

Central Board of Irrigation

Hydro-electric development  
in India

# ***Hydro-Electric Development in India***



**CENTRAL BOARD OF IRRIGATION**

**POPULAR SERIES**

**SECOND EDITION**

**LEAFLET NO. 5**

## FOREWORD OF THE SECOND EDITION.

The first edition of this leaflet was issued in 1948 and was based on the information available in the office of the Central Board of Irrigation at that time. Since then, many more projects have been envisaged and the information has also been brought up to date. The latest statistics from other countries have also been obtained and the leaflet has been rewritten so as to contain the up to date information.

The importance of developing hydro-electric power is well known and every layman even knows that the advancement of a country depends upon it. The main object of writing this leaflet is to bring to the notice of the public, the vast potential resources of water-power existing in our country, the most meagre use of these so far made and the genuine and natural anxiety of the Government of India and the State Governments to develop these resources, though the progress has to be determined by the finances at our disposal. The comparative backwardness of our country in the generation of the hydro-electric power has also been brought by giving the figures of power plants installed in other countries. Lastly a description of the important projects in hand or under contemplation has been given. It is hoped this edition will be received equally well by the public and will impress upon the mind of the reader the importance of giving first priority to power projects to push up which effectively, the Government of India is using all its resources in money, technical and administration personnel.

S. L. MALHOTRA

*Secretary*

KENNEDY HOUSE,  
SIMLA-4,  
*September 30, 1950.*

## FOREWORD TO THE FIRST EDITION

This is the fifth of a series of leaflets of general interest issued from time to time by the Central Board of Irrigation. A description is given

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herein of sources that constitute electric power and what has been done in our country, in the past, to develop such sources. India is fortunate in her vast resources of large rivers and high mountains and has a large hydro-electric power potential. The slow growth of hydro-electric power undertakings in India is compared with the rapid strides made by other countries of the world and a short account of the projects now under construction or investigation for the production of hydro-electric energy in India has been added.

**N. D. GULHATI**  
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**August 31, 1948.**

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# HYDRO-ELECTRIC DEVELOPMENT IN INDIA

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## ELECTRICITY—A MODERN NECESSITY

Electricity has a remarkable diversity of application. In the home, electric lights, fans, irons, vacuum cleaners, refrigerators, cold storage lockers, water pumps, stoves and kettles lead to comfort and cleanliness and lend charm to life. In the farm, electricity can be used in a number of ways—for grain grinders, feed mixers, cream separators, milk sterilizing equipment, incubators, rice hulling, milling flour, decortivating nuts, pressing oil, sugarcane crushing, cotton ginning, *etc.* Portable utility sets can be used for wood cutting, elevating grains and cleaning seeds. Electricity can provide cheap power for pumping water for irrigation and other agricultural operations. By these and many other labour-saving devices, too numerous to mention, electricity can eliminate the drudgery of the rural population and make their life rich and pleasant. Through the radio, electricity assists in providing both entertainment and education. The extensive use of electricity can thus bring about a radical and much needed change in rural life and surroundings and can thus assist considerably in reducing the influx of rural population into cities—a feature worthy of serious consideration at the present time when housing is a big problem in all cities in India.

Cheap electric power is regarded as a fundamental requirement for the industrial development of a country. In fact, modern life and industrial development depend so largely on the use of electricity that the quantity of electricity used *per capita* in any country is an index of the material and industrial development of that country and of the standard of modern civilization that has been attained in it. The present age has aptly been termed. "*The Age of Electricity*".



*Mahatma Gandhi Hydro-electric works—Pipe line middle section.*

## SOURCES OF POWER

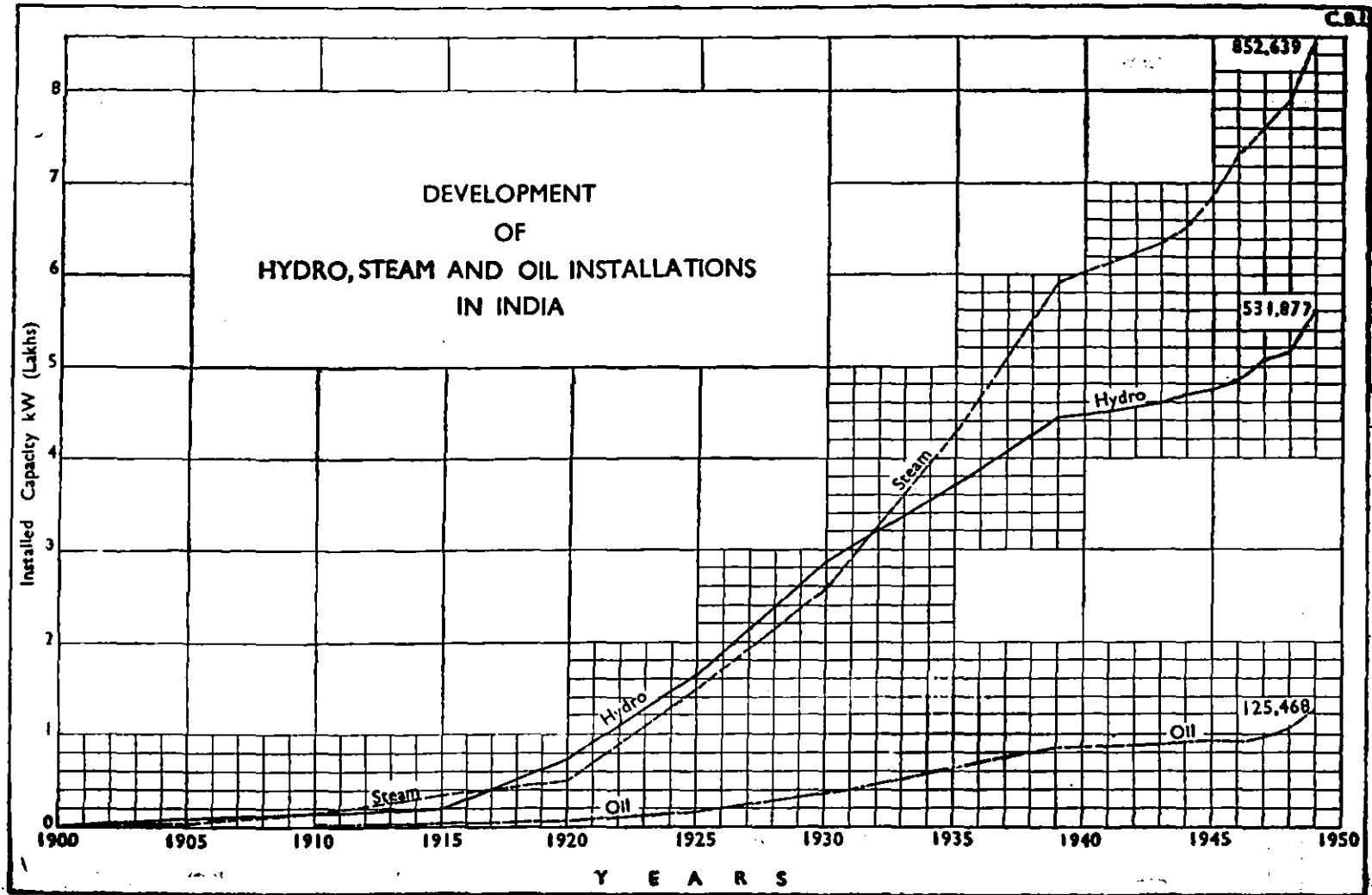
A student of Economics regards material and labour as the two fundamentals of production. In the olden days labour was synonymous with man-power. With the development of Science, however, power from winds, from flowing streams of water, from steam, from oils, from electricity has been progressively brought to the aid of man. All these sources of power can be divided broadly into two classes :—

- (1) Exhaustible, or those which represent accumulation of energy gradually formed under the action of the Sun's light and heat, e.g., coal, mineral oil, peat and natural gases; and
- (2) Inexhaustible, or those which are replenished by Nature as fast as they are utilised, e.g., water tides, winds and also forests.

The production of power from sources like tides and winds can by their very nature be limited. Among the fuels derived from growing vegetables, alcohol, which can be manufactured cheaply from potatoes, molasses and mahua flowers alone seems to hold out any promise. It has been used for some years in Mysore, but the output is negligible. The forests in India are hardly enough to meet other needs and the country can ill afford to use them as fuel on a large scale. Until atomic power comes into the field, the development of the power resources in India can thus only be from oil, coal and hydro-electric generation.

India's resources in mineral oil, so far as is known, are poor. She imports the major part of the oil that is now being used either directly for the production of power or indirectly after conversion into electric energy. There is thus little prospect of the country being able to develop power or industries based on her meagre resources of oil, except small power stations in areas which cannot economically be benefitted by any of the projects that are under construction or under investigation.

India's wealth of coal is confined mainly to Bihar, West Bengal and Orissa with small outliers in Assam, Madhya Pradesh and Hyderabad. The distribution is uneven and distance from the coal fields to different industrial centres in the Punjab, Bombay and the South are so great that except at or near localities where coal mines occur, power cannot be produced economically from coal. It has also been estimated that the entire quantity of coal available in India, excluding cooking coal which can be used profitably for conversion into liquid fuel, is only 700 to 750 million tons. If it is used at the present rate of consumption,



Figure



the coal resources of the country would be exhausted in the next 60 to 70 years. The Railways in India alone consume about seven million tons of coal annually—just one third of the total annual consumption in the country and it is a pity that a bulk of this high quality coal is being used to run steam locomotives.

With her large rivers and high mountains, India's resources of hydro-electric power are vast. As will be shown later, these resources have not even been surveyed so far in their entirety, while the limited resources of coal are being rapidly wasted. So far as the generation of electric energy in India is concerned, the first thermal station, Calcutta Electric Supply Corporation commenced supply in the year 1899. This was followed by Bombay Electric Supply and Tramway Co. in 1905, the Kanpur Electric Supply Corporation and the Madras Supply Corporation in 1906. Other installations followed and the following table (also see Figure 1) indicates the relative use in India, today, of different sources of power for the production of electric energy.

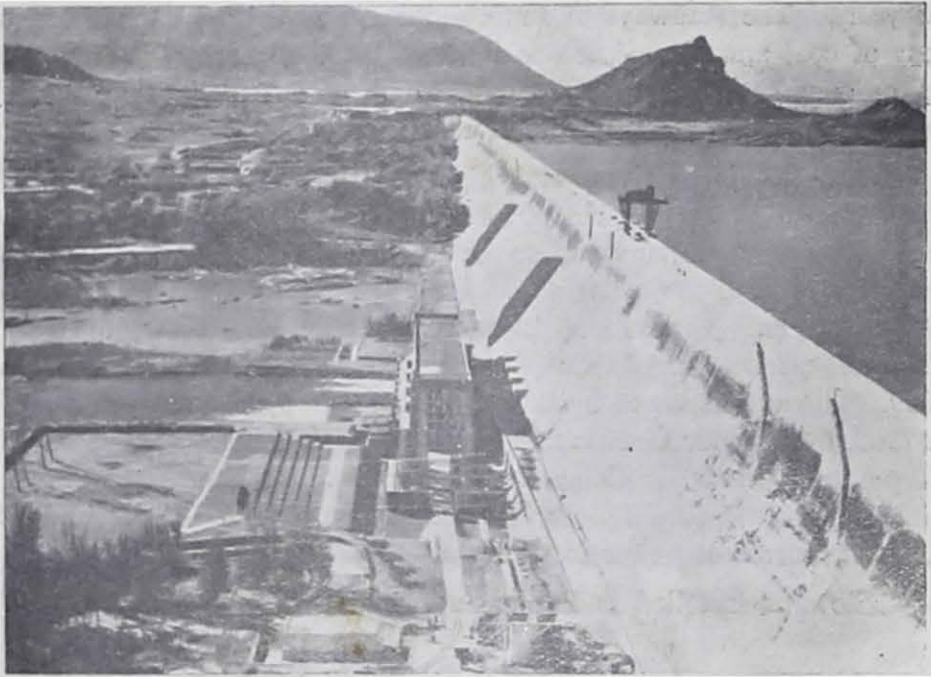
Kilowatts installed in Public Supply Undertakings :—

	1920	1949
Oil ... ..	5,847	125,468
Coal ... ..	48,495	852,639
Hydro ... ..	79,505	531,877

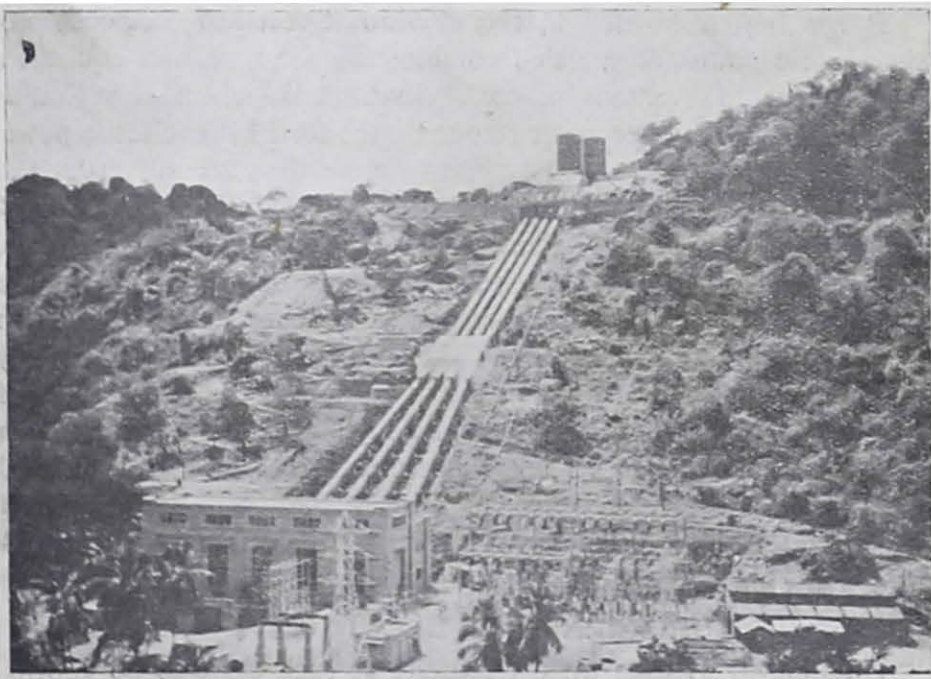
It has been estimated that one kilowatt installed capacity of hydro-electric power, if operated continuously for a year, is equivalent to about four to five tons of coal. In Canada, which is exploiting hardly 18 per cent. of her water resources, the total hydro-electric power generated during 1947 was equivalent to more than 26 million tons of coal. An idea of India's potential of hydro-electric power can be had from the fact that the equivalent of the entire power now utilised on the Railways in India can be generated from a single scheme like the Kosi Project. Coal can thus be conserved for more profitable use in metallurgical and other operations. The solution of India's poverty and material backwardness lies in the utilisation of the vast sources of energy available in her large rivers and high hills. It is proposed in this leaflet to examine in brief how these resources have been utilised so far in comparison with other countries of the world and to give a short account of the projects now under construction or under investigation for the production of hydro-electric energy in India.

### THE SCIENCE OF ELECTRICITY

It is difficult to state when electricity as such came to be known. There are references to Thales with whom the science is reported to



*Matur Dam and Power House*



*Papanasum Penstock and Power House*

have started about 600 B.C. with intermittent developments since then. One can, however, recall readily the work of Gilbert (1600), of Franklin (1750), of Winshurst and Volta (1800) and of Faraday who in 1831 made the fundamental discovery of electro-magnetic induction which is the foundation of the electric power industry.

Hydro-electric energy is of more recent origin. It is difficult to find when the first hydro-electric plant in the world was constructed. References have been traced, however, to the first hydro-electric plants having been installed in—

U.S.A.	...	...	...	in 1882
Japan	...	...	...	in 1892
Australia	...	...	...	in 1895
India	...	...	...	in 1897
Canada	...	...	...	in 1900
New Zealand	...	...	...	in 1904

Towards the close of the last century in the November, 1897 issue of the Scientific American it was recorded—

“The statistics of the present state of water power utilisation show that it is advancing with rapid strides. America leads the world with a total installation of over 70,000 h.p. Switzerland comes next with 32,000 h.p. France has 18,000 h.p. and the great power plant at Rheinfelden Germany, gives Germany the fourth place with about 17,000 h.p. Italy has nearly as much and Norway and Sweden are each credited with 15,000 h.p. In Great Britain there is a total installation of 4,000 h.p.”

Thus about the beginning of the present century the hydro-electric installations in the world had a total capacity of the order of 150,000 kW. and it was little realised that what was then regarded as rapid strides would before long become insignificant in the race for electric development.

### GROWTH OF HYDEL POWER IN INDIA

Water power has been used in India and the East for centuries past in wooden water wheels for driving corn mills; these are found in almost every valley of the Himalayas, even at the present day. Hydro-electric power development as already stated is an invention of the last quarter of the nineteenth century. The pioneer public utility hydro-electric undertaking in India is the small Municipal Town Lighting Plant at Darjeeling which was erected in 1897-98. This was followed by the hydro-electric scheme on the Cauvery river—the first of any magnitude—in Mysore in 1902. The principal object of this scheme



*Bhira Power House and Pipe Line*

was the supply of power to the mining companies on the Kolar Gold Fields about 92 miles from Sivasamudram, the site of the generating station. This initial undertaking has since grown steadily. Considerable expansion was made possible by the construction of the Krishnarajasagar dam and the plants at the Sivasamudram and Shimshapura. Generating Stations have now an installed capacity of 60,000 kW. Power was also generated in small quantities in Madras on the Kateri River in 1904 and in the high ranges in the Travancore State in 1905. Kashmir hydro-electric works were completed in 1908-1909. Small water power stations for the supply of electricity to municipal areas were constructed at Mussori in 1909 and Simla in 1911. Gokak Falls in Bombay were harnessed in 1914. No major work, however, appears to have been undertaken in the early stages.

World War I—1914-18 gave an impetus to the use of electricity all over the world. In India, the formation of the Indian Munitions Board was the first step in co-ordinating existing industries, and this was soon followed by the appointment of the Indian Industrial Commission. The Industrial Commission in its Report 1916-18 emphasized the necessity for a hydro-graphic survey of India. The Govt. of India appointed Mr. G. T. Barlow, then Chief Engineer, Irrigation Branch, United Provinces, to undertake the work in association with Mr. J. W. Meares, then Electrical Advisor to the Government of India. After the death of Mr. Barlow, Mr. Meares, issued a preliminary report in 1919 and a Triennial Report in 1921, indicating that a minimum continuous water power of nearly 3.5 million kW. with a maximum of eight million kilowatts could be developed in India.

By the time Mr. Meares Report was published, the Government of India had ceased to take direct interest in the development of Provincial Public Works and thus no serious notice appears to have been taken of the recommendations made in the Report, inadequate as these were. Meanwhile other countries went head long into the development of their hydro-electric resources and India was left far behind in the pace for electrification and consequently of industrialisation.

It is indeed a great compliment to Indian enterprise that the three biggest hydro-electric installations that exist in India today are the result of private effort sponsored by that great industrialist Sir Jamsetjee N. Tata. The first of these is owned by the Tata Hydro-electric Power Co.; and came into operation as early as 1915. This was followed by the Andhra Valley Power Supply Co. in 1922 and by the Tata Power Co. in 1927. Between these three companies the power installed amounts to 244,000 kW., almost half of the total hydro-electric installation in India today.

The major state-managed hydro-electric works completed in recent years are the Pykara Hydro-electric scheme, Madras and the Mandi Hydro-electric Scheme, Punjab (1933), the Mettur Hydro-electric

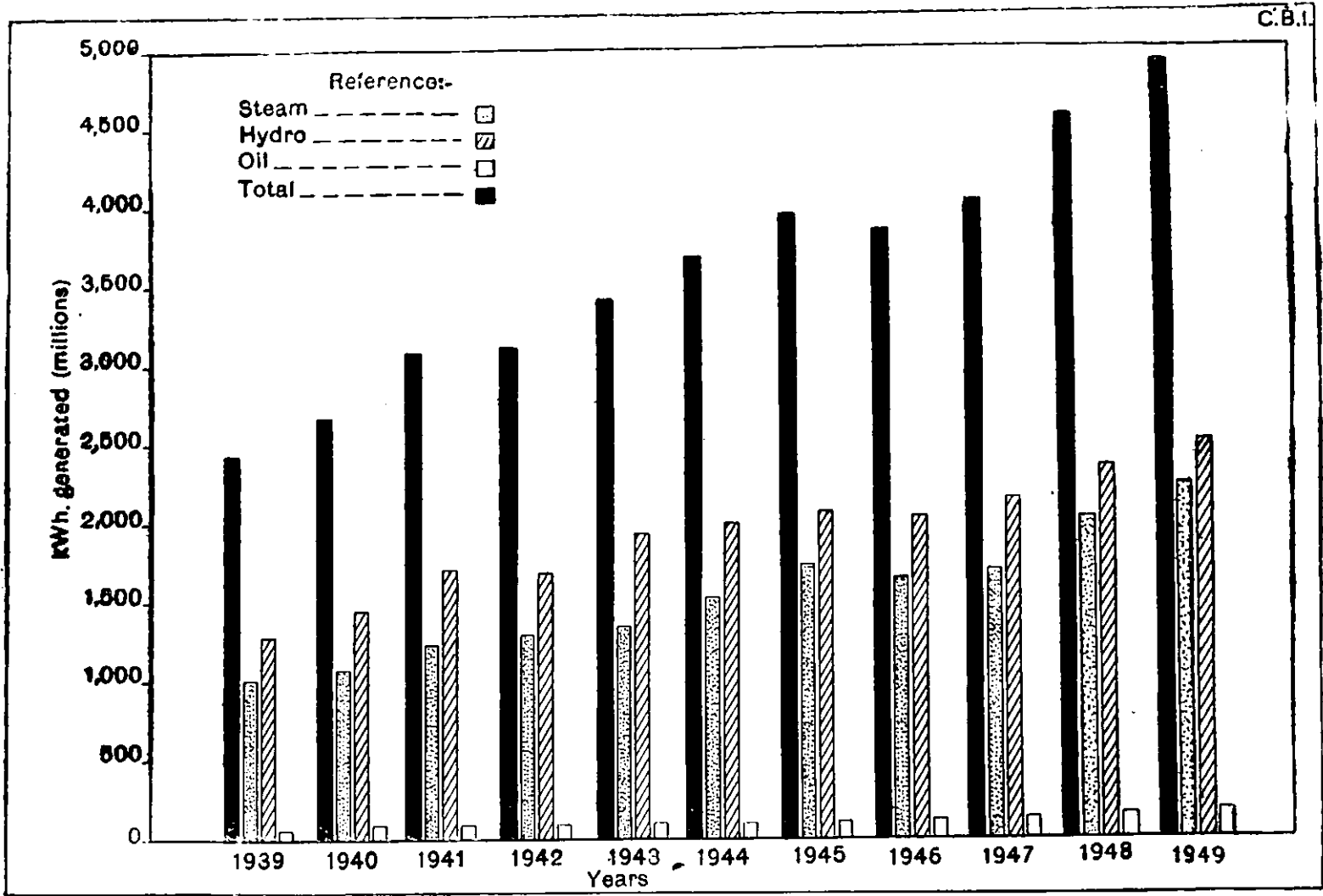


Figure 2.

Scheme Madras (1937), the Pallivasal System, Travancore (1940), Papanasam Scheme, Madras (1943), the Ganga Hydro-electric Grid, Uttar Pradesh (1930-1947) and the Mahatma Gandhi Hydro-electric Works, Mysore (1948-49). The last system is still under expansion.

A table showing year to year development of Hydro-electric installations is also given at the end.

Figure 2 shows the electric energy generated in India from 1939 to 1949 from oil, coal and water power plants. Reliable figures prior to 1939 are not available. It will be noticed by comparison with figure 1 that although the installed capacity of steam power plants is about one and a half times that of the hydro-electric plants, the energy generated annually by the latter is more than that generated by steam power plants.

As already stated, the total installed hydro-electric capacity in India is 555,877 kW. which is only about 14 per cent. of Mr. Meares' estimate of about 3.5 million kilowatts of firm potential power. Mr. Meares' estimate itself represents roughly about ten per cent. of the real water power potential of the country; or in other words the hydro power so far developed in India is only 1.5 per cent. of the country's potential.

## HYDEL POWER DEVELOPMENT IN THE WORLD

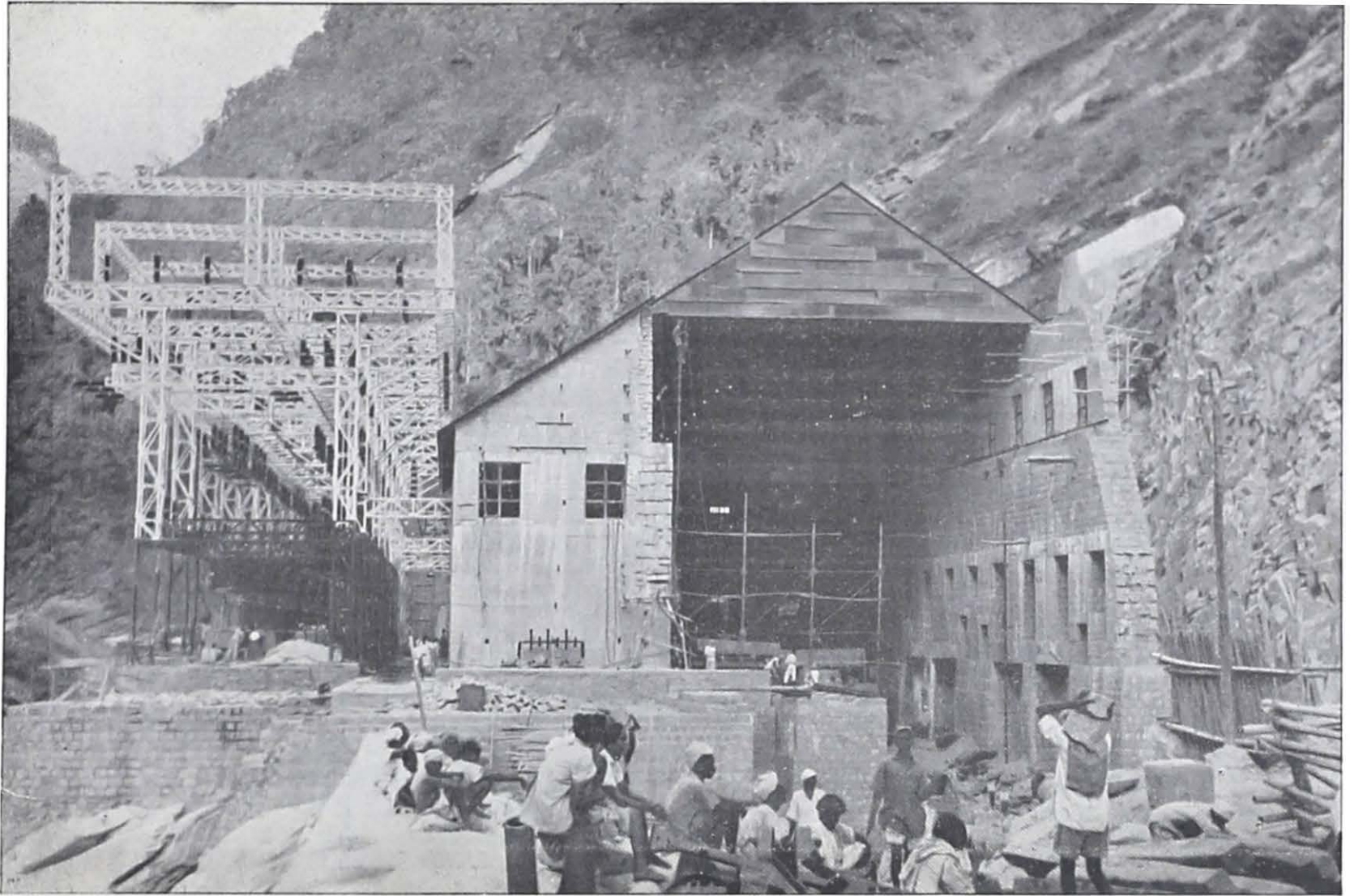
Having outlined the scanty progress made in India in the field of hydro-electric endeavour it is proposed to review briefly the long strides taken in this direction by other Nations of the world who had the shaping of their destinies in their own hands, when India was under foreign rule.

The pioneers in the field of hydro-electric development are the U.S.S.R., U.S.A., and Canada, but if the criterion be the percentage of a country's potential that has been developed, the place of honour to-day is taken by U.S.A., Austria, Ireland, Switzerland, Finland, Canada and Sweden in the order stated.

U.S.S.R. has the highest potential water power in the world. The first state-planned organisation for the development of electric power in Russia was established in 1921. From 1923 to 1935, twelve major hydro-electric plants were installed, the most important of which is Dnieprestroï Hydro-electric Station with an installed capacity of 310,000 kW. The country is now stated to have developed a considerable percentage of her potential hydro-power which is being used mainly in electro-metallurgical and electro-chemical industries and local mining.

The United States of America is one of the most advanced countries in the world in hydro-electric development. In the first twenty





*Mahatma Gandhi Hydro-electric Works—Generating Station and Outdoor Station.*



years of the present century she built up an installed capacity of about 4.0 million kilowatts ; but the biggest achievements is in the period after 1920 during which she has added as much as 13 million kilowatts to installed capacity. The total installed capacity of the Tennessee Valley Authority dams alone exceeds two million kilowatts which is about four times the total installed capacity in India. The Grand Coulee Dam and Boulder Dam, on full development, will have installed capacity of 2.0 million kW. and 1.4 million kW. respectively.

The Dominion of Canada presents the picture of a country whose economy as regards power is based on a non-wasting asset—water power. More than 98 per cent. of the electricity sold by public power stations is generated from this source. The major hydro-electric plant is the Queenston-Chippewa on the Niagra falls with an installed capacity of 417,760 kW. The total installed capacity in Canada, at the end of 1949 was 7.80 million kW., 70 per cent. of which was installed during the last 25 years. It is remarkable that Canada with about half per cent. of the world's population has attained a position of the world's third trading nation due to her industries based on electricity.

Switzerland, the playground of the world, has contributed in no small measure to the advancement of hydro-electric development. More than 50 per cent. mileage of her broad gauge railway lines are now electrified from water power. The Fully Power Station, utilises a net head of 5,410 feet, the highest so far in the world. A new enterprise is the power station, located in the Rhone Valley near Sion, equipped for 134,280 kW., and which will work under an effective head of 5,740 feet. Switzerland has an installed capacity of 2.4 million kW. and has exploited 53 per cent. of her water power potentials. About 80 per cent. of her works were constructed during the last 25 years.

No country in Europe has so many glaciers and fields of perpetual snow as Norway, and she has taken full advantage of these natural facilities for the development of waterpower, the most intensive in Europe. It is claimed that the height of the Norwegian waterfalls added together exceeds the total of all other waterfalls in the world. The total installed capacity of hydro-electric plants is 3.07 million kilowatts for a population of three millions. To attain this rate of electrification India should have an installed capacity of 340 million kilowatts.

France has an installed capacity of about 3.5 million kW. and has many interesting hydro-electric works. One of the most fascinating works is in the Pyrennes where a head of 4,620 feet is utilised by a small quantity of water collected by various devices from a number of small lakes, the average discharge for the year not exceeding 50 cusec. At this place, as also in some other countries, surplus power during periods of high supply is utilised for lifting water which is again used for hydro-electric generation during the period of low supply.

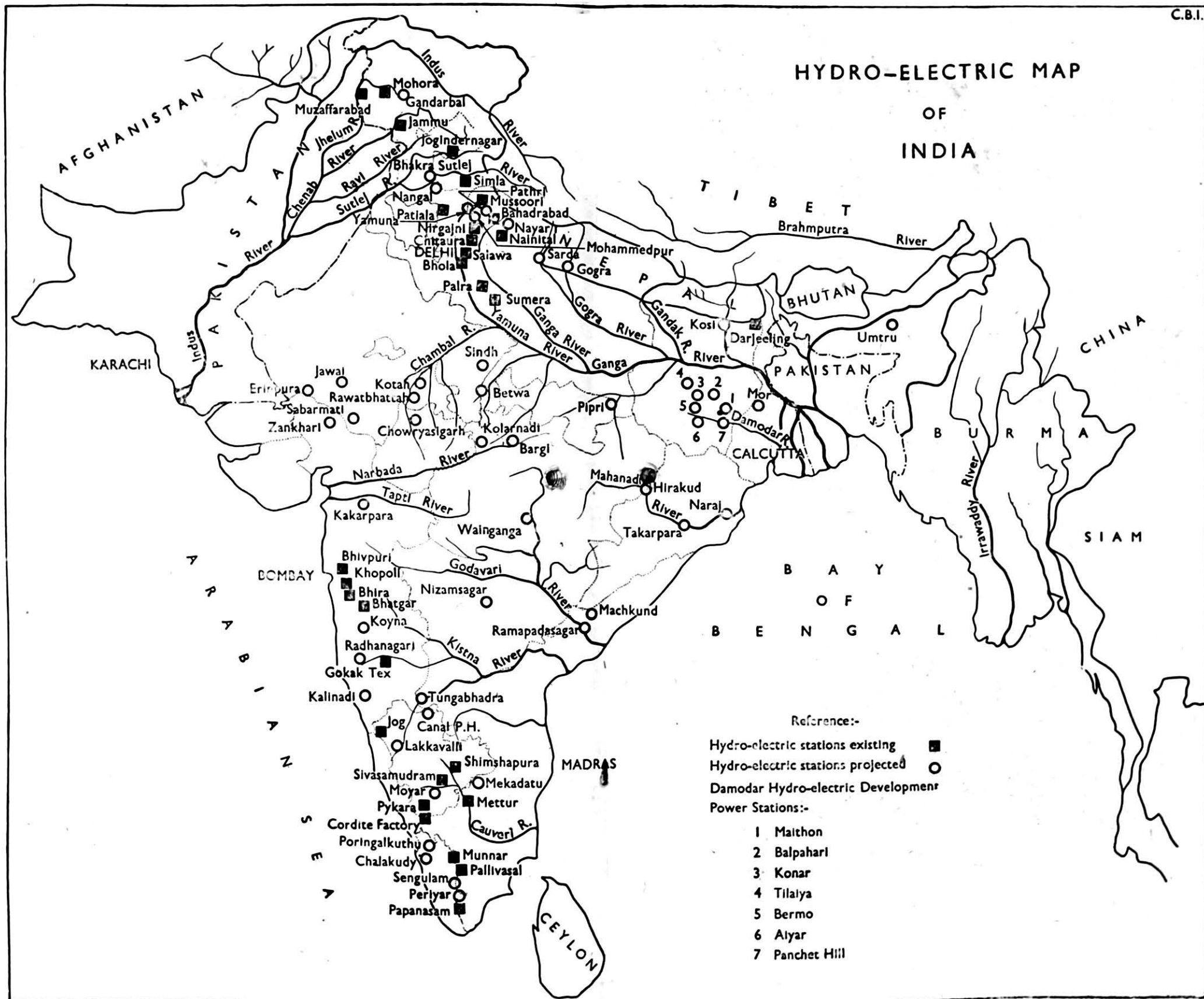
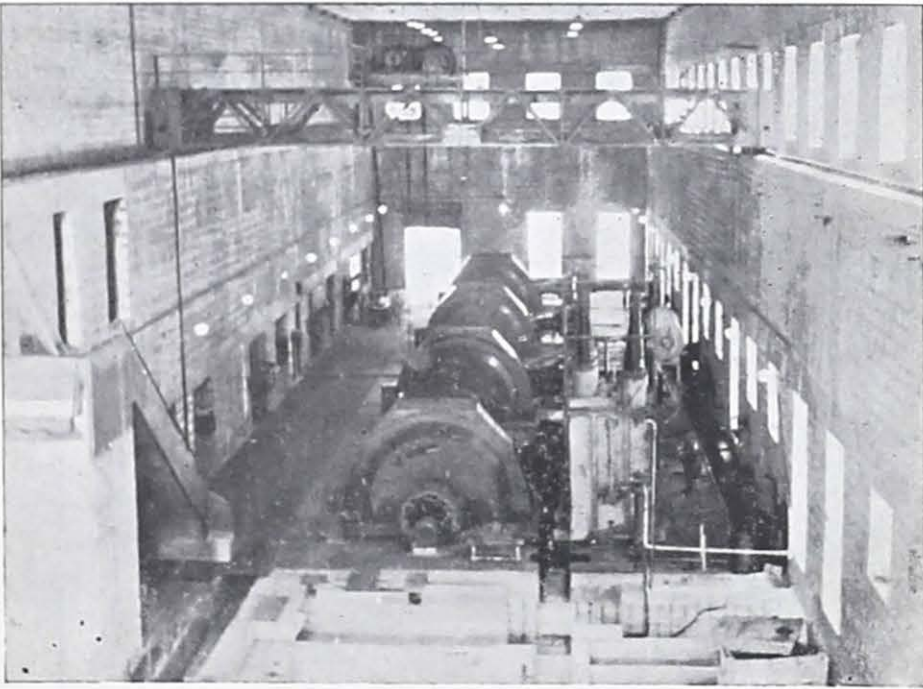


Figure 3.



*Pallivasal Hydro-electric Project—Sethu Parvathi Poran Dam*



*Mahatma Gandhi Hydro-electric Works  
Interior Generating Station*

Sweden claims to have electrified 85 per cent. of all homes in rural areas. She has an installed capacity of 3.0 million kW. Her output of electricity energy in 1948 was 16,000 million kWh. based almost exclusively on water power. Like Norway she has immense possibilities of hydro-electric development and with the works now in progress, she will soon have an installed capacity of 3.5 million kilowatts for a population of seven millions.

The table below gives important facts about the relative development of hydro-electric power in various countries of the world.

Name of the country	Population (millions)	Water power potential based on ordinary minimum flow at 100% efficiency (million kW)	Water power installed capacity (million kW)		Water power installed capacity as percentage of potential		Per capita consumption kWh	Year to which figures in cols. 5, 7, 8 & 9 relate
			1920	at present	1920	at present		
1. Canada	12	19.0	1.9	7.8	10	41	3,536	1949
2. Sweden	7	7.5	0.8	3.0	11	40	2,400	Latest
3. U. S. A.	132	25.0	3.8	17.6	15	70	2,290	1949
4. Norway	3	14.7	0.9	3.07	6	31	2,024	1947
5. Switzerland	5	4.5	0.5	2.4	11	53	1,688	
6. New Zealand	1.8	4.0	0.02	0.46	0.5	12	1,404	1946
7. Germany	67		0.6	3.2			1,240	
8. Australia	8	3.0	0.02	0.3	1	10	1,130	1947
9. Belgium	9			0.02			875	1947
10. U. K.	50		0.15	0.43			832	1946
11. Finland	4	1.9		0.88		46	717	1947
12. Australia	7	1.9		1.32		70	556	1949
13. France	41		1.1	3.5			465	1947
14. Italy	46			6.0			447	1947
15. Japan	81	20.0	0.23	6.3 (1912)		32	390	1947
16. Ireland	3	0.22		0.12		55	269	1949-50
17. U. S. S. R.	193	58		1.0		2		1938
18. India	337	30.40	0.08	0.55		1.5	14	1949
19. China	463			0.6				1935

## THE NEED FOR DEVELOPMENT

Judged by foreign standards, some of which have been described above, the progress on hydro-electric development in India is far from satisfactory. The total installed capacity to date is about 0.5 million kW. and the consumption of all kinds of electricity *per capita*, a true measure of the prosperity of a country, is only 14 kilowatt hours against 3,536 kWh. in Canada, 2,400 kWh. in Sweden, 2,290 kWh. in U.S.A., 2,024 kWh. in Norway and 1,688 kWh. in Switzerland. Another unwholesome feature of the scanty progress made in India is the fact that most of the existing installations have been planned to satisfy the demands of the urban areas. This will be clear when it is stated that Calcutta and Bombay, with a total population of one per cent. of the whole country between them consume half of the total electrical energy produced in India leaving the other half of the power for the remaining 90 per cent. of the population. Except in few villages in Madras, Mysore and Travancore the amenities of electricity are unknown to the common man.

It will not be of much use to dilate on the reasons for the present deplorable conditions. There is no doubt that freedom of action was denied to Indians for long. Some of the early schemes taken up were unduly expensive. The system of financing public works insisted on a minimum direct return which ignored the many and very important indirect benefits to the community and the Government. The machinery for initiating inter-provincial projects was either non-existent or highly ineffective. Some of the difficulties mentioned above, have disappeared with the dawn of independence. The Central Government have in 1948 enacted a legislation with a view to bring about proper rationalization of the industry of the country and to assist in the rapid development of electric power of the country. The Act provides for the formation of Provincial Electricity Boards in each state which will be semi-autonomous bodies and will control the generation of electricity by all licensees. With the formation of these Boards, each state will have an appropriate and adequate machinery to undertake power schemes in the larger and long term interests of the region. As provided in the Act, the Central Electricity Authority has also been set up for exercising a close scrutiny on the work of the Provincial Boards and to advise them on all major power development schemes, that may be taken up by the Boards from time to time.

The Government have also recently set up a Planning Commission to co-ordinate the development of the country and to frame programmes for development of schemes in states in keeping with the resources in money, material and suitable manpower available. Cheap power is the fundamental need for development in other spheres and it is hoped that the development of hydro-electric schemes will receive high priority by the Planning Commission and will proceed at a regulated organized and well planned scale.

## SCOPE OF FURTHER DEVELOPMENT

Meares' estimate of the potentialities of hydro-electric development in India, to which reference has been made before, excluded many of the major rivers and many sites on smaller rivers. Although no regular all-India survey of the hydro-electric resources of the country has still been made, many projects not included in Meares' Survey have since been taken up for investigation and some of them are now in an advanced stage of development. The table below gives a comparison of Meares' forecast and figures now available for projects at present in various stages of development :—

Name of State	Meares' figures (1917) based on ordinary minimum flow			Latest figures (1948)		
	Power developed (kW) installed capacity	Potential (kW.)	Total	Power developed (kW.) installed capacity	Projected or under investigation (kW). installed capacity	Total (kW)
Assam	..	414,000	414,000	500	1,250,000	1,250,500
West Bengal	800	619,250	620,050	2,360	337,000	32,360
Orissa	}	62,550	62,500	..	1,800,000	1,800,000
Bihar						
Bombay	52,574	576,910	629,484	247,714	1,176,600	1,424,314
Madhya Pradesh	..	138,240	138,240	..	1,049,560	1,049,560
Coorg	..	1,500	1,500	..	49,500	49,500
Madras	1,240	91,570	92,810	104,000	500,000	604,000
Punjab	1,775	688,400	690,175	49,750	836,000	885,750
U. P.	786	399,040	399,826	22,700	1,076,870	1,099,570
Madhya Bharat	..	43,300	43,300	..	136,645	136,645
Jammu & Kashmir	4,040	199,500	203,540	4,040	18,000	22,040
Mysore	12,750	24,500	37,250	108,000	237,000	345,000
PEPSU	240	..	240	240	27,000	27,240
Hyderabad	..	..	..	..	595,000	595,000
Rajasthan	..	160	160	..	16,500	16,500
Sikkim	..	5,000	5,000	..	..	..
Union of Travancore & Cochin	400	4,000	4,400	28,500	265,000	313,500
Bhopal	..	..	..	..	76,500	16,500
<b>Total</b>	<b>76,605</b>	<b>3,267,720</b>	<b>3,342,525</b>	<b>567,804</b>	<b>11,297,175</b>	<b>11,864,979</b>

It will be clear from a perusal of the tabel above that Meares' estimate of potential has already been exceeded three times over by projects which are already under contemplation. In addition there are several sites on the Narbada, the Tapti, on the Ghats and in the Himalayas which are still unexplored. It is not unlikely that the unsurveyed resources will far exceed those which have been developed or are under investigation. On a rough approximation, the hydro-electric resources of India are likely to be of the order of 30 to 40 million kilowatts. There is thus an immense scope for development.

### NEW HYDRO-ELECTRIC PROJECTS

Different administrations in India have launched on a number of hydro-electric projects. These have been shown on the map in Figure 3. A brief description of the more important of these which are under construction is given below :—

*The Pykara Hydro-electric Scheme, III Stage Extensions (Madras)* was sanctioned in 1946 in order to meet the increasing power demand in the Pykara areas and also the seasonal as well as emergency deficiencies of the Mettur and Papanasam Hydro-electric System. The extension comprises the construction of a dam 750 feet in length, 493.5 feet non-overflow section and 121.5 feet of central spillway section. Two generators such of 13,600 kW. capacity will be installed with necessary step-up transformer. The cost of the extension is Rs. 326.35 lakhs initially rising to Rs. 489.35 lakhs within ten years. The work is expected to be completed by 1954.

*The Chambal Irrigation and Hydel Development Project (Madhya Bharat and Rajasthan)* aims at harnessing the Chambal for irrigation, hydro-electric generation and flood control by construction of three dams and one barrage for the benefit of both Madhya Bharat and Rajasthan States. A dam 190 feet high will be constructed near Chausigarh Fort with a storage capacity of 7 million acre feet. Hydro-power to the extent of 28,000 kW. to 38,000 kW. at 100 per cent. load factor will be developed and the area to be irrigated will be 40,000 acres. The second dam, 100 feet high near Rawatbhata with a storage capacity of 1.3 million acre feet, will develop 30,000 kW. to 40,000 kW. power at 100 per cent. load factor and will provide irrigation facilities to 10,000 acres. The third dam 145 feet high will be located near Gapernath and will develop 30,000 kW. to 40,000 kW. power at 100 per cent load factor. The barrage will be located near Goanari village and the canal taking off therefrom will irrigate one million acres. The total cost of the scheme is Rs. 28 crores. The work on the project was started in October 1948.

*The Radhanagari Hydro Scheme (Bombay)* comprises the construction of a dam, 140 feet high, for a storage capacity of 194,000 acre feet across the river Bhogavati, 34 miles southwest of Kolhapur on Kolhapur-Malavan road. The scheme is meant to supply water for irrigation of 9,000 acres of sugar-cane and 10,000 acres of the dry crops and also water supply to Kolhapur city. In addition a low-head hydel station to generate 1,600 kW. continuous power is being constructed on the rear side of the dam. The power made available will cater for the needs of irrigation pumps and also both industrial and lighting load of Kolhapur town for the present. The scheme is estimated to cost Rs. 207 lakhs. The work on building the dam is well advanced and about 60 per cent. has been completed.

*The Kakrapara Project (Bombay).*—The project has been taken up by the CWINC on behalf of the Government of Bombay and is proposed to be developed in two stages. Stage I comprises the construction of a cement concrete dam in the river bed with earthen flanks impounding a gross storage of 1,000,000 acre feet for providing seasonal irrigation to 550,000 acres and perennial irrigation to 50,000 acres. The installed hydro-electric capacity will be 24,000 kW. The cost will be Rs. 12 crores. Work on this stage was started in November 1949 and is expected to be completed by 1952-53. In stage II the height of the dam will be raised for increasing the gross storage capacity to 3.55 million acre feet. There will be two power houses, one at the dam site and other at the end of a 16-mile power canal with a total installed capacity of 200,000 kW. The firm power available at 60 per cent. load factor will be 133,000 kW. There will be, in addition, high level canals commanding a gross area of 100,000 acres. Stage II will cost Rs. 31 crores. The scheme will ensure partial flood control of the river Tapi.

*The Tungabhadra Project (Hyderabad and Madras)* is a joint scheme between Hyderabad and Madras States. It comprises the construction of a masonry dam, storage capacity 2.6 million acre feet, with canal system in both the States. The length of canal on Hyderabad side is 149 miles with a carrying capacity of 7,000 cusec. at the head, to irrigate 671,000 acres. Hydro-power is proposed to be generated at the dam and at the drops on the canal to the extent of 150,000 kW. The estimated cost of the project on Hyderabad side is Rs. 18.1 crores. The work is well in hand and is programmed to be completed by 1954.

The canal on the Madras side will be 225 miles long and will irrigate about 250,000 acres of dry crops with 25 per cent garden and perennial crops. The food production is expected to be 60,000 tons and of commercial crops, 40,000 tons. About 7,000 kW. of firm power will be developed. In addition 14,000 kW. of seasonal power could also be developed for eight months in a year. The cost of the project to Madras is Rs. 17 crores. The project was inaugurated in February 1945 and is programmed to be completed by 1953.



*The Godavari Project (Hyderabad)* is a multipurpose scheme and envisages the construction of four dams, two on the main river Godavari and two on the tributaries, the Kaddam and the Manair. The canals will take off from the lower dam on the Godavari on both the north and south banks. The total capacity of the reservoirs formed by the dams will be about 3.0 million acre feet. The total area irrigated will be two million acres. In addition hydro power to the extent of 175,000 kW. will be generated at the dam and the drops on the canals. The total cost of the scheme including power development and transmission lines is estimated at Rs. 75 crores. As a first step in the implementation of this scheme, a part consisting of the dam on the Kaddam tributary and the canal from it, 90 miles long, has been taken up at a cost of Rs. 8.4 crores. This partial scheme will bring under irrigation 227,000 acres. The work is programmed to be completed by 1955.

*The Sindh Valley Hydro-electric Scheme (Jammu and Kashmir)* comprises the construction of a headworks at Prang, 22 miles away from Srinagar, across the Sindh Nala, a tributary of the Jhelum. About 375 cusec of water will be carried by a 10-mile long lined canal from the head-works to the generating site at Ganderbal, about 13 miles away from Srinagar. A static head of about 460 feet is available there. It is proposed to have an ultimate installed capacity of about 18,000 kW. with sets of 3,000 kW. each and one set as stand-by. A reservoir of about 80 acre feet capacity will be made near the forebay which is sufficient on the load factor basis to give 15,000 kW. firm capacity. At present only two sets of 3,000 kW. each will be installed. The estimated cost of the scheme is Rs. 150 lakhs. The work was started in 1947-48 and is expected to be completed by 1953-54.

*The Machkund Hydro-electric Project (Madras).*—This scheme is for harnessing the Machkund river in the Visakhapatnam District on the borders of Madras and Orissa States, at the Doduma Falls where a gross head of 840 feet is available. 100,000 kW. of power could be developed at the site and the scheme is proposed to be worked out in stages. The scheme is being worked jointly by the Madras and Orissa Governments; the cost and power to be shared by the two Governments in the ratio Madras 70 per cent and Orissa 30 per cent. Work is in good progress and the initial stage with a generating capacity of 52,000 kW. is expected to be completed by the middle of 1953. The cost of the joint scheme is estimated at Rs. 484 lakhs initially rising to Rs. 759 lakhs in 10 years.

*The Moyar Hydro-electric Project* is designed to utilise the tail race of the Pykara Power Station with a head of about 1,250 feet available at the Moyar slopes, nine miles lower down. The power plant capacity will be 36,000 kW. The civil works of the project are in an advanced stage of construction and the power house is expected to be commissioned by 1951. The estimated cost of the scheme is Rs. 364 lakhs initially rising to 476 lakhs in five years.

*The Mahatma Gandhi Hydro-electric Works (Mysore).*—The magnificent Jog Falls on the Sharavati river have been harnessed and the first unit capable of generating 12,000 kW. was switched on in February, 1948. Since then three other units each of 12,000 kW. have been erected and put into service. Work on the erection of four further generation sets each of 18,000 kW. is in progress and these will be ready to go into service in 1951-52. The project under construction, when completed will have an installed generating capacity of 120,000 kW. The estimated cost of the scheme is 8.25 crores.

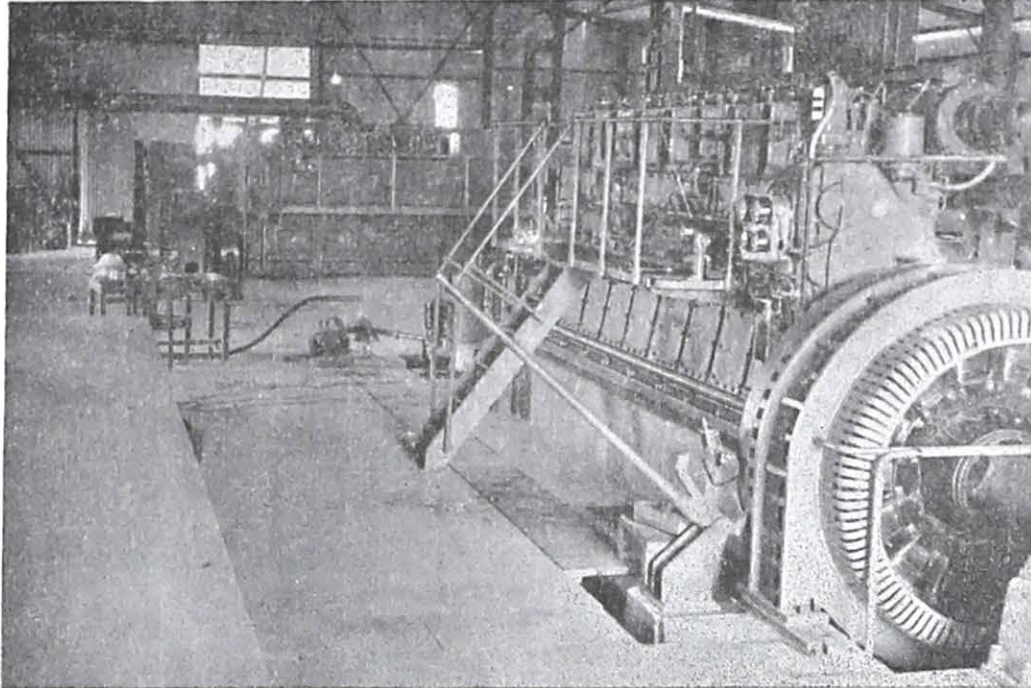
*The Unified Development of the Mahanadi Valley (Orissa)* as designed by the Central Waterpower, Irrigation and Navigation Commission will consist of three units, namely the Hirakud Dam Project, the Tikkarapara Dam Project and the Naraj Dam Project, each with its own canal system and hydro-electric power installation. As a first step, the Hirakud Dam Project has been taken in hand. This dam will be nearly three miles in length across the main channel with 17 miles of low dykes on the two sides. The maximum height of the dam above the bed rock will be about 150 feet. The reservoir will have a gross storage capacity of 598 million acre feet. Nearly 0.9 million acres of land will be irrigated; of this, nearly 0.4 million acres will be irrigated by pumping the water by means of electric power generated in the power houses.

There will be two power houses; one at the dam with an installed capacity of 2,25,000 kW. and other about 17 miles downstream (at a subsidiary dam) with an installed capacity of 96,000 kW.

With the construction of the Hirakud Dam, it will be possible to afford a substantial and adequate measure of flood protection to the delta area at relatively small cost. The regulated releases of water from the Hirakud reservoir will permit of an appreciable improvement in the navigability of the Mahanadi. Orissa through centuries in the past has been haunted by spectres of flood and drought. The construction of the Hirakud Dam will substantially relieve the state from flood and drought, by providing stored supplies.

The cost of the Hirakud Dam Project including main transmission lines and grid substation is Rs. 48 crores.

*The Bhakra Nangal Project*, the completion of which will turn Punjab into a granary land and industrial area, thus helping to wipe out most of the food deficit of the country, is now under active construction. The most important feature of the project is the construction of a 680 feet high dam on the river Sutlej, forming a reservoir with a live capacity of 5.725 million acre feet. The 90-foot Nangal Dam which is under construction on the same river about eight miles downstream of the Bhakra Dam will provide necessary storage to smoothen out the diurnal variations in releases from Bhakra Plant and a diversion for the Nangal Hydel Canal which takes off just above this dam. The Nangal hydel canal is designed for a capacity of over 12,500 cusec. and three power houses, two of which having a head of 98 feet each are under construction on this canal. The Nangal Dam is nearing completion and it is



*Hirakud Dam Project. A view of Hirakud Diesel Power Station.*

expected that the erection of the first generating set at Power House I will be completed early in 1952 and the second set will be ready by the middle of 1952. Thus it will be possible to commence commercial supply of electricity from this Power House by about the middle of 1952. Power House II is expected to be ready for commercial supply of power by the end of 1952.

The firm power potential of the project works out to 400,000 kW. at 100 per cent factor. This power will be utilised in the States of the Punjab, PEPSU, Himachal Pradesh, Delhi and Rajasthan.

New irrigation canals of an aggregate capacity of 15,400 cusec., *i.e.*, Bhakra main line which takes off from the Nangal canal. Bist Doab Canal which takes off at Rupar and Sidhwan which takes off from the existing Sirhind Canal, are under construction and will command an area of 6.5 million acres in the States of the Punjab, PEPSU, and Rajasthan, out of which 1.6 million acres is at present virgin waste land. Annual irrigation expected is 3.6 million acres which will yield 1.13 million tons of food grains and 800,000 bales of cotton. The project is estimated to cost Rs. 132.9 crores. Cost chargeable to irrigation and hydro-electric portions works out to Rs. 57.4 crores and Rs. 75.5 crores respectively. The whole project including the dam and canal is programmed to be completed by 1957-58.

*The Pallivasal Hydro-electric Stage II Project (Union of Travancore and Cochin)* comprises the construction of Madupalty dam in the upper reaches of the Mudiropusha river for impounding 45,900 acres feet of water to maintain a continuous discharge of 250 cusec in the river for the most part of the year. Only on its completion the Pallivasal Power House will give out its full firm output of 32,500 kW. The dam is expected to be completed by 1953.

*The Sengulam Hydro-electric Project (Union of Travancore and Cochin)* envisages the utilisation of the tail water discharged from the Pallivasal Power station over a head of 1,200 feet. The project is under execution and is estimated to cost Rs. 269 lakhs. The water discharged from the Pallivasal generating station will be taken through the channel about 1,400 feet long to a storage pond from which it will be pumped over a head of 50 feet into concrete lined tunnel 17,500 feet long. This tunnel will emerge into a balancing reservoir created by constructing a gravity dam about 70 feet high. The water from the balancing reservoir will be taken to another tunnel 5,500 feet long through a low pressure pipe line and two penstocks to feed four Pelton-driven generators each rated at 12,000 kW, housed in a power station in the bank of a Mudira Puzha river at Vallathuval. The combined output of the Pallivasal and Sengulam generating stations will be about 73,000 kW. at 70 per cent load factor. The various hydraulic works are yet under way and nearly 60 per cent of the tunnel work has been completed. The first unit in the Sengulam power station is anticipated to be put on commercial load by the end of 1951 or beginning 1952.

*The Poringalkuthu Hydro-Electric Scheme (Union of Travancore and Cochin)* is proposed to be developed in five stages. The work on the first stage is in progress and when completed in 1954, will develop 16,000 kW. at 50 per cent load factor. It consists of building of a dam across the river above Poringalkuthu falls to obtain a storage of 27,840 acre feet. The water will be taken from this reservoir through a tunnel approximately 4,000 feet long to a valve house and thence through three pipe lines to feed three Francis turbines driving alternators each rated at 8,000 kW. with a gross head of 595 feet. The first stage works are estimated to cost Rs. 234 lakhs. The construction of the dam, tunnel, roads and buildings are in progress.

*The Sarda Canal Hydro-electric Scheme (Khatima Power House, Uttar Pradesh)* is one of the major schemes the Uttar Pradesh Government have in hand at present. It is proposed to combine into a single drop a number of existing drops on the existing Sarda Canal between its mile 7 and mile 20 and to instal a power station near Khatima about 9 miles from Banbassa, the headworks of the Sarda Canal. The power house will generate 41,400 kW. out of which 23,000 kW. will be firm power. The cost of construction of the power station including plant, about 12 miles long tail race channel and allied works, is estimated to be Rs. 7 crores approximately. This project will supply electric power to the Kumaon, Rohilkhand and Oudh divisions for domestic, agricultural and industrial purposes. It will also augment the power supply of the existing Ganga Hydel Grid.

*The Pathri Power Station Project (Uttar Pradesh)* will add an installed capacity of 19,500 kW., out of which 10,000 kW. will be firm power, on the Ganga Hydro-electric Grid by the construction of a power house on a by-pass power channel at Bahadrabad on the Main Ganga Canal. The project is under construction and is expected to cost approximately Rs. 1.8 crores.

*The Damodar Valley Project (West Bengal and Bihar)* which is one of the most important multipurpose schemes and is to benefit the provinces of Bihar and West Bengal has its main features the construction of :—

- (a) A number of multipurpose storage dams with hydro-electric plants;
- (b) Two additional hydro electric plants at Kanar No. II and Bormo respectively;
- (c) A stream power plant of 20,000 kW. capacity;
- (d) An irrigation project with a net work of irrigation canals and distributaries measuring 1,553 miles in length;
- (e) A 90 miles long navigation canal; and
- (f) A power transmission grid.

The ultimate benefits that will accrue from this scheme include—

- (a) Effective flood control of the Damodar Valley;
  - (b) Perennial irrigation of 967,000 acres including 185,000 acres now irrigated in the *kharif* season, resulting in additional yield of rice and *rabi* crop amounting to Rs. 18.65 crores a year;
  - (c) Generation of 240,000 kW. electric power which will enable the growth of industrial concerns, electrification of railways, etc.; and
  - (d) The cheap transport facilities through the navigation canal.
- The estimated cost of the scheme is Rs. 67.90 crores. The work on some of the dams was started in 1948 and 1949 and the entire project is programmed to be completed by 1954-55. The development of the Damodar Valley was planned on T.V.A. lines and the Damodar Valley Corporation set up by the Central Government by an Act is in charge of the Project.

The *Mayorakshi Reservoir Project (Bengal)* comprises the construction of a low masonry dam of 117 feet high to store 0.5 million acres of water, a weir at Tilpara and a canal system extending over 1,240 square miles on both sides of the river Mayorakshi. The scheme will bring under irrigation an area of 5,95,000 for *kharif* and 100,000 for *rabi* crops. In addition 4,000 kW. hydro power will also be generated. The estimated cost of the scheme is Rs. 15.5 crores. The project is under construction and is programmed to be completed by 1954.

When the projects described above and others under contemplation at present or hereafter are completed, they will add over 11 million kW. of power to the existing 0.5 million. At present there are three power and eight multipurpose projects under actual construction which, if completed, according to their scheduled programme will progressively add to hydro-electric installed capacity as under :—

Year	Capacity (1,000 kW)	Year	Capacity (1,000 kW)
1952-53	351	1957-58	791
1953-54	554	1958-59	817
1954-55	596	1959-60	910
1955-56	636	Ultimate	1,996
1956-57	708		

Thus in the next ten years, the installed hydro-power capacity will be trebled. It will also be possible to inter-link different power houses into a grid so that loads can be transferred from one station to another in case of emergency. Electricity will be made available to villages in rural areas and life there will no longer be bleak.

## A FEW IMPORTANT SUGGESTIONS

Before the large blocks of power, proposed to be created by the projects described above can be utilised in the service of the people, we shall require in the country large quantities of manufactured goods for the transmission and distribution of energy, poles, wires, transformers, insulators, switchgear, *etc.*, and great numbers of different devices for the utilisation of this energy—motors, large and small, heaters, accumulators, pumps, meters and various other appliances. Some of these articles will be required by the thousand and hundreds of thousand, very few of these are produced in the country at present. All these items constitute incurring of heavy expenditure in foreign countries. For speedy, efficient and economic execution of various hydro-electric projects, it is highly important that immediate steps be taken to establish in India sufficient factories for the manufacture of equipment and appliances for the construction of projects and for the utilisation of power to be made available by them. We cannot depend on imports for the large quantities of machinery required. Sufficient attention has not perhaps been paid to this aspect of development and it is important that due energy be directed towards this important field. It is interesting to mention that for the Dnieper Dam, Russia bought from Schenectady only three 98,000 kW: generators, while she was able to manufacture six generators of the same size herself. Prior to this Russia was not able to produce even a 10,000 kVA transformer. It is reported that Japan imported capital machinery of one type only once, after which she managed to manufacture them herself. This shows how these nations were able to achieve a remarkable degree of success in a short time. There is no reason why India cannot do the same. The Central Board of Irrigation has been persuading the Government to start factories for manufacture of hydro-electric machinery in India and it is hoped necessary action is being taken.

It is often remarked that research in hydro-electric machinery will automatically develop with the establishment of industries as each one of them will have a separate research organisation of its own. But for the transition period we require necessary facilities to test the machinery which have been imported for finding its suitability to our local environments. It is, therefore, essential to equip our research stations for these facilities, if nothing big is possible for the present.

Huge blocks of power are to be made available by the new projects. To make these costly undertakings economical from the very beginning, it is essential that industries must be developed to utilise that power. This is a social and economic aspect of the projects and conditions of confidence should be created so that the industrialists come forward to invest their money. Facilities should be afforded to them for the material and machinery required by them and wide publicity should be

arranged regarding the prospective industries that can be economically developed in the areas to be served by these projects. In fact there should be proper load planning. The advisability of popularising nursery development in the prospective areas of the region should also be looked into.

So far industries have developed in only big cities in this country, leaving the villages in poor condition and unattractive. This has to be avoided in new developments. The industries to be set up should be dispersed in every remote part of the country and as far as possible setting up of new industries in cities which are already crowded should be discouraged. In brief the policy should be decentralisation of the industries and development of rural industries.

The creation and utilisation of these large blocks of energy present numerous problems for the engineer and the scientist. Some of these have been tackled in other countries, but there are many which call for a solution here in India, keeping in view the peculiar needs of the country. Research on hydro-electric machinery, electric transmission and distribution and electrical devices and appliances must, therefore, be taken up in India at a number of centres and without delay.



## COMPREHEND THE TERMS

Water, at the rate of one cusec through a height of 150 feet can generate 10 kilowatts or units of electric power sufficient to drive a 12 h.p. car at a speed of 40 miles per hour on a reasonably good road, and roughly equal to the power output of a hundred men. One Kilowatt or unit of electric power is sufficient to light 25 average sized electric bulbs. Not more than one thousand such units are required to drive a passenger train at a speed of 50 miles per hour. One Kilowatt of power generated continuously for a year can irrigate annually 50 acres of land by pumping water from a depth of about 20 feet. Every Kilowatt of hydro-electric power, if operated continuously represents a saving of 5 tons of coal per year.

One cusec represents a volume of water equivalent to the flow of one cubic foot of water per second. An acre foot denotes a volume of water sufficient to cover an acre to a depth of one foot. Two acre-feet of water are equivalent to one cusec flowing for 24 hours. A million acre feet of water is equal to 43,560,000,000 cubic feet and is sufficient to cover an area of ten square miles to a depth of 156 feet. This represents a storage sufficient to supply a mean discharge of 1,381 cusec to a hydro-station throughout the year.

