APPENDIX IV.

Cost of development of 60,000 K. W. on the Sutlerj near the Bhakra dam site.

Head = 330 et. Cusecs = 2,700.

	Rs.
1. Headworks	3,00,000
2. Tunnel, 30 feet by 15 feet for 12,000 r. f. at Rs. 300 per r. foot	36,00,000
3. Short open cutting, balancing reservoir and overflow channel	5,00,000
4. Two 16 feet dia. reinforced concrete pipes for 3,000 feet at Rs. 175 per r. f.	10,50,000
5. Surge tower	1,00,000
6. Four steel pipes, 11 feet dia. by 3/8 in. thick for 14,500 r. f. (13,700 tons at Rs. 450 per ton)	61,70,000
7. Five steel pipes, 9 feet dia. by 3/8 in. thick for 500 r. f. (482 tons at Rs. 450 per ton) ...	2,18,000
8. Three steel pipes, 6½ feet dia. by 1/4 in. thick for 500 r. f. (140 tons at Rs. 450 per ton) ...	63,000
9. Five 10,000 K. W. generating units at Rs. 8½ lacs each	42,50,000
10. Three 5,000 K. W. generating units at Rs. 5 lacs each	15,00,000
11. Buildings, etc.	3,00,000
12. Anchors, etc. for pipes	2,50,000
13. Escape channel, etc.	2,00,000
	1,85,01,000
Add 10 per cent for contingencies, etc. ...	18,50,000
Total ...	2,03,51,000

Capital cost per kilowatt installed Rs. 313.

APPENDIX V.

Cost of the development of 10,000 K. W. on the Upper Bari Doab Canal site.

		Rs.
1.	Four miles of 16 feet dia. reinforced concrete pipe at Rs. 175 per r. f.	37,06,000
2.	Surge tower, etc.	60,000
3.	Three miles of double 11 feet dia. by 3/8 in. thick steel pipes (7,500 tons at Rs. 450 per ton)	33,80,000
4.	Half mile of three 8 feet dia. by 5/16 in. thick steel pipes (1,130 tons at Rs. 450 per ton) ...	5,10,000
5.	Three 5,000 K. W. generating units at Rs. 5 lacs each	15,00,000
6.	Buildings, etc.	2,00,000
7.	Headworks and escape channels to both the existing canal and the Beas River	4,00,000
		97,56,000
	Add 10 per cent. for contingencies, etc. ...	9,76,000
	Total ...	1,07,32,000

Capital cost per kilowatt installed Rs. 716.

APPENDIX VI.

Cost of the development of 10,000 K. W. at 330 feet head on the Sutlej, assuming 7,500 K. W. as working plant.

		Rs.
1.	Headworks	2,00,000
2.	Tunnel 12 feet by 6 feet for 12,000 feet at Rs. 70 per running foot	8,40,000
3.	Balancing reservoir	2,00,000
4.	Reinforced concrete pipe 8 feet dia. by 3,000 feet long at Rs. 70 per r. f.	2,10,000
5.	Surge tower	30,000
6.	Double steel pipes 6 feet dia. by $\frac{1}{4}$ in. thick for 14,500 feet (2,500 tons at Rs. 450 per ton) ...	11,28,000
7.	Double steel pipes $4\frac{1}{2}$ feet dia. by $\frac{1}{4}$ in. thick for 500 feet (65 tons at Rs. 450 per ton) ...	30,000
8.	Single steel pipe $6\frac{1}{2}$ feet dia. by $\frac{1}{4}$ in. thick for 500 feet (47 tons at Rs. 450 per ton) ...	21,000
9.	One 5,000 K. W. generating unit at Rs. 5 lacs.	5,00,000
10.	Two 2,500 K. W. generating units at Rs. 3 lacs each	6,00,000
11.	Buildings, etc.	2,00,000
12.	Anchors, etc. for pipes	1,00,000
13.	Escape channel, etc.	1,00,000
		41,57,000
	Add 10 per cent. for contingencies, etc. ...	4,16,000
	Total ...	45,73,000

Capital cost per kilowatt installed Rs. 458.

APPENDIX VII.

Cost of the development of 10,000 K. W. at 200 feet head on the Sutlej, assuming 7,500 K. W. as working plant.

		Rs.
1.	Headworks	2,00,000
2.	Tunnel 15 feet by 7 feet for 12,000 feet at Rs. 95 per r. f.	11,40,000
3.	Balancing reservoir	2,00,000
4.	Reinforced concrete pipe 10 feet dia. by 3,000 feet long at Rs. 80 per r. f.	2,40,000
5.	Surge tower	40,000
6.	Double steel pipes 7½ feet dia. by 5/16 in. thick for 7,000 feet (1,875 tons at Rs. 450 per ton)	8,45,000
7.	Single pipe 7½ feet dia. by 5/16 in. thick for 500 feet (67 tons at Rs. 450 per ton) ...	30,200
8.	Double steel pipes 5½ feet dia. by ¼ in. thick for 500 feet (79 tons at Rs. 450 per ton) ...	35,600
9.	One 5,000 K. W. generating unit at Rs. 5 lacs.	5,00,000
10.	Two 2,500 K. W. generating units at Rs. 3 lacs each	6,00,000
11.	Buildings, etc.	2,00,000
12.	Anchors, etc., for pipes	75,000
13.	Escape channel, etc.	1,00,000
		42,05,800
	Add 10 per cent. for contingencies, etc. ...	4,20,600
	Total ...	46,26,400

Capital cost per kilowatt installed Rs. 463.

APPENDIX VIII.

Extract from Simla Waterworks Committee's Report of 1904.

"The annual payment to a sinking fund to meet interest at 4 per cent, "and repay capital in thirty years comes to about 6 per cent. The sum of "Rs. 50,000 entered against this item in addition to interest is therefore "not understood. It is not usual to charge depreciation when a sinking "fund is maintained, as a new loan can be raised to replace worn out "machinery, etc., when the old loan has been paid up."

APPENDIX IX.

Estimate of the cost of the transmission network for the Sutl project.

Route.		Distance in miles.	Approximate load in kilowatts under emergency conditions.	Gauge of wire.	Tons of copper.	Number of structures.
From	To					
1 Station	Jullunder	56	3,500	5	56	560
2 Jullundur	Amritsar	49	3,000	6	40	490
3 Amritsar	Lahore	27	3,000	6	22	270
4 Lahore	Ferozepur	46	3,000	6	38	460
5 Ferozepur	Ludhiana	82	3,500	6	67	820
6 Station	Ludhiana	45	4,500	4	53	450
7 Ludhiana	Ambala	80	3,500	6	66	800
8 Station	Kalka	36	5,500	4	43	360
9 Kalka	Ambala	34	3,500	6	28	340
10 Ambala	Delhi	124	2,500	7	84	1,240
11 Ambala	Meerut	108	2,500	7	74	1,080
12 Meerut	Ghaziabad	27	2,500	7	19	270
13 Ghaziabad	Delhi	13	2,000	7	10	130
	Total	727	...	...	600	7,270

ABSTRACT.

		Rs.
600 tons of copper wire at Rs. 2,500 per ton	...	15,00,000
7,270 reinforced concrete H structures, cross-braced, at Rs. 400 per structure	... ...	29,08,000
21,810 strings of insulators at Rs. 40 per string	...	8,72,400
Telephone wires and insulators	... ...	1,95,000
Erection at Rs. 150 per mile	... ...	1,10,000
		55,85,400
Add 10 per cent. for contingencies	...	5,58,600
		61,44,000

Capital cost per mile = Rs. 8,450.

Note.—Line drop = Impedance of line × current

and

Impedance per mile of three-phase line of No. 4 wire = 2·190 ohms at 50 cycles and 12½ feet spacing.

Impedance per mile of three-phase line of No. 5 wire = 2·480 ohms at 50 cycles and 12½ feet spacing.

Impedance per mile of three-phase line of No. 6 wire = 2·903 ohms at 50 cycles and 12½ feet spacing.

Impedance per mile of three-phase line of No. 7 wire = 3·295 ohms at 50 cycles and 12½ feet spacing.

APPENDIX X.

Data concerning existing electric installations in India.

Town.	Population.	Number of consumers.	Percentage of consumers to total population.	Units generated per annum.	Average number of units per consumer per annum.
HYDRO-ELECTRIC INSTALLATIONS.					
1 Darjeeling ...	17,400	743	4·27	736,330	990
2 Mussoorie and Dehra	38,000	1,691	4·45	2,380,000	1,405
3 Simla ...	39,320	1,922	4·88	3,235,908	1,682
4 Bangalore ...	100,834	3,070	3·05	8,800,000	2,868
5 Mysore City .	71,306	590	0·83	2,300,000	5,595
Total ..	266,860	8,016	17·48	18,452,238	12,540
Averages ...	...	...	3·50	...	2,508
PRESIDENCY TOWNS.					
1 Bombay ...	979,445	9,033	0·924	79,542,000	8,800
2 Madras ...	518,660	2,305	0·444	7,634,400	3,315
3 Calcutta ...	900,000	9,700	1·078	30,744,000	3,170
Total ...	2,398,105	21,038	2·446	117,920,400	15,285
Averages ...	...	...	0·815	...	5,095
DELHI AND PUNJAB TOWNS.					
1 Lahore ...	228,687	1,417	0·622	5,409,500	3,820
2 Delhi ...	232,837	3,400	1·465	3,891,780	1,145
3 Amritsar ..	152,756	1,071	0·705	997,500	930
Total ...	614,280	5,888	2·792	10,298,780	5,895
Averages ...	...	..	0·931	...	1,965

APPENDIX X—*concluded.*

Town.	Population.	Number of consumers.	Percentage of consumers to total population.	Units generated per annum.	Average number of units per consumer per annum.
TOWNS IN NATIVE STATES.					
1 Baroda ...	99,345	346	0·348	380,000	1,098
2 Bikaneer ...	58,000	421	0·726	848,600	2,015
3 Gwalior ...	105,000	450	0·429	750,000	1,667
4 Hyderabad (Deccan)	446,500	1,072	0·240	2,405,500	2,245
Total ...	708,845	2,289	1·743	2,384,100	7,025
Averages ...	...	...	0·436	...	1,756
OTHER TYPICAL TOWNS.					
1 Ahmedabad ...	150,000	579	0·386	500,000	863
2 Dacca ...	91,000	450	0·494	432,790	961
3 Cawnpore ...	200,000	2,083	1·402	4,330,800	2,065
4 Karachi ...	614,000	765	0·125	661,300	865
5 Barrakpore ...	21,000	117	0·557	95,200	814
6 Nagpur (C. P.) ...	130,000	174	0·134	209,390	1,200
Total ..	1,306,000	4,168	3·098	6,229,480	6,768
Averages ..	...	...	0·516	..	1,128

OVERALL AVERAGES.

	Per cent.
Percentage of consumers to total population ...	1·24
Units per annum per consumer	2,490
Units per annum per consumer after eliminating the Presidency towns	1,839

An estimate of the probable consumption of electric power in the Punjab and Delhi.

Town.	Population.	Probable maximum demand in kilowatts.	Percentage of consumers to population	Estimated number of consumers.	Units per annum per consumer.	Total units per annum for each town.	Units now generated in each town (*i.e.* during 1916-17.)
Lahore	228,687	1,750	1·5	3,420	2,000	6,840,000	5,409,500
Delhi	232,837	1,750	1·5	3,489	2,000	6,960,000	3,891,780
Amritsar	152,756	900	1·25	1,900	1,750	3,320,000	997,500
Ferozepur	50,836	350	1·5	763	1,500	1,145,000	250,000
Patiala	46,974	250	1·0	469	1,750	822,000	300,000
Nabha	13,620	100	1·0	136	1,500	204,000	115,000
Meerut	119,140	700	1·25	1,490	1,750	2,605,000	403,000
Ambala	80,131	550	1·5	1,200	1,500	1,800,000	...
Jullundur	69,318	400	1·25	866	1,500	1,300,000	...
Ludhiana	44,870	250	1·25	550	1,250	688,000	...
Karnal	21,961	70	1·00	219	1,000	219,000	...
Kapurthala	16,367	100	1·00	163	1,500	244,000	...
Malerkotla	23,880	130	1·00	239	1,500	358,000	...
Ghaziabad	11,275	50	1·00	113	1,000	113,000	...
Total ...	...	7,350	...	...	...	26,618,000	11,366,780

Other probable markets that should be obtained at the start.

Other towns *en route*	3,000,000
Kalka-Simla Railway and towns *en route*	3,000,000
Cotton ginning, etc.	3,000,000
Irrigation Department	12,000,000
Total of what might reasonably be expected during the very early stages of the development	47,618,000

APPENDIX XII.

Average price obtained in annas per unit during 1916-17.

HYDRO-ELECTRIC INSTALLATIONS.

	Towns.	Price in annas per unit.
1	Tata Bombay	0·539
2	Darjeeling	2·340
3	Mussoorie	2·500
4	Simla	1·167
	Average ...	1·637

FUEL DRIVEN INSTALLATIONS.

1	Karachi	4·70
2	Dacca	4·84
3	Lahore	4·45
4	Delhi	2·86
5	Ahmedabad	4·32
6	Nagpur	5·40
7	Bombay	2·79
8	Calcutta	2·304
9	Madras	2·207
10	Rangoon	2·79
	Average ...	3·666

Overall average ... 3·086

Average of two averages ... 2·6515

APPENDIX XIII.

Details of the cost per unit (excluding capital charges) of the Delhi and Lahore Electric Supply Companies under existing (1916-17) and future conditions.

		Total units generated.	Maximum load in kilowatts.	GENERATING COSTS PER UNIT IN ANNAS.								
				Coal and other fuel.	Oil, waste, water and engine room stores.	Wages and salaries excluding management.	Repairs and maintenance.	Rents, rates and taxes.	Management, Directors' fees, salaries, office and legal expenses.	Fixed charge.	Purchase of current.	Total works costs.
	Present.	1,993,580	668	0·634	0·089	0·184	0·223	0·061	0·362	*nil*	*nil*	1·553
DELHI.	Present conditions of distribution with power purchased in bulk.	1,993,580	668	*nil*	0·010	0·150	0·160	0·061	0·362	0·402	0·100	1·245
	Future conditions	4,000,000	1,150	*nil*	0·005	0·100	0·100	0·040	0·181	0·345	0·100	0·871
	Present	1,337,500	380	0·758	0·061	0·228	0·191	0·005	0·774	*nil*	*nil*	2·017
LAHORE.	Present conditions of distribution with power purchased in bulk.	1,337,500	380	*nil*	0·010	0·190	0·140	0·005	0·774	0·342	0·100	1·560
	Future conditions	4,000,000	1,150	*nil*	0·005	0·150	0·009	0·004	0·387	0·345	0·100	1·000

DISCUSSION.

MR. MILNE, as an introduction to his paper, wrote that he wished to mention that it was drawn up last summer, before Messrs. Barlow and Meares had been deputed to investigate the hydro-electric possibilities of the country, and as it was written at a time when there was no idea of the war coming to an end, the rates quoted might be considered as representing approximately war rates. The cost of the steel pipes had been arrived at from the price paid for a welded steel pipe line erected on the Simla extension early in 1916. This actually worked out to a little less than Rs. 450 per ton, and included erection at site by an imported engineer, but did not include carriage from f.o.r. Calcutta to site. As the pipes proposed in the paper would be riveted steel pipes, made at site, the cost should not be any more, as steamer freight was naturally very high for such bulky things as pipes. In connection with the pipe line it might be mentioned that there appeared to be enormous possibilities for the utilization of reinforced concrete pipes manufactured on the "Hume" process, particularly for low and medium head hydro-electric plants. The first cost should be considerably less than steel, and depreciation a practicably negligible factor, and if they were all that was claimed for them, they would revolutionize hydro-electric work in cases where the pipe line formed an important item in the capital cost of the scheme, as was the case in the particular project advocated in his paper.

In the estimates of the transmission lines, the price of copper was taken as Rs. 2,500 per ton, whereas at the present time it was nearer Rs. 1,750 per ton delivered in large quantities in India, and there appeared to be a steady downward tendency.

A careful examination of the site proposed for development would possibly and very probably reveal a better lay out of the scheme than that suggested, and should the compilation of this paper in any way assist towards such an investigation being carried out, the author would feel that his efforts had not been entirely wasted.

MR. MEARES congratulated Mr. Milne on writing a very interesting paper at a time when hydro-electric power was much to the fore all the world over. The possible amount and location of water power was at present being investigated over the whole Empire, including India, and if anything was to be done, beyond the barren collection of statistics, some optimists would be wanted. The originator of the Tata scheme, Mr. Gostling, was a confirmed optimist, and in the end saw his

visions translated into a profitable business enterprise. There were some other optimists in India, and people were apt to smile at their visions, but he laughed best who laughed longest.

That there were great possibilities for the utilization of cheap power in the Punjab was undeniable. Mr. Milne's paper did not show the location of the Ravi project, but the estimated cost of this was so much greater than the Sutlej scheme that he was right to concentrate on the latter. He had examined the rough figures of cost and considered that they were not unreasonable. Unquestionably, if the project matured, it should be so laid out in the first instance that the full subsequent development was possible, *i. e.*, the whole 330 feet head should be utilized, and the full sized tunnel built. Plant and transmission lines could be added as required, and the start could be on a modest scale. Engineers were so used to visiting towns in India, with plant units of 100 H. P. or thereabouts, that they might possibly be surprised to hear Mr. Milne suggesting beginning on a small scale with four sets of 2,500 kilowatts ; but both steam and water turbines and generators of 25,000, and even 50,000, kilowatts were becoming the practice now. He would like to see comparative estimates of a corresponding power station at the centre of gravity of demand, supplied with steam turbines and oil fired boilers, as they would have to reckon with the Punjab oil fields as a possible competitor to water power. To look at the question from a somewhat unusual, but very instructive, point of view, and without pretending to any exactness, the cost of the hydraulic works for 60,000 kilowatts (Appendix 4), was 124 lakhs, on which the author's standing charges for interest, depreciation, and sinking fund, might be taken as about 10 lakhs. With a steam plant, in the middle of the area instead of at the edge, the remaining costs would not differ greatly. Now a 60,000 k. w. plant, on a 33% load factor, would generate some 165 million units per annum, so the above 10 lakhs represented one-tenth of an anna per unit for fuel. It was a fairly generous figure, and showed the matter to be worth careful computation. The chief unknown was the future price of oil.

He wished to dissociate himself entirely from the view* that sinking fund and depreciation should both be charged, although as a member of the Simla Waterworks Committee he had put his signature to the report in question. He had always held that, after the actual sinking fund payments had been calculated, any excess of the properly estimated depreciation charges over those repayments should also be taken into

* See page 81.

account. Government as a rule took no account of depreciation, with the consequence that a plant purchased outright (not on a loan) often continued to stand at its original book value, when it would have been written off entirely in a commercial undertaking.

The crux of a scheme of this sort was the market for power, and Mr. Milne had discussed this very thoroughly. He had been too modest to say so, but he had created his own market in Simla by his own patent designs of heaters, which had brought in a large revenue, both from their hire, and from the million of units used in them. Hitherto other hill stations appeared to have done but little in this line, with the result that they lagged behind, as shown in the appendices. It might be true that in Canada water power had in every case brought industries, but he was not sure that it was not rather that the projectors of industries had caused the water power to be developed. In any case Canada was more alive to industrial development than India, and did not require so much prodding. Nevertheless the possibilities were immense, and if neither Indian nor British capital came forward, it was certain that in the end their American friends would do so. The estimated number of units which could be sold in the very early stages of the scheme were enumerated in Appendix XI, and he did not think they were unreasonable as far as the main table went. The addenda were more problematical, especially the twelve million units to be taken by the Irrigation Department for lift irrigation to uncommanded areas, and for tube wells. That both these would be extensively used some day he had not the slightest doubt, but he was afraid, judging by past experience, that it would be a great many years hence. Nevertheless Mr. Milne based his estimated consumption largely on considerations of the load factor, and here he was on safe ground, for it was known what load factors were actually got in public supplies in India. The following table showed these (except Barrackpore and Ahmedabad), and it would be observed that they were almost universally high :—

	Per cent.		Per cent.
Simla	... 48	Calcutta	... 30
Madras	... 36	Cawnpore	... 30
Mussoorie	... 35	Tata H. E.	... 30
Lahore	... 35	Nagpur	... 29
Delhi	... 32	Dacca	... 26
Rangoon	... 32	Darjeeling	... 25
Bombay	... 30	Karachi	... 21

It was very hard to convince non-engineers that the ments on pages 83 and 84 were true, and that when the total costs of a hydro-electric installation might be nea anna a unit, it was possible to make a large profit off pea selling at a quarter o . The old lady who sold her below cost price and ma a fortune, because she sold so was often used as evidence of the absurdity of the cla.m, but i true for all that.

RAI BAHADUR GANGA RAM dealt with the in trial point of view, and said that the most important point the question of supply and demand of water power. question had been taken up some time ago by Sir Tho Higham, who got a concession to utilize the falls of the Upper Doab Canal. This was very carefully considered by an Engl expert from the industrial point of view, but finding no satisfac demand, the syndicate was wound up.

As canals ran with intermittent supplies, and were liable t closures, the power from canal falls was unsuitable for industri purposes, and he thought that in designing canals, regard should i future be paid to power generation, by making fewer and bigge falls than at present. There were immense possibilities of develop ment in regard to such schemes, but unless the canal department found means of giving perennial water, it would be impossible to utilize the power for industries. The only industry on which falls, with intermittent supply, could be used, was to pump up water from wells by electricity. Power from water falls should be sold at very cheap rates.

MR. W. C. CHOPRA exhibited a plan of his division, and a statement showing the power available on the falls of over three feet on the Kas r and Sobraon branches of the Upper Bari Doab Canal (according to Messrs. Meares and Barlow falls below three feet were not worth considering for power development) and showed how these falls could be utilized hydro-electrically, for pumping subsoil water in the non-irrigated part in the head reaches of the branches, as well as in Kapurthala State and in the Jullundur District, by taking short transmission lines from the Sobraon branch across the Beas river. An eminent authority had remarked that on account of the high cost of lifting water there, the Jullundur Doab was likely to become the least prosperous part of the Province, and therefore such a scheme was worth consideration.

SARDAR BAHADUR LEHNA SINGH, as a land-owner in a tract in which there was no canal irrigation, and in which

there was no likelihood of canals being built in the near future, welcomed the coming of power for irrigation by lift from wells, as it would then be possible to pump water at cheaper rates. He said that the colonies were already very extensive, and the Indus Canal would open another large area for agriculture, while the breeding of cattle was daily getting less and less. In America they used small oil engines for irrigation purposes, and some equally cheap source of power was required in the Punjab.

RAI SAHIB MAKKHAN LAL mentioned that a scheme was being investigated near Riasi on the Chenab, which carried great possibilities of a large amount of power being developed at that place. There had been practically no complaints in connection with the small hydro-electric installation at Jammu, where there was a 26 foot fall on the Ranbir Canal, though the canal had to pass, in its head reach, through heavy cutting, where it was sometimes blocked.

MR. F. H BURKITT asked for figures of the efficiency of hydro-electric machinery for the guidance of irrigation engineers in framing schemes.

MR. A. I. SLEIGH wished to particularly draw the attention of the Congress to a very useful and practical suggestion which the Hon'ble Mr. H. J. Maynard had made when Mr. Dorman's paper on " Highways in the Punjab " was being discussed ; the suggestion being that the Director of Industries should sit on the Road Board. He considered that the development of industries and of communications were very closely dependent on each other, and the development of industries entirely depended on the supply of power, and one practical source of cheap power was now brought to the notice of the Congress by Mr. Milne.

Another point, which Mr. Maynard commented on in Mr. Dorman's paper, was the question of railways reducing the rate of carriage of road metal, even to a rate below the total cost of carrying the ballast, as the railway might, in the end, benefit by the improvement of the roads. Mr. Sleigh, in mentioning this criticism, considered that if the Irrigation Department of the Punjab used the various falls at their disposal for generating electric energy, and supplied this energy to the railway at a rate less than it took to produce the energy, the railway would find no difficulty in falling in with the Hon'ble Mr. Maynard's suggestion.

He agreed with Rai Bahadur Ganga Ram's remarks regarding the enormous scope which lay before the Irrigation

Department in generating electric energy, and regretted the apathy shown by that department in the matter. In this connection he had asked the Irrigation Department if they could so arrange details in the design of the dam, which they were proposing to construct across the Sutlej, near Bhakra, so that the necessary electrical power could be generated to work the Kalka-Simla Railway. The reply received was that the Irrigation Department regretted that it would not be practicable to provide the power required for electrifying the Kalka-Simla Railway without sacrificing the efficiency of the Bhakra Dam from an irrigation point of view.

Mr. Milne's proposal short circuited this objection, and he looked upon Mr. Milne's scheme as one of the most practical sources for obtaining electrical power for the Kalka-Simla Railway. The question of the electrification of this railway had now reached the phase of practical politics, and it was necessary that communication between the Summer Capital and the rest of India should be rendered as up to date and efficient as circumstances would permit.

MR. T. MILLER-BROWNLIE asked the Irrigation Department particularly to notice the rates given in Mr. Milne's paper. Eight or nine years ago, when he was preparing an electric scheme for the Amritsar municipal area, he asked that department for power from the canal. A rate of one anna six pies per unit, was quoted and refused, because he thought that he could generate at a lower rate. The Irrigation Department ther offered to supply at one anna three pies per unit, but this he also refused, because he considered it too high, and the members of the Municipal Committee were ultimately convinced that the could do better, by leaving the Irrigation Department alone, and the scheme, put through in 1916, now generated its power for just under an anna a unit total running costs. The Irrigation Department should therefore consider the matter with reference to installing further schemes for pumping water from the sub-soil, so that water power should be given for not more than a tenth of an anna per unit. The cost of the installation to be paid by applicant. If the Irrigation Department would give power at that rate it would benefit the public at large and derive some profit for itself.

MR. F. W. WOODS began by remarking that he was not an electrical engineer and did not propose to discuss electrical technicalities. He happened, however, to have prepared the first hydro-electric project at Amritsar, and although that was

a simple scheme, with a canal fall within a couple of miles of the place of utilization as the source of power, he found that for irrigation the scheme would not pay at all. The Irrigation Department sold their water so cheaply that it made it impossible for them to pay more than nine pies per unit for their power to render water available for irrigation by pumping; and he found that he could only make the scheme remunerative by charging the municipality and the canal workshops two annas a unit. He questioned Mr. Brownlie's figures of the cost of the municipal scheme. He agreed with Rai Bahadur Ganga Ram regarding the location of canal falls. In the past, falls had often been faultily located for the sake of the slight economy that accrued from combining them with road bridges. He thought Mr. Milne had under-estimated the cost of transmission lines. At any rate he had been informed by another electrical expert, that, in the case of long transmission lines, it was necessary to have observation posts established at twenty mile intervals along them, with a responsible officer in charge at each post, in order to prevent people from damaging them.

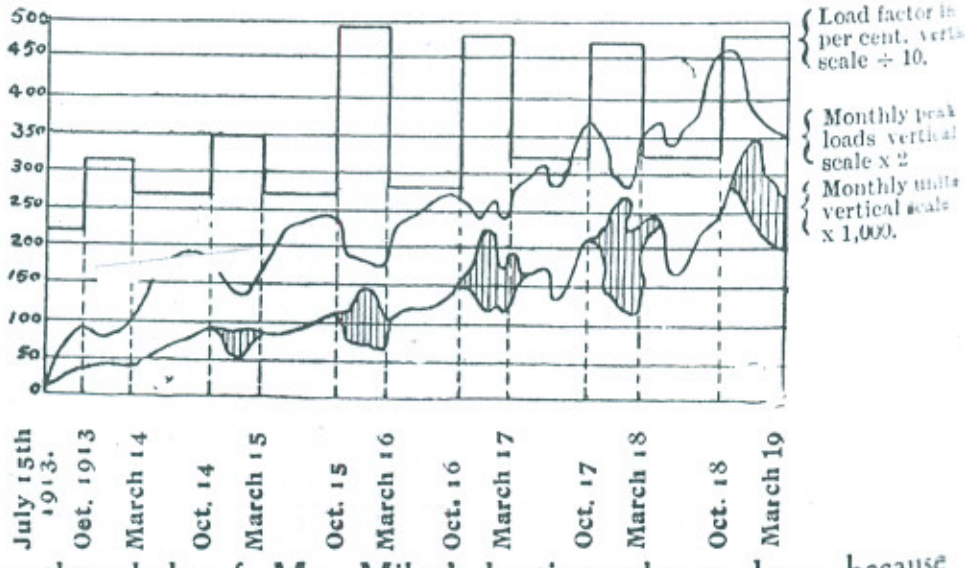
MR. M. S. DHODY noted that canal power could only be intermittent, but it could be easily arranged so that, by creating available power at all suitable stations, when one canal was closed the current could be switched on from another canal which had begun to flow. The total power thus available would be limited by the minimum supply in the rabi season, but that need not be allowed to go to waste.

MR. MEARES stated that Mr. Milne would reply fully in the proceedings, but he would answer a few points. Oil fuel could not compete with water power on the spot unless it could be sold for about Rs 17 a ton. Rai Bahadur Ganga Ram pointed out the advantages of electrical pumping for irrigation, but it was necessary to have a reserve plant of some sort, if intermittent canal power was to be used for other purposes than pumping. He wished to remove the impression that it was impossible to develop power with a head of less than three feet, as suggested by Mr. Chopra, though that was roughly the economic limit below which it would seldom pay. As to Sirdar Bahadur Lehna Singh's question regarding supply and demand and a low selling cost, he agreed with him, but nevertheless people were very glad to pay five or six annas a unit for lighting purposes rather than go without a supply. The man in the street thought that electric supply companies charged too much, but many did not realize the influence of the load factor in determining the rates which

had to be charged for power to consumers who took their power at the time of peak loads, because, in lighting schemes, peak loads were demanded for so short a part of the twenty-four hours. Industrial power could naturally be sold far cheaper.

In the case of the Jammu problem there appeared to be nothing for it but to put up a reserve plant. A good deal had been said about the value of combined water and steam plants in America. It did not necessarily pay to develop water power to the utmost limit of demand, unless it was required for continuous power. In water turbines one could get an efficiency of 86 per cent. or more on the full load. A power station must be prepared to supply the maximum peak load, and engines had to be kept running the whole time ; with water power it cost no more to generate current than to run the turbines idle, therefore power could be sold at non-peak times for any rate that would find a market.

Mr. Sleigh had talked about the supply of power from the Bhakra dam and a good many gentlemen smiled, but Mr. Milne had prepared a diagram for the meeting which showed the reason why current derived from water power could be sold actually below cost price. In Simla, the Municipal Committee tried to



turn the whole of Mr. Milne's heating scheme down, because they thought that it was a ludicrous problem, whereas it had turned out a gold mine. Mr. Brownlie mentioned one-tenth of an anna a unit as a practicable price for hydro-electric power from a scheme of some 3,000 or 4,000 horse-power, where the water happened to be otherwise unutilized, and though it was possible that the cost might sometimes come down to this figure it was only on a larger scale than that mentioned that one could

get such a low cost, and then only for continuous industrial power with a load factor of 90 per cent. or so.

Mr. Woods spoke about cheap rates of supply, and also about canal falls rendered useless for development of power. He entirely agreed with him in saying that one thing which had been very much overlooked in the past by the Irrigation Department, and in fact by most people in this country, was that when a question came up for using water power, whether from a canal or a river, they proceeded to bargain on the basis of the price of either horse power or cubic feet of water per second; it was a question of selling gravity not water, and the rate should be absolutely nominal. Regarding the cost of transmission lines, he considered Mr. Milne's estimate fairly reasonable. There must be some arrangement for patrolling the lines, since, when the insulators were broken or the wires cut down, the power was cut off, hence it was necessary to have constant supervision.

MR. A. S. MONTGOMERY, in closing the discussion, remarked that he thought there was a great advantage in having such a paper for discussion. It came to him as a welcome relief from the many problems which the irrigation engineers put up, as the paper raised a discussion on more general lines, and industrialists and private people were able to criticize from the public point of view. He only regretted that Mr. Milne was not present to reply to the criticisms which had been made on his paper. He was also sorry that their Electrical Engineer, Mr. Eastgate, had not been able to attend, but he might just mention for the information of members that Mr. Eastgate was now himself investigating electrical schemes for the larger towns in the Punjab, and would shortly put them before Mr. Meares. These included the combination of electric supplies for cantonments, civil stations, and cities. For instance, in the case of Multan and Ferozepur, the military authorities had put up electrical installations, while the cities and civil stations had done nothing, though there was no reason why the two should not combine as a paying concern

They all regretted the absence of Colonel Battye, who was the pioneer of the Simla hydro-electric scheme, when Mr. Milne had been one of his right hand men. If he had been present, it would have given him great pleasure to congratulate him on the way the scheme had run since the commencement. This scheme had been a great success, and everything Colonel Battye said about reducing the sale cost of current had been borne out,

He was sure the Congress had learned with deep sorrow of the sudden death of Mr. G.T. Barlow, C.I.E., Chief Engineer for Irrigation in the United Provinces, who had been specially deputed by the Government of India to make a preliminary reconnaissance of the water power potentialities of India. His loss would be very keenly felt by Government and the people alike, at a time when he was engaged on a most important problem for the benefit of the country as a whole.

MR. MILNE, while agreeing generally with Mr. Meares's replies to the questions raised, wished to enlarge on one or two points brought forward. With regard to Mr. Meares's non-committal opening remarks regarding optimism, he wished to add that optimism, when combined with true enterprise, and given a fairly free hand, and not burdened by "red tape," invariably spelled "success."

The head works of the alternative project on the Ravi river, mentioned in the paper, would be located near Madhopur, which was shown on his map, and he thought there was no doubt that any additional generating sets installed would be of considerably greater individual capacity than those suggested, as a beginning, in the paper. Mr. Meares had raised an interesting point by mentioning the oil fields of the Punjab, but there was no fear of these as an immediate competitor of hydro-electric power, within the province itself, for the following reasons,

(1) The working costs would not be less. Assuming that the very best steam turbines required 10,900 B.T. U. per B. H. P. hour, and taking the efficiency of the alternator at 95 per cent. :—15,350 B. T. U. per kilowatt hour* would be required to be utilized in the boilers.

Good liquid fuel had a calorific value of about 19,000 B.T.U. per lb., therefore, to replace the coal, $\frac{15,350}{19,000} = 0{\cdot}807$ lb. of oil per kilowatt hour would be required, and if the cost of this was not to exceed one-tenth of an anna, the cost of the oil should not exceed $\frac{0{\cdot}1 \times 2,240}{0{\cdot}807 \times 16} =$ Rs. 17·35 per ton, a figure not at all likely to be reached in the near future, if ever.

A large Diesel plant (which however would not be suitable for a scheme of this magnitude, owing to the comparatively small units available) would require an average of 0·7 lb. of fuel per kilowatt hour, and if this was to cost one-tenth of an anna, then the cost of the oil should not exceed Rs. 20 per ton, which was also a very unlikely figure.

* $\frac{10,900 \times 100 \times 1000}{95 \times 746} = 15,350.$

(2) The maintenance, and particularly the depreciation, of oil fired boilers and steam turbines or engines, would be considerably higher than that of water turbines with their necessary pipes and civil engineering works, and the capital cost of the boilers and steam plant would be higher than that of the water turbines.

(3) Fuel oil, obtained from the Punjab, would be required to meet the needs of other provinces, where water power was not available and the cost of coal was high.

(4) In India the utility and manifold advantages of electricity required advertising on a *practical* scale, and, with hydro-electric power, current for this purpose could be supplied which cost practically nothing, whereas, with any kind of fuel, every unit generated cost a definite amount for fuel. When electricity had been proved to be a necessity and not a luxury, then, and only then, would advertising become unnecessary, and oil be in a better position to compete with water power.

He was interested to hear Mr. Meares's views as regards a sinking fund and depreciation. An equitable compromise between the two, provided depreciation was properly estimated and allowed for, was the correct solution of the question. Without pretending to an expert knowledge in finance, he based his conclusions on the common-sense remarks made by Abraham Lincoln when he said " Posterity has done nothing for us, and, theorise on it as we may, practically we shall do very little for it, unless we are made to think we are at the same time doing something for ourselves." If both a sinking fund and depreciation were provided for in full, it would be the future generation that would benefit, at the expense of the present generation.

Mr. Meares had alluded in very kindly terms to the electric-heating campaign in Simla, and, as the results obtained proved conclusively the truth of the statements on pages 83 and 84, he had drawn up a curve* which spoke for itself. Although electric-heating was only dabbled in during the winter of 1915-16, yet, as the curve showed, the results obtained were exceedingly satisfactory. For the next two winters the curve gave an idea of the advantages to be obtained by pushing the enterprise.

With reference to Rai Sahib Makkhan Lall's remarks in connection with the blocking of the Jammu canal he would like to know whether covering it, in the bad places, had been considered ?

* See page 102*h*.

Mr. Burkitt's request regarding the efficiency of hydro-electric plant might be answered by saying that turbines were now manufactured with an efficiency, on test, as high as 90 per cent. and most makers would guarantee 86 per cent. on the full load. The overall efficiency of a turbine and generator varied according to the size of the units adopted. If an overall efficiency of 80 per cent. was assumed, it would be well on the safe side, except probably for very low heads and small generating sets, in which latter case it would probably be advisable to adopt the figure of 75 per cent. Referring to Mr. Miller Brownlie's remarks about the cost of water power, this was mainly a question of policy, the decision of which would depend upon the extent to which Government decided to encourage the generation and use of hydro-electric power. The figure of one-tenth anna per unit appeared high for the use of the water power for a public utility concern, *e. g.*, a plant of 3,000 kilowatt so, with a load factor of 50 per cent, generating some 1,000,000 units per annum, would have to pay no less than Rs. 8,000 a year for the use of the water power, and this sum capitalized at five per cent, represented nearly $1\frac{3}{4}$ lakhs. A 3,000 kilowatt plant, installed on a canal fall, should not cost more than about 8 lakhs, so that the capitalized value of the water charges was a very large percentage of the capital cost of the installation.

Mr. Woods's remarks in connection with transmission line were not quite clear. He mentioned observation posts at intervals, with a responsible officer in charge, as being necessary for the satisfactory operation of the system, and considered that the figures given in the paper were therefore underestimated. His estimate, however, was one of capital cost, whereas Mr. Woods's remarks applied to maintenance costs. He did not consider that it was at all necessary for a responsible officer to be located at the intervals mentioned by Mr. Woods. This might have been deemed advisable in the early days of electric transmission, but not at the present time, particularly with a duplicate system of transmission to each supply area. Faults on transmission lines could easily be located from one end, and a repair gang could be sent to the spot in a comparatively short time, if means of communication existed, as was the case in this instance. Responsible officers would of course be necessary at all the receiving stations, but probably only a few patrol posts would be required, where there were very long stretches of line, for the purpose of housing break-down gangs for a ight, and keeping a small stock of repair material.

The shaded portions in the diagram, (page 102*h*) referred to by Mr. Meares in his reply, gave some idea of the number of units sold during the winter in Simla, which cost the Municipality absolutely nothing extra to produce,