the erection of a steam reserve to tide over closures of the canal.

As already shown in Appendix H, the cost per k. w. for transmitting power up to say 2,000 k. w. maximum demand to a distance of say fifty miles would not exceed Rs. 352, including step-up and down transformers and their switchgear. Assuming a load factor of 25 per cent. the cost per unit for transmission amounts therefore to ·26 annas a unit only, making a total of ·31 annas a unit delivered at the centre of the supply. The market value of a unit for municipal and lighting purposes may be considered as equal to $3\frac{1}{2}$ annas a unit sold to the consumer. Then allowing ·3 annas per unit to cover the capital and maintenance charges on distribution (which is equivalent to Rs. 412 per k. w. for distribution against Rs. 352·5 in Appendix D), we are still left with the 2·89 annas per unit to cover standing and other charges on the cost of a fuel reserve plant. The cost of a fuel reserve plant to be used during closures of the canal would cost about Rs. 360 per k. w., *i. e.*, Rs. 36 per k. w. year. Fuel charges at one anna per unit, on 1-10th of the units sold, *i. e.*, assuming closures lasting $1\frac{1}{4}$ months each year amount to Rs. 14 per k. w. year, *i. e.*, a total of Rs. 50 per k. w. year which is equivalent to ·365 annas a unit only on the whole out-put leaving 2·89-·365 = 2·52 or $2\frac{1}{2}$ annas per unit clear nett profit.

The cost of transmission for such small quantities could in all probability be reduced 30 per cent. by the adoption of high tension direct current on the Thury system, so fully dealt with by Mr. Highfield in recent papers before the Institute of Electrical Engineers which is that which would in all probability be adopted, thereby making these bi-products still more profitable.

Conclusion.

The Indian Ordnance Department at present import a maximum of some 100 tons of nitric acid yearly for use in the manufacture of ammunition at the several cordite factories in India. Our supply of nitrates is therefore entirely dependent upon the command of the sea and any scheme which will render us independent of imported material is worthy of serious consideration, on strategic grounds alone. The proposals

made in this paper would, if carried out, enable the required amount of nitric acid to be manufactured locally as a bi-product.

Now India is essentially an agricultural country and it has been stated that should the use of manure become general throughout India, the country would be the richer by some £20,000,000 sterling per annum. This fact alone would justify Government embarking upon such schemes with the sole purpose of improving the productive power of the soil, upon which the well-being of the whole countries depends and treating them entirely as non-productive works.

This paper however shows conclusively that some of the larger falls now coming into existence can be economically developed for this purpose and carried out as productive works with a return of some 30 per cent. nett profit after covering all the working and depreciation charges, and that without considering any of the profit to be derived from bi-products.

When to this however is added the profits resulting from the sale of current for public and municipal purposes as a bi-product and the encouragement thereby given to industrial enterprise, as well as the provision of the power so long needed for pankha pulling in British cantonments, the proposals made in this paper appear to be deserving of serious and immediate attention.

This paper was first thought of late in November and it has only just been possible to collect the necessary data and rush the paper through in time for the Congress. In consequence much of the cost data, which it was intended to include in the appendices has only just come to hand at the time of going to press. It is, however, hoped to supplement the information contained in the paper by further data regarding costs and details of the latest Birkeland and Eyde processes, which are expected to arrive in time for the Congress.

The main purpose of the paper is to ventilate the subject and show generally the possibilities now existing for the production of artificial fertilizers and, if posible, get something practically started in this line at an early date in the Punjab since proposals are, I understand, already on foot for the experimental manufacture of fertilizers by electric power in the Central Provinces.

The writer expects to pay a visit to Norway and Sweden next summer, circumstances permitting, and hopes to be able to submit a more up-to-date paper to subject before the Congress next year and, meanwhile, wishes to express his thanks to Mr. Hamilton, Director of Agriculture, Punjab, and Mr. Noyce of the Revenue and Agriculture Department of the Government of India, for so kindly supplying information on the agricultural side of the question and to Mr. Milne of the Simla Hydro-Electric Division for assistance in checking the figures and proofs.

APPENDIX A.

Extract from the "Times" Engineering Supplement, dated Wednesday, October 15th, 1913.

THE FIXATION OF NITROGEN.

Progress in Scandinavia.

One of the most striking developments in recent times in the electro-chemical industries has been the use of calcium carbide on a commercial basis as a medium for the fixation of atmospheric nitrogen with the formation of calcium cyanamide, which in turn is now to be utilized on a manufacturing scale as a substance for the production of nitric acid by the oxidation of ammonia in the presence of heated platinum. From the purely scientific point of view none of the processes is new. The various reactions involved were accomplished in laboratory experiments long ago. The interest attaches therefore to the steps which have made commercially possible the chemical reactions well known to the scientific worker. Calcium carbide—a combination of carbon and lime—has been in use for a long time as a source from which acetylene gas could be generated for lighting and welding; and although it was known that when 20 per cent. of nitrogen was added to it the result was cyanamide, or nitrolim—a fertilizer of great value—there was the serious disadvantage that carbide was not produced at a sufficiently low cost to enable the resultant cyanamide to compete with Chile nitrate. All this has been changed, and there seems now no fear of any failure to meet the undoubted need for nitrogenous fertilizers, which must increase greatly if the world's growing population is to be fed despite the natural impoverishment of the soil.

Formation of Cyanamide.

The first efforts to fix nitrogen in association with the carbide on a commercial scale were by passing air over heated copper; the oxygen was absorbed, and the free nitrogen liberated was led into retorts which contained the carbide in a powdered state, the reaction giving cyanamide. But the desired economy in production was achieved only when the Linde process was applied for the liquefaction of atmospheric air by mechanical means. Once liquid air was obtained it became possible by rectification or distillation to separate the oxygen and nitrogen, since the boiling point of the former is lower than the latter. The adoption of this process on a large scale and the utilization of water power in great volume to carry on manufacture in huge quantities have together greatly reduced costs.

These steps were the result of the formation in 1906 of the Alby United Carbide Factories. Having re-organized their plant at Alby in Sweden, and adopted the Linde process, they later established new works at Odda, on the west coast of Norway, where immense amounts of hydro-electric power are available, for the making of calcium carbide. An associated company, the North-Western Cyanamide Company, took the greater proportion of this carbide and formed cyanamide, or nitrolim, utilizing the Linde process of manufacturing the nitrogen. Since the new works were started five years ago there has been almost continual development not only in the volume of production but also in the perfection of the process to ensure regularity in the chemical contents of the product and economy in output. New uses for the cyanamide were also discovered whereby nitric acid can be economically produced. At the same time new factories are being established, others are in contemplation, and ultimately the company will have an annual output of nitrogen products rivalling the whole natural supply from Chile.

Power Supply.

In the process cheap electric power is a fundamental consideration, and thus it is that the principal works are in Norway, and preferably on the seaboard, so that the transport of the raw material and finished product is not so expensive as would be the case were inland waterfalls utilized. The choice of Odda was influenced by the existence of a company to construct a power station at Tyssefaldene, three miles from Odda. The watershed extends to 378 sq. km., the average annual rainfall being 49in. and the head of water 1,269ft. The first installation was of about 30,000 h. p. in seven units ; now there is 83,000 h. p. in use, and extensions are being pushed forward to increase the amount to 125,000 h. p. These works include the heightening by 15m. of the dam which stores up the water in the lake on the mountain top. Some idea of the magnitude of the work is afforded by the fact that this dam impounds water equal to 80 per cent. of that stored by the great Assuan dam on the Nile. Again, there is sufficient storage to run full load for five years without snow or rainfall. The water is conveyed through two tunnels from each of two lakes, the intake being at the bottom so as to ensure supply during the winter when the lakes are icebound. The larger generating units are now each of 12,500 k. w. at 120 r.p.m.; the new units will be of 15,000 k. w. The current generated is three-phase, and it is transmitted at 12,000 volts, and by static transformers, exceptionally well ventilated in view of their great size, reduced at the carbide furnaces to 50 volts and at the cyanamide furnaces to 60 or 75 volts. The current is bought in bulk at Odda, but in the newer works the carbide and cyanamide works will possess their own hydro-electric power supply station.

Carbide Furnaces.

The most important feature in the carbide factory is the electric furnaces. Originally there were 10 of these, each producing continuously seven to eight tons of calcium carbide in 24 hours : but 10 more have recently been added, each of a capacity of 16 to 18 tons a day. The electrodes of the former utilize 1,400 k. w. and of the latter 3,500 k. w., and the temperature maintained is 5,720 deg. F. The charging with powdered anthracite and burnt lime is almost continuous, and the tapping of the molten calcium carbide is at intervals of 45 minutes. The material is conveyed in trays to a cooling bed, crushed in separate plant to the size required by the market, and subsequently filled into tinned drums enclosed in barrels for dispatch. Up till recently the annual output at Odda was 32,000 tons, but now it is 80,000 tons.

Associated with this increase is a great improvement in the electric furnace, whereby the efficiency is increased. The new furnaces are so built that the radiation of heat is less than from a steam boiler, the charging is automatic, and the internal distribution such as to obviate waste heat at the top, while the products of combustion are drawn off for utilization in the limekilns instead of producer gas. There is thus not only increased economy, but the contamination of the atmosphere due to the escape of gases and smoke is reduced to a minimum.

The preponderating proportion of the calcium carbide is passed direct to the cyanamide works. There also great developments have been made. The Linde process plant is the largest installation in the world, liquefying, 100 tons of atmospheric air a day, from which is obtained 77 tons of nitrogen, which is utilized not only in the production of the cyanamide in the electric furnaces, but also throughout the operation of crushing the carbide prior to the fixation of the nitrogen and throughout the grinding of the cyanamide to sizes to meet market requirement. Since the works were opened four years ago the number of furnaces has been increased nearly sevenfold, the annual output of the Odda factory being now 80,000 tons of cyanamide. The furnaces have been greatly improved in design. They are of one ton capacity and electrical current at 60 to 75 volts is applied through an electrode in the

centre, while nitrogen is applied through valves at the side. By the maintenance of a temperature of 1,650 deg. F. for about 24 hours the calcium is converted into cyanamide containing 20 per cent. of nitrogen, 12 per cent. of free carbon, 60 per cent. of lime, free and chemically combined, and 8 per cent. of inert substances.

Production of Nitric Acid.

While cyanamide is being increasingly used in this form as a fertilizer throughout the world the most recent and important development is its utilization for the production of ammonium salts and nitric acid. Although in 1830 it was shown, by laboratory experiments, that nitric acid could be catalytically produced by the action of platinum on ammonia in the presence of air, the fact had no commercial significance, as there was no source of ammonia at reasonable prices. By his experiments in 1900 Dr. Ostwald succeeded in producing nitric acid from ammonia by means of superheated steam, and later, at works in Belgium the process was further developed so as to obtain ammonia from cyanamide—the source of the cheapest form of chemically pure ammonia. This discovery enabled nitric acid, nitrate of ammonia, and other important subsidiary compounds to be produced chemically and economically, and at the same time removed all doubt as to future supplies. A large company known as the Nitrogen Products and Carbide (Limited) was formed not only to acquire the rights of the new process for the whole world, excepting Westphalia and Rhineland, and to establish works for the manufacture of nitric acid, nitrate of ammonia, etc., but to develop existing carbide and cyanamide factories. The increased producing capacity of the works at Alby and Odda is a direct result. Entirely new works are now in process of construction at Aura—a hydro-electric power station—and the first unit of 100,000 h. p. is being installed with carbide and cyanamide furnaces to make 200,000 tons annually of cyanamide. The company have also purchased waterfalls at Toke and Blekestad-Bratland, so that with the Aura works 600,000 h. p more will be available in Norway. The company further possess the Dettifoss water rights in Iceland, where 400,000 h.p. will be available. The several waterfalls will be "harnessed" as the demand for cyanamide justifies successive steps, the full possibility at present contemplated being nearly two million tons of cyanamide a year.

Manufacture of Explosives.

The likelihood of increased demand is obvious from what has been stated, especially when the variety of applications of nitrates is taken into consideration. Of first significance is its use for explosives for peace and war purposes. At present the essential constituents of gun projectile propellants are nitro-cellulose and nitro-glycerine, requiring nitric acid for their production. Dependence on the supply of the raw material from overseas sources involves an element of danger in war times. It has therefore been decided to establish works on the Thames at Dagenham for producing from cyanamide 12,000 tons of nitric acid a year, at Trafford Park, Manchester, for a like capacity, in Scotland for 9,000 tons output, and in Ireland for a production of 3,000 tons. Large stores of cyanamide will be kept; but as a last resort the ammoniacal liquors from coke ovens, blast furnaces, residual recovery plant, and gasworks may be used by the same process instead of cyanamide. It is the intention also to make nitric acid at the cyanamide works in Norway.

By the new process cyanamide is also utilizable in the manufacture of sulphuric acid, as the raw material for cyanides such as ferrocyanide, sodium and potassium cyanides, and for the production of urea and guanadine salts used for a variety of purposes in the production of synthetic dyes and other chemical products.

Extract taken from the "Proceedings of the Institute of Civil Engineers, Vol. CXC, page 456".

NORWEGIAN NITRATE-INDUSTRY. A TROLLER.

(La Nature, Paris, 1912, Vol. 40, Deuxieme Semestre, pp. 50-54.)

A description is given of the locality 62 miles west of Christiania, where two considerable torrents, the Maana and the Tinne, descending from Mount Gausta, in a chain of water-falls and small lakes, furnish power for the great nitrogen works on the process introduced by Messrs. Birkeland and Eyde. The original factory, founded in 1905 at Notodden, disposed of 2,500 h. p. Two years later, the works were extended by harnessing the Svaelgfos falls with 45,000 h. p. to be again increased by water from the Lienfos falls, yielding 15,000 h. p. A new factory is now working at Saaheim on the river Maana, which utilizes the falls of Rjukan, producing 120,000 h. p., and in about two years the second portion of the falls will yield in addition 125,000 h. p. The group of hydro-electric works at Rjukan will then furnish 250,000 h. p. and the current generated will be conveyed by overhead wires to the receiving station at Saaheim. Nowhere else, not even in the vicinity of Niagara, will a like amount of water power be utilised for the generation of electricity. A description, with photographs is given of the Rjukan works, which derives power from water descending from lake Mos, from which a regular supply of 10,340 gallons per second, on a fall of 971 feet, is available. This water is conveyed in ten wrought-iron pressure mains, which have an initial diameter of sixty-one inches at the falls, reduced to 49·21 inches at the Power House. The ten Voith turbines are each of 20,000 h. p. and each drives a 15,700 h. p. alternator. One of the turbines is held in reserve. The alternating tri-phase current is conveyed to Saaheim, 5,085 yards distant, at a pressure of 10,500 volts, by means of sixty overhead cables, divided into 10 sets of double lines. For the first 1804 yards copper wire is used, and for the rest of the distance aluminium is employed. The copper wires are 0·23 square inch in section and the aluminium wires 0·46 square inch. A full account follows of the methods of the manufacture of the nitric acid from the atmosphere by means of the electric arc at a temperature approaching 3,500° C. All the nitric acid produced is converted into nitrate of lime, and some important improvements in the manufacture have recently been devised by Mr. Schloesing, Jun., by the adoption of a dry process.

G. R. R.

APPENDIX B.

Comparative cost of Part A., *i. e.*, Head Works Flume, Reservoir, etc., in Hydro-Electric Schemes.

Item No.	Name of Scheme.	Maximum Demand Capacity of Part A. in k.ws.	Cost of Part A.	Rate per k.w.	Remarks.
1	Simla	1,500	Rs. 3,86,859	Rs. 258 (£17·2)	
2	Kinloch-Leven	24,250	Rs. 46,50,000	Rs. 192 (£12·8)	Generally considered to be an expensive scheme per k.w. in view of its size. Includes some £200,000, *i. e.*, 66 per cent. on a large dam.
3	Kashmere*				
4	Cauvery*				
5	Bombay†				
6	Malakand	40,000		Rs. 100	Estimate only—*vide* Appendices F. and G.
7	Lower Jhelum Canal ...	20,000		Rs. 25	

* Data not received in time for publication. Available figures include large expenditure on subsidiary plant in mines, etc.

† Scheme still under construction. Data not available.

APPENDIX C.

Comparative cost of Part B., *i. e.*, Head Stocks and pipes in Hydro-Electric Schemes.

	Name of Scheme.	Capacity of plant in k.ws. installed.	Cost of Part B.	Rate per k.w.	Rate per k.w. reduced to a slope of 1-3 and 6' sec.	Remarks.
1	Simla	750	Rs. 92,612	123·4 (£8·22)	Rs. 148	Actual slope $\frac{1}{1·25}$ speed 6' per sec.
2	Kinlock-Leven ...	21,100	£1,80,000	128 (£ 8·55)	Rs 63·	Actual slope $\frac{1}{7·1}$ speed 7' sec.
3	Kashmere*					
4	Cauvery*					
5	Bombay†	25,500				
6	Malakand... ...	40,000		Rs. 86	Rs. 100	Actual slope = $\frac{1}{7·5}$
7	Lower Jhelum Canal	20,000		Rs. 75	Special ducts of concrete.	Estimates only—*vide* Appendices F. and G.

* Data not available in time for publication. Available figures include large expenditure on subsidiary plant in mines, etc.

† Scheme still under construction. Data not available.

APPENDIX D.

Distribution of cost of Simla Hydro-Electric Scheme.

Item No.	Description.	Total cost.	Capacity k. w. installed.	Cost per k. w. Rupees.	Capacity in other units.	Unit.	Cost per unit.	Remarks.
		Rs.					Rs.	
1	Part A. Head Works, flume, etc.	3,76,859 (3,86,859)*	1,500 – *a* (1,500)	... 258	... ...	... ...	... ...	*a*.—The flume will have to be raised slightly to increase the carrying capacity. Actual slope ... $\frac{1}{2{\cdot}5}$
2	Part B ...	99,612 (92,612)*	750 + *b* (750)	123·4	13,640 Cusec feet	Cusec foot of head	6 79	F. L. Velocity—6 /sec. *b*.—Provision for extra three pipes in track, valves, etc.
3	Part C	...	...	...	...	...	...	
	1. Generating Sets ...	77,912	(750)	104	1,500	K. W / 1,000 r. p. m.	52	250 k. w. sets at ·95 Power Factor and 500 r. p. m.
	2. Switchgear ...	27,098 (22,098)*	750 + *c* (750)	29·5	...	...	...	*c*.—Includes provision for empty cells and blanks for extensions.
	3. Buildings, etc. ...	70,203 (90,203)*	2,000 – *d* (2,000)	45	...	...	...	*d*.—Main Turbine room will have to be extended to accommodate three extra sets; remaining buildings all completed.
	4. Quarters and Roads	49,923	2,000	25	...	...	...	
	Total Part C ...	...	...	203½	...	...	..	

4	*Part D. Transmission* ...							
	1. Transformers ...	47,318 (46,318)*	750 + *e* (750)	61·75	...			*e*.—Includes blank cement cells for extra E. H. T. Switch cells.
	2. Transmission Lines	78242*	1,500	52·1	25,500	K. W.	3 065	* Wooden H. Poles 17 miles long.
	Total Part D ...	...	...	114	...	Miles. ...	...	
5	Part E. Distribution ...	3,79,870 (5,29,820)*	1,500 − *f* (1,500)	352·5	...	...	..	*f*.—The mains will have to be extended to distribute the full 1,500 k. w.
6	Contingencies ..	61,751 (76,751)*	2,000 − *g* (2,000)	38·4	...	per cent.	3 65	*g. h. k.*—Are due to additional expenditure required to complete whole scheme.
7	Tools and Plant ...	27,366 (32,366)*	2,000 − *h* (2,000)	16·2	...	,,	1·54	
8	Establishment ...	1,25,000 (1,35,000)*	2,000 − *k* (2,000)	67·5	...	,,	6·4	
	Total Scheme proper ...	14,21,161	...	...	...	,,	11·59	

* These figures in brackets are alternative corrected totals as explained in the text.

APPENDIX E.

Comparison of several different Hydro-Electric Schemes in full.

Item No.	Name of Scheme.	Total capacity in k. w.	Average size of each set.	Part A.	Part B. Pipes.	Part C-1 Generating Sets.	Part C-2 Switchgear.	Part C-3 Buildings.	Part C-4 Roads and Quarters	Total C.	Total B. and C.	Total whole *i.e.*, A. B. and C. Cost Rs. per k. w.	Remarks.
			K. W.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.		
1	Simla	2,000	250	258	123½	104	29½	45	25	203½	327	585	540' Head, 2 miles flumes.
2	Kinloch-Leven ...	24,000	2,000 / 1,000	192	128	35½	3½	25	...	64	192	384	950 Head, 5 miles flumes.
3	Kashmere ...	...	...	...	...	...	...	...	...	...	...	...	Items 3, 4 and 5. Information not yet available. See remarks Appendix B.
4	Cauvery ...	...	...	...	...	...	...	...	...	...	...	...	
5	Bombay ...	...	...	...	...	...	...	...	...	...	...	...	
	6 well-known European schemes.			Parts A	and B								
6	A	3,600	600	117	...	175	25	20	31	251	...	368	200' Head. Pipeline slope ½
7	B	450	150	200	...	252	30	30	16	328	...	528	280' Head. No. flume, slope $\frac{1}{1\frac{1}{2}}$.
8	C	16,000	2,000	209	...	53	17	18	5	93	...	302	470' Head, 5 miles of flume, slope $\frac{1}{6\cdot4}$
9	D	6,600	1,000	106	...	50	13	10	6	79	...	185	1,200' Head, 3 miles of flume, slope $\frac{1}{1\cdot6}$
10	E	6,000	1,500	278	...	160	24	40	23	247	...	525	1,000' Head, 1½ miles of flume, slope ½.
11	F	26,000	2,000	173	...	44	12	23	24	103	..	276	1,200 Head, 6 miles of flume. Plant situated in 2 stations.