A PROJECT FOR PROVIDING THE PUNJAB WITH A CHEAP SUPPLY OF ELECTRIC POWER.

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Introduction.

The project outlined in this paper, though only meant to be the beginning of much greater things, will not, it is hoped, be condemned on the grounds that it is too ambitious to receive consideration at the hands of the present generation, since the war has instilled in all a spirit of enterprise which engineers must feel at least as keenly as any other body of men.

Comparative Statistics.

As Appendix 1 shows, the state of the electrical industry in India is, at the present time, nothing else than a by-word when compared with other countries in the world, but great things may now be expected by those electrical engineers who realise the enormous possibilities of development in this phase of engineering as a result of the deliberations of the Industrial Commission; and it is to be hoped that these expectations will not be disappointed.

As this paper is meant primarily to deal with the electrical development of the Punjab and Delhi, a statement comparing these two provinces with most of the others of India has been drawn up, and is shown in Appendix 2. The area of the whole of the Punjab, excluding the Feudatory States, is in the neighbourhood of 97,000 square miles, and, at the present time, the watts installed per square mile is as low as 67, which, in common parlance, represents approximately the energy taken by an ordinary 50 candle-power electric lamp such as one generally instals over a writing table.

General Suggestions.

Thanks to our eminent irrigation engineers, the Punjab is now covered with a network of most excellent canals, of which the province may well be proud, and there seems no reason why it should not also be covered with a network of extra high tension transmission lines, supplied with power from several conveniently located power stations, capable of being interlinked with each other. This question of interlinking of stations is receiving close attention at the present time in England, and there seems very little doubt that large state-owned super-stations, feeding into common networks, will come into being in the very near future.

Considering that the density of population per square mile in England is 650 as compared with 250 in the Punjab, and also taking into consideration the comparative stages of advancement of the respective countries, it would obviously be out of the question to consider a project of this kind if the power had to be derived from fuel of any sort. When, however, the natural power resources of the province are examined, it is obvious that enough power to meet the needs of the Punjab for an indefinite period can both easily and economically be obtained from water within the province itself, and the object of this paper is to endeavour to place before the Congress a rough outline of what, in the author's opinion, is the correct procedure to adopt in order to stimulate that spirit of enterprise and advancement that is making itself felt in all circles of the engineering and industrial world at the present abnormal time.

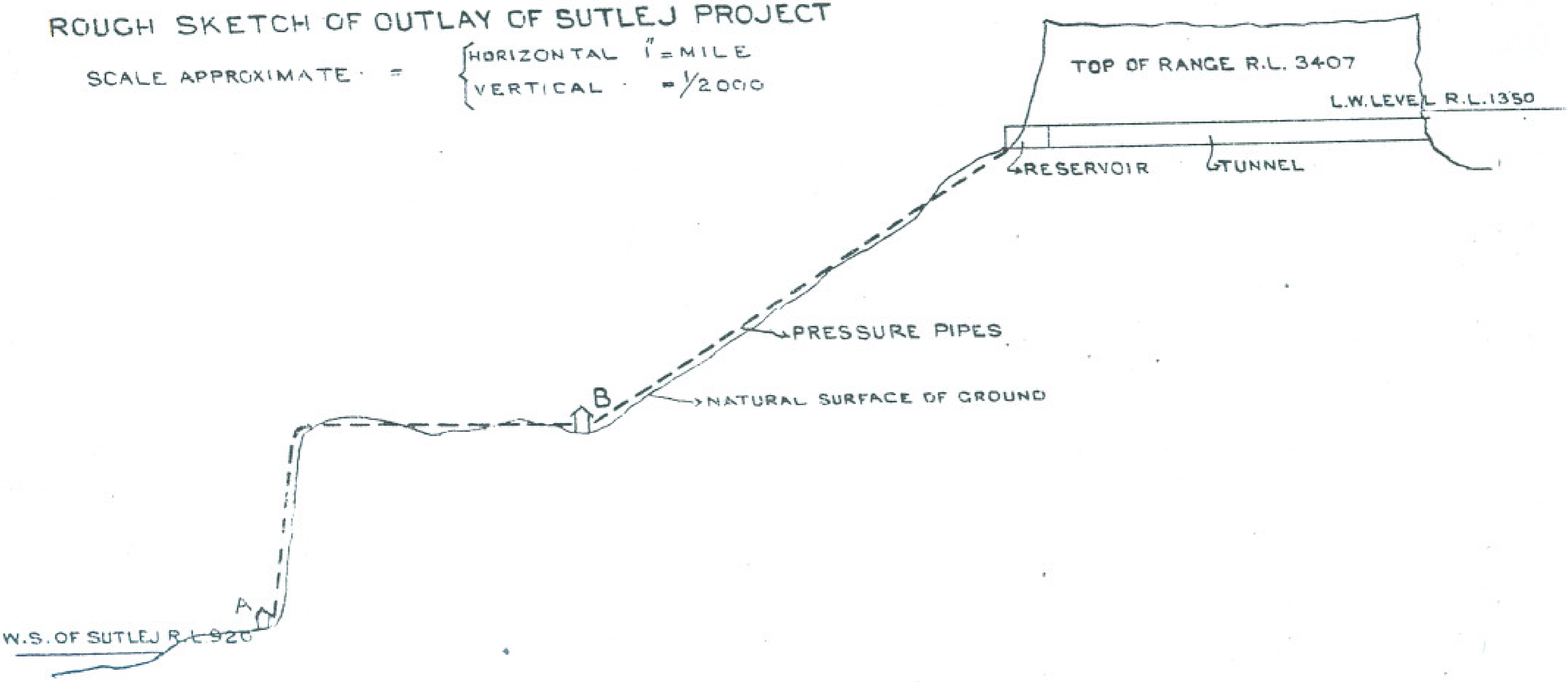
Available Water Horse-Power.

Appendix 3 will give members some idea of the amount of water horse-power available, and the percentage of the total that has been developed in various countries of the world.

In a paper read before this Congress in 1914, Capt. (now Lieut.-Col.) B. C. Battye, R. E., D. S. O., explained how 30 and 15 thousand kilowatts could be obtained from the Malakand and Lower Jhelum projects respectively. In addition to these there is the Upper Bari Doab, which is capable of economically yielding another 10,000 kilowatts continuously, and, should the Bhakra dam project materialize, there seems no reason why a further 60,000 kilowatts could not be obtained

ROUGH SKETCH OF OUTLAY OF SUTLEJ PROJECT

SCALE APPROXIMATE = { HORIZONTAL 1" = MILE; VERTICAL = 1/2000 }



from this source on the Sutlej river. In fact, although the possibility of obtaining the power does not in any way depend upon the construction of this dam, yet, if the dam is constructed simultaneously with the electrical project, there is no doubt but that the civil engineering works of the electrical portion will be greatly cheapened.

A reference to the map at page 75 will show that three out of the four of these projects are quite conveniently situated to facilitate distribution over a very large area, and to give duplicate supplies to all places so as to render continuity of service more assured.

As the Lower Jhelum scheme has already been brought before this Congress, the author proposes to deal only with the Upper Bari Doab and Sutlej projects ; but it should be remembered that the utilization of small canal falls, wherever convenient, is a matter that will naturally add greatly to the balancing and regulation of the system, provided arrangements can be made to locate such stations on branches which would not be subject to rotational working at the same time. This, however, is a matter that need not be considered in the first stages of the development.

General Description of Sutlej Project.

The author proposes to deal with the Sutlej project first, this being certainly the more fascinating and larger scheme of the two. There was, apparently, at one time a proposal to cut through the spur at a point about fifteen miles upstream of the proposed site of the dam, and thus, by diverting the river away from the enormous hair-pin bend of something like fifty miles that it now takes, to bring it through this cutting to a point about twenty miles above Rupar. The distance through this neck is only about seven miles, while the difference in level is about 450 feet. There is further the great advantage that, at the power station end of the cutting, the river would have a very wide basin, this feature naturally assisting greatly in overcoming a difficulty that is likely to be experienced by the difference in high and low flood levels of a river like the Sutlej, while it also shortens the distance between the headworks and the power station, as the latter can be placed about three-quarters of a mile back from the natural bed of the main stream (*vide* sketch).

The minimum discharge of the river at the point where the cutting would take off is about 2,700 cusecs, and, with a working head of 330 feet, no less than 60,000 kilowatts could be continuously obtained. The utilization of the minimum flow of the river will not interfere in any way with the essential purpose for which the dam is to be built, as this flow has to be allowed to pass through the dam at all times in order to supply the existing Sirhind Canal.

The map at page 75 shows that the situation is quite suitable for a power station with an extra high tension transmission network. It is most conveniently situated for taking in the supply of many important towns, and for the electrification of a considerable length of railway, particularly the Delhi-Ambala-Kalka and Kalka-Simla lines.

The possibility of utilizing the power of the Sutlej at this place was reported on by the Punjab Government early in 1905 as the result of an enquiry from the Govenment of India, dated November 7th, 1904. The Punjab Government looked into the matter, while investigations had also been carried out by a small syndicate between the years 1899 and 1901. The chief objection to the project at that time was the length of pressure pipe that would be required, the cost of which would add greatly to the development of the scheme. The syndicate concluded that 'there was not the least chance of the project being commercially possible for *many years* to come.' Considering the enormous strides that have been made in hydro-electric development and the transmission of electric power since the syndicate expressed this opinion, and also taking into consideration the necessity of the economic development of the country at the present time, the author believes that the period of *many years* has now passed and that it is time the matter was taken up again, this time taking full advantage of the up-to-date knowledge the country now possesses of hydro-eletric development.

The minimum recorded discharge, over forty years, of the Sutlej opposite Kirathpore is 2,700 cusecs, and if this were led through a tunnel of a little more than two miles in length, with an open cutting and a balancing reservoir at the far end, and pressure pipes taken off this reservoir for a distance of about three-and-a-half miles, a working head of at least 330 feet could be obtained, which, as already stated, would be capable of yielding no less than 60,000 kilowatts continuously. If the bed slope of the tunnel were arranged to give a velocity of seven feet per second, a heading of approximately 400 square feet, or say 30 by 15 feet, would be required. Two sixteen feet diameter reinforced concrete pipes could be led from this reservoir for a distance of about half a mile, and steel pipes for the last length of three miles or so. For a total development of 60,000 kilowatts it would perhaps be advisable to have four steel pipes of eleven feet diameter up to the end of the bluff (*vidè* sketch at page 80) ; these pipes being interconnected at intervals with valves in order that any three of them should be capable of carrying the full supply for short periods without the water attaining an abnormal velocity, while the last section should be finished up with one pipe per unit installed. For purposes of this estimates five units of 10,000 K. W. and three of 5,000 K. W. each are assumed , these will necessitate five pipes of 9 feet diameter and three of 6½ feet diameter for this last section of about five hundred feet Details of the approximate cost of this project for the full development of 60,000 K. W. are shown in Appendix 4 where it will be noticed that the capital cost of the works for the generation of the power would be Rs. 313 per kilowatt installed.

General Description of Ravi Project.

In the Upper Bari Doab scheme, a static head of about 140 feet in 7½ miles, or 200 feet in 13 miles can be obtained, and it will probably be advisable to sacrifice the extra sixty feet of head in order to save 5½ miles of very expensive penstock pipes (unless these pipes are of *very* liberal si-e, frict'on losses etc. will leave only an unprofitable working hea[illegible].

The minimum recorded discharge of th' Ravi at the head of the Upper Bari Doab Canal is 1303 cusecs, and, with a working head of about a hundred feet, approximately 10,000 K. W. continuously can be obtained. If this work were constructed with four miles of a 16 feet diameter reinforced concrete pipe with a surge tower at th[illegible] bottom, and three miles of double 11 feet diameter steel pi[illegible] with interconnectors at intervals, finishing up with three [illegible]el pipes of 8 feet diameter, each of these latter feeding a 5,[illegible] K. W. unit, the total approximate cost of the project w[illegible] amount to Rs. 1,07,32,000, or Rs. 716 per K. W. instal[illegible], as shown in detail in Appendix 5.

Comparison of the two Projects.

A comparison of appendices 4 and 5 shows that the Sutlej project is considerably cheaper per kilowatt than the Ravi project ; the former can also embrace a much larger area of supply than the latter, and it is suggested that the Sutlej scheme should be taken up first and developed for a total installation of 10,000 K. W., of which 7,500 K. W. might be considered as working plant. Details of the approximate cost of this development are shown in appendices 6 and 7; the former on the assumption that the power station is located at the point *A*, and the latter at the point *B*; (*vide* sketch).

The difference in capital cost of the two alternatives is so small that it would appear advisable to locate the station at *A* in the first instance, as there is very little doubt that extensions will be necessary shortly after the inauguration of the supply. How far these extensions should be anticipated when designing the original scheme is a question that needs very careful consideration before hand, and this can probably best be done by a complete co-ordination between government and industrialists.

Transmission Lines.

The routes of the transmission lines as proposed are shown in the map at page 75; and details of the approximate cost given in Appendix 9. These calculations are based on a line voltage of 100,000 volts. If a lower voltage (say 66 or 80 thousand) were adopted, the cost of the copper would be increased, but this would be more or less compensated for by a reduction in the cost of insulators and structures, owing to the fact that for the lower voltages, pin type insulators could be utilized, whereas, with the higher voltage, it would be necessary to use suspension insulators; with pin insulators the height and width of structures could be made considerably less than with suspension insulators. Taking everything into consideration it would undoubtedly be better to adopt the higher voltage in the first instance, so that when the load developed, the line pressure could be increased to 120, or even to 150 thousand volts, by simply adding additional insulators to the existing string, whereas if pin insulators were put in at first, it would mean that all the original insulators on the line would have to be scrapped, or the size of the copper would have to be increased in order to prevent abnormal line losses and bad regulation on the system.

Capital Charges.

Appendices 6 and 9 shew that the total approximate cost of the project so far works out to nearly 107¼ lacs of rupees; to this should be added 7 lacs for transformers and switchgear for distribution purposes, making a total of 114¼, or say 115 lacs of rupees. Interest at 5 per cent. and a sinking fund at 1½ per cent. for a thirty year loan would require a little less than 7½ lacs per annum, and maintenance (*i. e.* establishment and repairs) should not exceed 1½ lacs per annum, making a total of nine lacs of rupees per annum as capital and running charges. Depreciation may be taken as below :—

						Rs.		Rs.
1.	Concrete pipes	$1\frac{1}{2}\%$	on	2,10,000	...	3,150
2.	Steel pipes	$3\frac{1}{2}\%$	on	11,77,000	...	41,150
3.	Machinery	$4\frac{1}{2}\%$	on	18,00,000	...	72,000
4.	Structures	$1\frac{1}{2}\%$	on	29,08,000	...	43,600
				Total Rs.	...	1,59,900
				Say, Rs.	...	1,60,000

This makes the total recurring charges Rs. 10,60,000 per annum.

While on the subject of recurring charges on a project of this nature it is interesting to note that the Simla Waterworks Committee of 1904 took exception to General Beresford Lovett providing for both a sinking fund and depreciation in his estimates. If this is to be accepted as the correct commercial method of dealing with the question, then total recurring charges of only nine lacs per annum need be assumed.

For the information of those who may not have read this report an extract of the part referred to is given in Appendix 8, and considering that the committee consisted of such well known engineers as Messrs. Du Cane Smithe, Goument, Meares and Stanley, it is justifiable to accept their views as representing those of the Government in respect to the financing of productive works of this nature.

Considerations in regard to selling Electricity.

The next point to consider is how a yearly revenue of at least nine lacs to meet the recurring charges can be obtained, and in this connection the fact must not be lost sight of that the Punjab, and for the matter of that the whole of India is at present in a most undeveloped state, and, therefore, a demand ready to hand must not be expected for purposes of estimating the financial possibilities of the project as a whole. The policy should be adopted of giving the supply at very favourable rates and resting assured that the demand will follow in a surprisingly short time. It is no use asking prospective promoters of new industries whether they will take an electric supply in the event of its being inaugurated—there is no question but they will do so—but it should be taken for granted that they will not be prepared to bind themselves down to anything, until they have either seen for themselves that it will be greatly to their advantage, or that the projected scheme is an established fact. Canada has proved that where cheap hydro-electric power is made available industries will spring up in districts where originally neither population nor means of communication existed.

Statistics relating to existing Supply Installations in India.

Appendix 10 contains a list of towns in India that derive their electric supply from hydro-electric installations, and are, consequently, in a position to supply current at reasonably low rates. Some of these towns, though having few industries, have water pumping installations on a fairly large proportionate scale to the total output of the plant ; this fact will tend to balance matters as, in the Punjab, industries will predominate, and water pumping for domestic purposes will be on a smaller scale. This appendix shews that in hydro-electric installations the percentage of consumers to the total population averages $3\frac{1}{2}$ per cent., and the number of units per consumer per annum averages 2,508. From these figures Appendix 11 has been compiled taking as a guide similar figures obtained from Appendix 10, which relate to several other towns in India that have an electric supply obtained from fuel driven plant. It will be noticed that Appendix 11 only takes in those towns through which the main transmission system would actually pass. Appendix 12 shows the average price obtained per unit during the financial year 1916-17 for both hydro-electric and fuel driven stations.

Return per unit.

To enable us to obtain the required nine lacs per annum to meet the recurring charges, it will be necessary to sell only nine million units a year at an average price of 1-6 annas per unit, or approximately $14\frac{1}{2}$ million units at one anna per unit, as an average. The former represents a load-factor of only 13·7% and the latter of 21·9%, both of which figures are very low for a hydro-electric station ; but there would be very little likelihood of getting bulk licensees to take a supply at rates as high as either of those mentioned above. If however, an average return of 0·6 anna per unit is assumed (the Tata hydro-electric installation in Bombay obtained an average of 0·539 during the financial year 1916-17), it means that a market for 24 million units per annum will be necessary and this latter represents a load-factor of $36\frac{1}{2}$ per cent., which is quite a reasonable figure.

Market.

Appendix 11 shows how these units can readily be sold. But in addition to these which may be called certain marketable units, it may safely be assumed that three million units will be utilised in cotton ginning etc., and twelve million by the Irrigation Department for pumping water in water-logged areas, for high lying land irrigation, and for irrigation purposes in districts where there is at present no irrigation water. In fact it is very doubtful whether it would not be considerably cheaper to run transmission lines instead of canals to certain areas requiring water for irrigation purposes. It appears that the well system for irrigation offers great possibilities for the utilisation of cheap electric power by the installation of a number of small pumping units over a large area, supplied with lines radiating from a common centre. The pumping of water in water-logged areas could be done on a much larger scale than at present, and more high lying country could be brought under cultivation by means of pumping.

Electro-chemical works can be run economically, if very cheap electric power is available, and there seems no reason why the Punjab should not be the pioneer in this direction. Probably both electro-chemical and paper pulp works would be set up in the vicinity of power stations, and with a network of transmission lines as suggested in this paper, new industries could be located in the most convenient places to suit individual requirements ; and it may be safely assumed that cotton spinning would be introduced into the Punjab on a fairly large scale if cheap power were available in the province.

At the present time some $11\frac{1}{4}$ million units are generated per annum in the towns through which it is proposed to run transmission lines. The average price obtained by the Lahore Electric Supply Co, during the financial year 1916-17 was no less than 4·45 annas per unit, and it stands to reason that when current is available at such an average price, it will be used most sparingly and the greatest economy will be exercised by consumers. Considering that in the Punjab and Delhi fuel charges alone average 0·695 anna per unit, it is easily understood why electric power is not utilised on any very large scale.

Advantages of Hydro-electric Power.

A point that should always be kept very much in mind by those responsible for the financial arrangements of hydro-electric installations is, that there is, strictly speaking, no limit to the selling price of current derived by means of water power, as the working costs of a hydro-electric installation are not materially affected by the generation and sale of additional units; this fact makes it possible to sell current at *any* price provided no extra capital expenditure is involved for additional plant. Consumers can, therefore, be taken on after the plant is loaded up to its limit, provided they agree not to use current during the few hours each day when the "peak" load is experienced by the station; as such consumers help considerably in giving work to the plant, which would otherwise be lying idle, they can be given current at exceedingly low rates, and all this means extra revenue to the supplier which costs him nothing.

The author found in Simla that a reduction in the rate for heating purposes resulted in no loss whatever from existing consumers on the heating tariff, for the simple reason that the average consumer is guided by the amount of his monthly bill in *rupees* and not in *units*; he consequently used considerably more units and got them for the same total amount he paid previously when the higher rate was in force. The main point, however, was that the reduction in the rate brought in a very large number of new consumers who otherwise would not have contributed anything towards the revenue; the net result being that a considerably enhanced revenue was obtained with no extra cost whatever. With a hydro-electric installation it costs no more to supply a twenty-four hour load than a one hour load of the same kilowatt rating, and it is for this reason that the figure of total units generated by a hydro-electric plant is of considerably more importance than the kilowatt capacity of the plant.

It was suggested in Switzerland some short time back that, in order to encourage cooking by electricity, three rates should be charged to consumers, a high rate for the period of 'peak' load, a medium rate for all the remaining hours of the day except for five hours in the early morning and two hours about midday, when it was proposed to supply current *gratis* except for a small fixed charge to cover capital expensse. This arrangement would probably prove advantageous on a hydro-electric installation, but it is questionable whether any engineer or manager would care to try the experiment on a fuel driven project where each unit generated costs a definite amount for fuel.

Other Probable Markets

While on the subject of electric cooking it will not be out of place to mention that there is an enormous opening for this in the country. It is being taken up most vigorously in England, and is proving a great success both from the point of view of economy, and also on account of the superior quality of articles cooked by this means. As an absolutely safe figure it may be assumed that, even with careless Indian servants, the cost, with current at half an anna per unit, will not exceed two annas per head per day, this, for an average household of say four, will come to approximately Rs. 15 per month which compares very favourably with present fuel charges in most places. For hotels and large institutions it has been found in England that the energy consumed per head per day is in the neighbourhood of one unit. Electricity at half an anna per unit can be used to advantage in bakers' ovens and for the heating of bath water; both of which can quite conveniently be done during the 'off-peak' period. Another market for the sale of 'off-peak' current can be introduced with great advantage to the nation generally by the adoption of electric road vehicles for town use in place of petrol cars. The electric vehicle is much cheaper to run, easier to manipulate, and the depreciation considerably lower than in the petrol car; they are being adopted on a large and increasing scale by municipalities and such corporations in other countries for road watering, disposal of refuse etc. and have proved to be cheaper and in every way superior to both petrol and horse drawn vehicles. For pleasure driving they are of course considerably superior to the petrol car, particularly for ladies and for town use, where high speeds are not desirable.

The electrification of the main railway lines is a matter that will probably be taken up later, but it would appear that shunting yards and coal waggon marshalling depots will find it cheaper to electrify their services in the first instance than to keep up steam for shunting purposes etc. all through the twenty-four hours. In the author's opinion there is no question but that both the Delhi-Ambala-Kalka and the Kalka-Simla lines (particularly the latter) would electrify their systems if they could obtain power at a cheap rate, and should these two railways adopt electric traction, most valuable data would be made available for purposes of comparison of the working costs, etc. of electric and steam power, as the former railway is a hill line, and the latter in the plains. The Kalka-Simla Railway would require approximately two million units per annum for its own working and a further million or so for the electrification of towns *en route.*

Need of starting on a Small Scale.

The suggestion of starting the project with 10,000 kilowatts is, in the writer's opinion, only a stepping stone in the direction of attaining what is sure to follow at a very early date after the inauguration of the supply. It is not desired to make any attempt in this paper to advocate a scheme that has not every likelihood of proving a financial success, and the writer is of opinion that if a beginning is made on a small scale it will tend immensely towards imparting a greater confidence in electrical development in this country than at present exists, and this in turn will finally lead, not only towards overcoming the strenuous post-war economic struggle as to which all are agreed, but it will also assist greatly in gratifying the widespread desire of making India self-sufficing in all matters, electrical, electro-chemical, and electro-metallurgical.

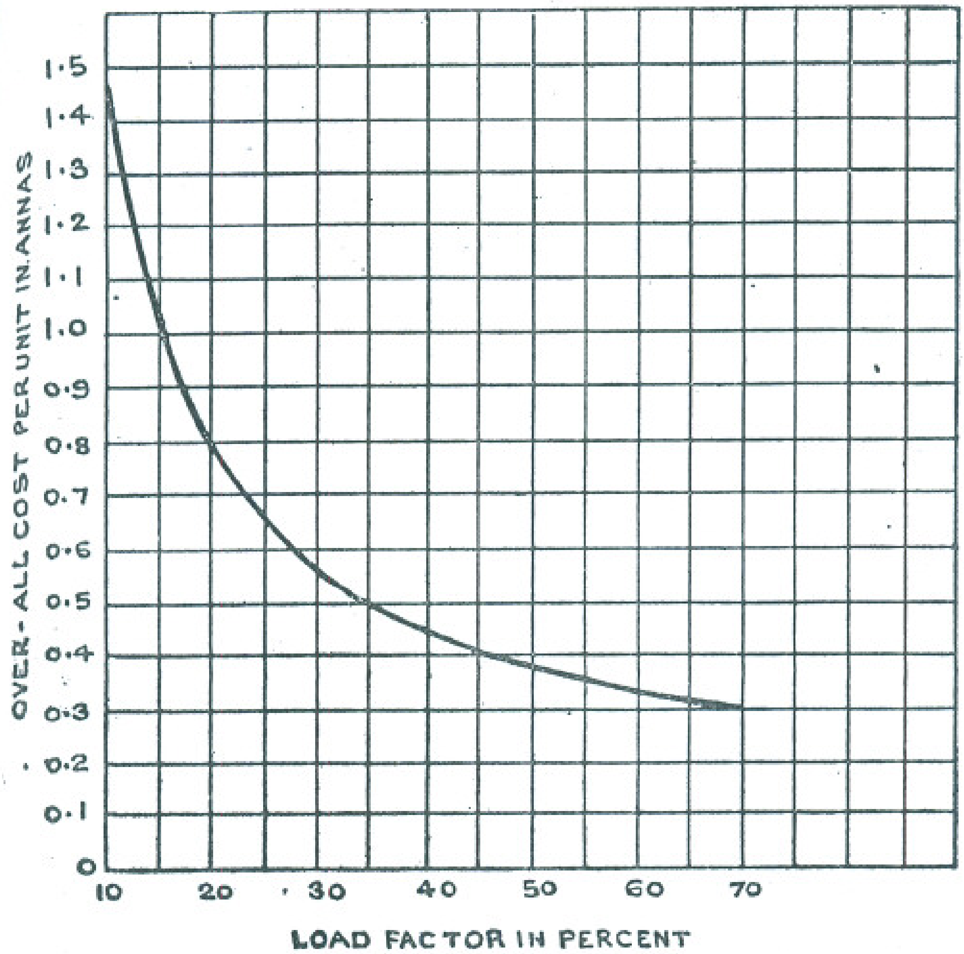
Modus Operandi.

The question of leaving the initiative to private enterprise should, in the author's opinion, not be considered. The policy that should be adopted, without doubt, is a nationalization of all the water power in this country, as is now being done by every other country in the world ; and this arrangement will, in turn, lead to a real monopoly under a single control. With the control entirely under one authority, it will probably be found that current can be sold at half the price at which it could otherwise be, and consequently it will be the country generally that will benefit greatly. From what has just been said it is not meant that local distribution should necessarily be undertaken by the government ; the remarks made refer particularly to the development and transmission of the power only, the distribution and maintenance of individual systems may be left to private enterprise and local bodies working under license.

There seems no reason whatever to postpone a work of this nature, as there is very little doubt that high prices will prevail for some time after the conclusion of peace, and the benefit of industrial activity in the years immediately following the war will be of immense importance to the country, and anything that contributes to it will be of general advantage.

Rates.

A few words regarding rates that are likely to prove suitable to both the supplier and the consumer. It will probably be advantageous to charge a fixed sum per kilowatt of maximum demand plus one-tenth of an anna per unit. A fixed charge of Rs. 75 per kilowatt per annum would be about correct to cover capital charges on the plant, and it will now be considered how this appears when looked at from the bulk purchaser's point of view; the two towns, Delhi and Lahore, being taken as typical examples. Details of the returns for the year 1916-17 are shown in Appendix 13, and the curve below shows the variation in the overall cost of a unit for different load factors.



Typical Examples.

Let us consider as examples Lahore and Ambala under the new system. In the year 1916-17 the Lahore Electric Supply Company generated 1,337,500 units; their works costs amounted to 2·017 annas per unit; the maximum demand experienced was 380 kilowatts, representing a load factor of about 40%; so that their fixed charge would amount to

$$\frac{380 \times 75 \times 16}{1,337,500} = 0{\cdot}341 \text{ anna per unit,}$$

and the overall works costs would be reduced by 0·457 anna per unit (Appendix 13). Now assume that they obtained customers who were prepared to utilize current only during the "off-peak" period, and the company agreed to supply them with say a hundred kilowatts at half an anna per unit or a total of 300,000 units per annum, the result would be that the company's load factor would rise from 40·1 to 49·20 per cent, and their liability for purchase of current would be reduced from 0·441 to 0·379 anna per unit, while in addition to this they would get nearly Rs. 9,500 extra revenue from new consumers, or a total of approximately Rs. 16,000 per annum enhanced revenue. The above is on the assumption that no extra capital expenditure would be necessary on account of mains, etc., but it will serve to give some idea of the amount that may be expended on extensions in order to obtain new consumers.

Considering Ambala from a bulk purchaser's point of view with respect to undertaking the distribution and sale of current in the town, the estimated number of consumers is 1,200, and the estimated number of units per annum is 1,800,000 (Appendix 11). Without going into details it may be assumed that the capital cost of distribution will not exceed Rs. 350 per consumer; this will make the total capital expenditure say Rs. 4¼ lacs. Recurring charges on this sum may be taken as below;

	Rs.
Interest and repayment of capital at 6½ per cent.	27,600
Depreciation on lines, 1½ per cent. on, say, Rs. 3,50,000	5,250
Depreciation on transformers and switch gear, 3½ per cent. on, say, Rs. 30,000.	1,050
Depreciation on meters, 10 per cent on, say, Rs. 45,000. ...	4,500
Management and running charges, say 5 per cent.	21,250
Total ...	59,650
Now, with a load factor of, say 35 per cent, the bulk purchaser will have to pay for current. at the rate of 0·49 anna per unit, and, for 1,800,000 units, his liability on this account will be.	55,150
Making the total recurring charges ...	1,14,800

Now, if he retails only $1\frac{1}{2}$ million units, (allowing the balance of 300,000 units to cover losses and units on works) at an average price of $1\frac{1}{2}$ annas per unit, it means that his revenue from the sale of current alone (omitting meter rent and other miscellaneous income) will amount to	1,40,625
And his profit from the sale of current will be	25,825

which represents a little more than six per cent of the capital invested ; this might reasonably be expected within three to four years of the inauguration of the supply.

The total recurring charges, excluding pa ment for current purchased, amount to almost exactly fourteen per cent of the invested capital; and assuming that during the first year of working only five hundred consumers are obtained with a total demand of 750,000 units, and the capital cost of this is Rs. $2\frac{1}{4}$ lacs (*i.e.* Rs. 450, per consumer), the following figures will show the financial condition of the licen ee during the first year of working.

EXPENDITURE.

	Rs.
Recurring charges on capital, depreciation and maintenance; 14 per cent of $2\frac{1}{4}$ lacs	31,500
Cost of current purchased, assuming rate as before *i.e.* 0·49 anna per unit	23,000
Total ...	54,500

REVENUE.

(From sale of current only.) 650,000 units sold (allowing 100,000 for losses, etc.) at an average price of $1\frac{1}{2}$ annas per unit	61,000
Profit	6,500

which represents a little less than three per cent of the capital invested.

During the first year of working an additional revenue of probably Rs. 2,500 will be obtained from meter rents and other miscellaneous sources, and this will increase the percentage of income over expenditure to almost exactly four per cent of the invested capital.

Location of Industries.

In cases where the cost of the carriage of raw material, etc tends to balance advantages likely to be gained by a supply of cheap power, it may prove beneficial to locate some industries a certain distance away from the main transmission lines, and it will now be considered up to what distance it will pay to extend the transmission.

The cost ot transmission averages Rs. 8,470 (or say Rs. 8,500) per mile (Appendix 8), and recurring charges on this sum may be taken as Rs. 750 per annum ; so that, roughly speaking, both parties are likely to benefit by an extension of transmission lines to any reasonable distance, provided a maximum demand of not less than ten kilowatts per mile of transmission is assured. This is on the assumption, of course, that no extra expenditure has been necessary on account of generating plant, etc., and that the distance is long enough to warrant an *extra* high tension transmission service. For short distances a *high* tension line would naturally be run at a considerably lower cost per mile.

Conclusion.

Finally, the writer, without in any way committing them, wishes to express his indebtedness to Messrs. Meares, Eastgate, and Batchelor for kindly criticising and offering suggestions regarding the drafting of this paper in the first instance; his thanks are also due to Messrs Loughran, Hadow and Nicholson of the Irrigation Department for kindly furnishing particulars, etc., regarding irrigation works in the Province, and particularly to Mr. Nicholson for supplying most useful data and suggestions in connection with the Sutlej project which has been advocated in the paper.

APPENDIX I.

Electric plant installed in certain countries.

	Country.	Population.	Total kilowatts installed.	Watts installed per head of population.
1	British Isles	45,221,615	1,491,014	33·0
2	Canada	7,206,643	1,067,051	148·0
3	Australasia	4,555,005	282,088	61·9
4	Union of South Africa ...	5,973,394	340,063	56·9
5	India	315,156,396	233,800	0·742

APPENDIX II.

Electric plant installed in India.

	Province.	Population.	Total kilowatts installed.	Watts installed per head of population.
1	Madras	41,405,404	12,283	0·297
2	Bombay	19,626,477	70,987	3·613
3	Bengal	45,483,269	59,721	1·315
4	United Provinces ...	47,182,044	6,565	0·139
5	Punjab	19,576,687	5,200	0·266
6	Delhi	412,821	1,461	3·540
7	Burmah	10,610,256	9,782	0·922
8	Central Provinces ...	13,916,308	3,760	0·270
9	Bihar and Orissa ...	34,490,038	19,850	0·575
1	Mysore	5,806,193	15,750	2·710
2	Kashmir	3,158,126	4,800	1·522
3	Patiala	1,407,659	750	0·534
4	Hyderabad	13,374,676	3,000	0·225

APPENDIX III.

An estimate of the water-power available and developed in certain countries.

	Country.	H.-P. Available.	H.-P. Developed.	Percentage of total utilized.
1	United States	28,100,000	7,000,000	24·90
2	Canada	25,914,000	3,410,843	13·16
3	France	5,587,000	650,000	11·60
4	Austria-Hungary ...	6,460,000	566,000	8·80
5	Germany	1,425,000	618,100	43·40
6	Spain	5,000,000	440,000	8·80
7	Norway	5,500,000	1,120,000	20·40
8	Sweden	4,500,000	704,500	15·60
9	Italy	4,000,000	976,300	24·40
10	Switzerland	2,000,000	511,000	25·50
11	Great Britain	963,000	80,000	8·30
12	India	10,000,000	122,000	1·22

Most of the above figures were obtained from a paper presented at the International Engineering Congress in San Francisco by Mr. Charles H. Mitchell, and are for the year 1915. The available horse-power and the percentage in the case of India are approximations, as no authentic figures are available, the horse-power developed is for the financial year 1916-17.