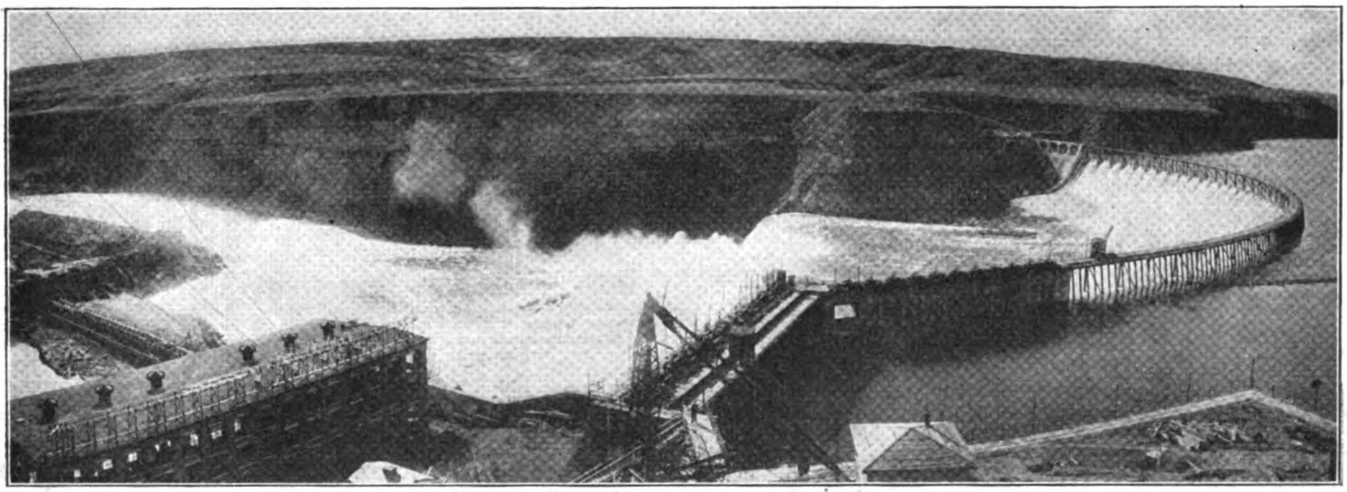


POND ABOVE THOMPSON FALLS DAM THAT DEVELOPS 30,000 KW.

What Interconnection Has Done for Montana

The Montana Power Company, with Thirteen Hydro-Electric Plants and No Steam Reserve, Assures Continuity of Service to Mines, Smelters, Refining Plants and Railroads at Lowest Average Price in the Country

ELECTRIC service can be pointed to as the agent that has made Niagara Falls the great electrometallurgical and electrochemical center and as the very lifeblood of comfortable existence in California, but few persons probably realize how vital a factor it has been in Montana in fostering the native industries and making it possible for them to be carried on more economically than would be possible otherwise.

Prior to 1912 electric service was furnished by several independent companies not co-ordinated, but since that time the Montana Power Company has consolidated and unified the systems by tying together the generating plants and operating them as a whole rather than as separate entities. Unlike many systems that have been formed out of several old ones, the Montana system has been laid out with future development in view, the transmission network being arranged to take care of almost any industries that may develop and to permit ready connection with new hydro-electric plants that may be constructed. Not only have provisions been made for assuring almost absolute continuity of service, but energy is supplied at the lowest average rate per kilowatt-hour offered by any company doing a similar business. The company claims as well the highest energy consumptions per capita. The system is also peculiar in that it operates without any steam reserve.

In the application of electricity to extensive mining operation Montana has easily assumed first rank, and the energy obtained from distant water power is being conducted to remote places, difficult of access, where it performs an infinite variety of work in a most economical and efficient manner. So satisfactory have been the results that electricity has practically superseded steam power and is now driving enormous hoists, compressors, pumps and other mechanical appliances used in the gigantic mining, reduction and refining operations at Butte, Anaconda and Great Falls.

In the electrification of railroads Montana has secured first place. Starting with the electrification of the Butte, Anaconda & Pacific Railway, with its 90 miles (144 km.) of track, the Montana Power Company next electrified the Chicago, Milwaukee & St. Paul Railway, which has 450 miles (724 km.) of its electrified track in Montana.

Even coal mines, which would be expected to be able to develop power as cheaply as it could be done, are served extensively with electricity from this system. Not a single flour mill—and there are many in this great wheat region—is operating on any power but what is furnished by the Montana company. While electric service has made industry in Montana, it in turn has been made available at the attractive rates offered because the demand has been in large blocks and not in small, widely scattered units.

Importance and Nature of Industrial Loads

Based on their connected loads (see Table I) the industries which take chief rank are, first, smelters, including electrolytic and electrometallurgical processes, and, second, electrified railroads. Mines, irrigation and pumping of all kinds, cement works and rock crushers, mine mills, railroad shops and flour mills also provide very important loads. While copper is the principal metal mined, market prices are making it attractive to devote considerable attention to silver, zinc and ferro-manganese. In fact, the increased activity in connection with these materials has appreciably offset the slump in the copper business. The copper and zinc mines in the Butte district use electricity almost exclusively, while the smelters of the Anaconda Copper Mining Company and American Smelting & Refining Company employ it entirely.

To give some idea of the nature of some of the most important loads, nine have been listed in Table II, with their average and maximum demands for one day. It

TABLE I—DIVISION OF CONNECTED LOAD IN 1919

		Horsepower
Commercial arc and incandescent lighting		25,470
Domestic heat applications and electrical appliances (principally electric ranges)		13,306
Commercial power		266,657
Smelters	95,419	
Electrified railroads (motor-generators)	71,005	
Mines	69,223	
Irrigation and pumping	7,532	
Cement works and rock crushers	4,256	
Mine mills	2,844	
Railroad shops	2,697	
Flour mills	2,685	
Miscellaneous		10,477
Total		315,910

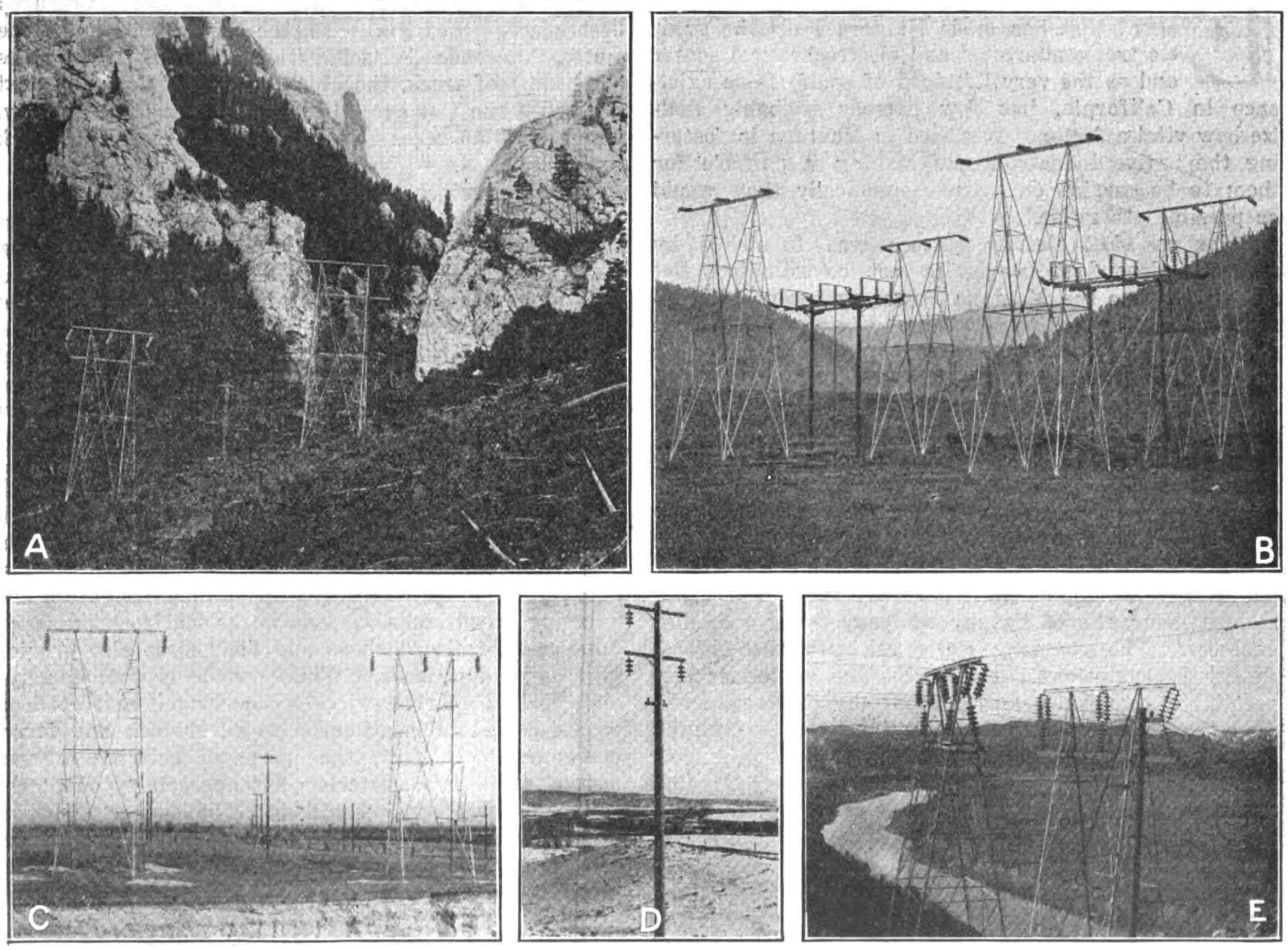
TABLE II—NATURE OF PRINCIPAL LOADS
(System load factor 93 per cent, March 13, 1920)

Industry	Load (Kw.) Average	Load (Kw.) Max.	Load Factor Per Cent
Great Falls zinc plant	31,083	31,500	99
Butte mining load	30,250	35,000	86
Anaconda copper smelter	17,458	19,400	90
C., M. & St. Paul electrification:			
Rocky Mountain division	9,450	16,000	59
Missoula division	9,000	14,000	64
Electrolytic copper	4,530	5,200	87
Ferromanganese *	5,950	7,900	75
Butte miscellaneous power and lighting	6,312	8,000	79
Butte, Anaconda & Pacific electrification	1,458	4,400	33
	1,316	5,000	27
Coeur d'Alene Mines	5,100	6,200	82

* Only two furnaces working; five eventually will give still better load factor.

is interesting to note the very high load factors of the zinc plant, copper smelter and electrolytic copper plant, ranging from 99 to 87. Mining ranks closely as a business with high load factor, while the load factor from railroad electrification ranges from 39 per cent for the Butte, Anaconda & Pacific Railway to 60 per cent for the Chicago, Milwaukee & St. Paul. Miscellaneous power and lighting gives a load factor of 79 per cent. While the load factor of the ferromanganese furnaces is only 75 per cent at present, it will be considerably higher when more furnaces are working to give a greater diversity factor. The load factor of the Montana Power system on the day to which the foregoing figures refer was 93 per cent.

Some persons may contend that the copper mines could operate without electric service from a large system like the Montana Power Company's. They have done so and they could still do so, but not at the power cost which electric service from this system makes possible. Power cost would not be so important to some industries, but copper mining, smelting and electrolytic refining require considerable energy per ton of output and the price of power is an important factor. By reason of the low energy rate available to all, the mines can afford to work up closer to the rock facings than they would otherwise do and hence are able to remove copper that would otherwise be left in the mines. The gold dredges, particularly, are benefited by electric service, not only because no individual could generate electricity so cheaply as the public service company but



TYPICAL TRANSMISSION LINES IN MONTANA

A—Great Falls-Butte transmission line in Beaver Canyon. B—Outdoor switching on 100,000-volt line. C—Double-tower 100,000-volt line near East Helena. D—Typical 50,000-volt line on wood poles. E—Great Falls-Butte line crossing the Missouri River.

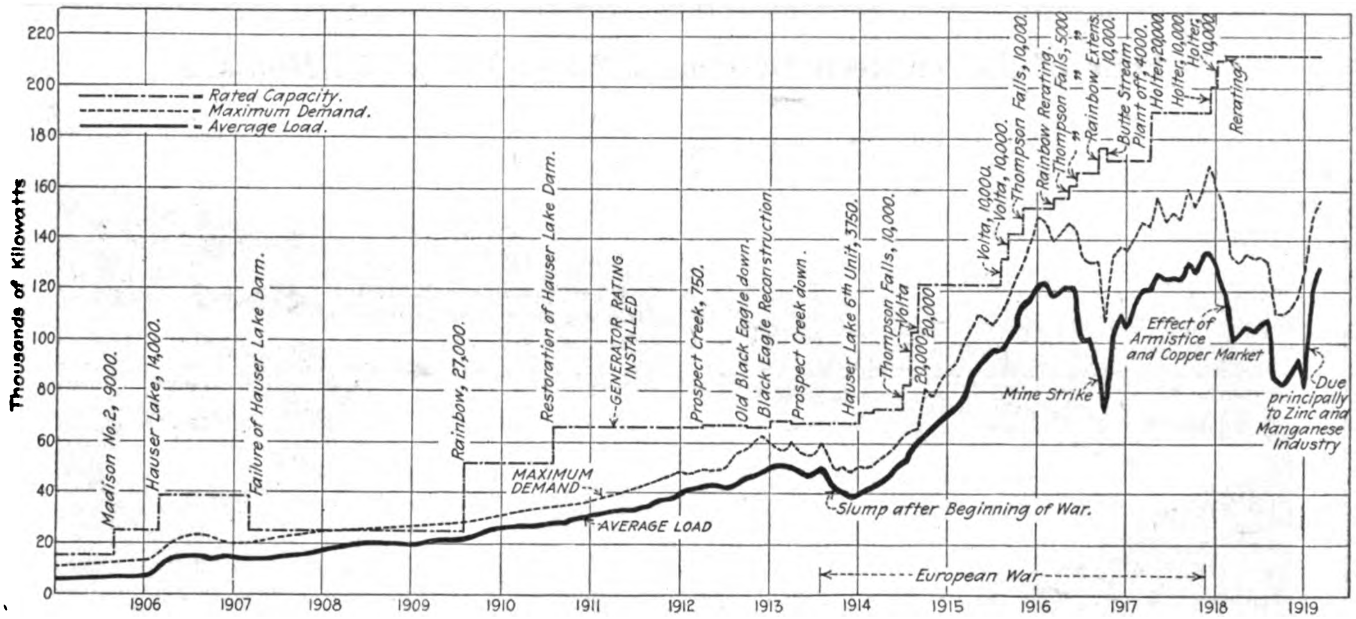


FIG. 1—SUPERIMPOSED MONTHLY PEAK AND AVERAGE LOADS AND STATION CAPACITY (1905 TO DATE)

It will be noted that this average load curve is almost a historical picture of industrial development. The effect of the war, the strike and the zinc and manganese industry are very evident.

because the handling necessary to place coal on the dredges adds to the unit cost.

The value of electric service to industries in Montana is well illustrated by the following example: A large coal-mining concern at Roundup equipped itself with a modern turbo-generator station. After running the plant for a considerable time and keeping accurate records of the costs it decided to salvage the plant and buy energy from the Montana Power Company. Since then it has greatly increased its production per dollar spent for power. This coal mine is not the only one which has found it more economical to give up an isolated plant. Every coal mine in Montana, except one group which cannot be reached economically by a transmission line, is using central-station energy.

As a result of electrification both the Butte, Anaconda & Pacific Railway and the Chicago, Milwaukee & St. Paul are saving money per ton-mile transported, hauling larger loads per train, saving in locomotive maintenance, reducing delays, increasing schedule speed, and thereby getting along with less rolling stock than would be the case with steam locomotives. Aside from these advantages, they have been able to dispense with water tanks and coal docks and have got rid of the trouble they used to meet in braking. The train hands are better satisfied, freight is not so easily stalled, passengers are pleased, and numerous other advantages accrue. With the great increase in the price of coal the advantages of electrification over steam operation have multiplied.

RELATIVE POSITIONS AND FEATURES OF HYDRO-ELECTRIC STATIONS

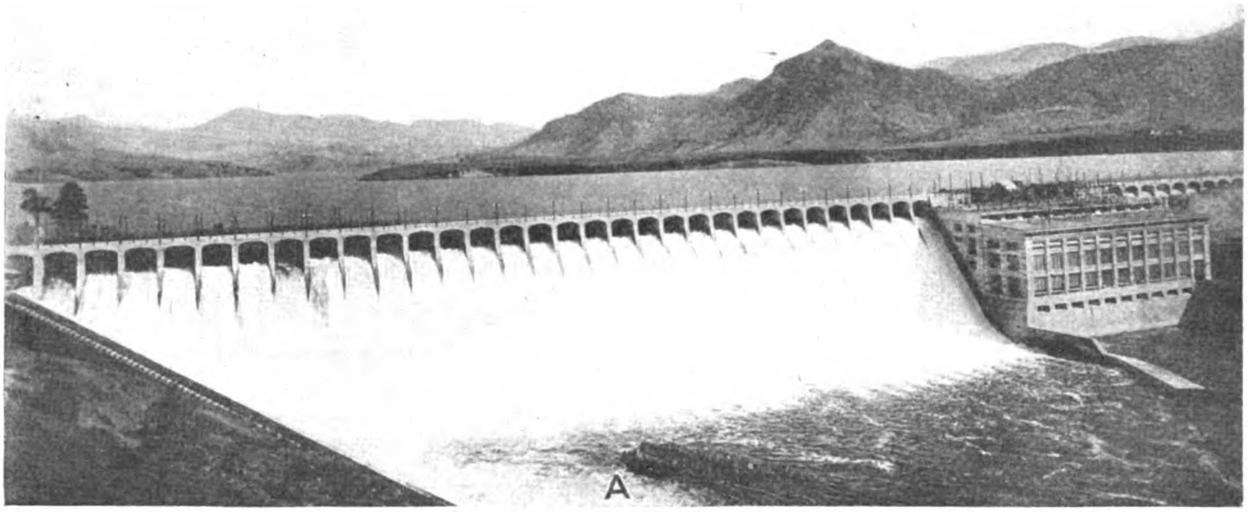
To serve these industries the Montana Power Company is operating thirteen hydro-electric plants with a combined rating of 212,340 kw., distributed as shown in Table III (see map on page 1056). Some of the plants can operate at full load all year; others have considerable reserve for daily peak loads. Thompson Falls, on the Clark Fork of the Columbia River, is over on

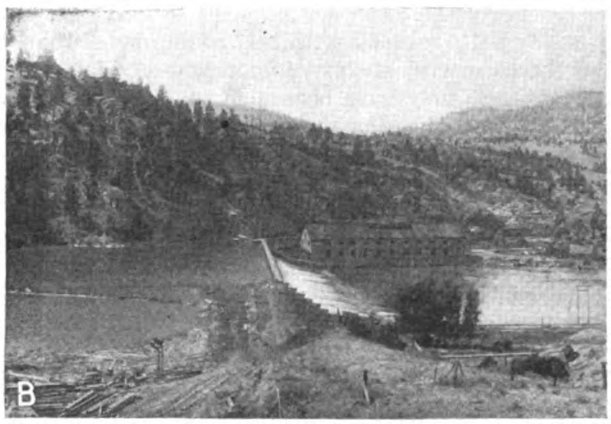
TABLE III—OPERATING DATA REGARDING HYDRO-ELECTRIC PLANTS FOR YEAR 1919

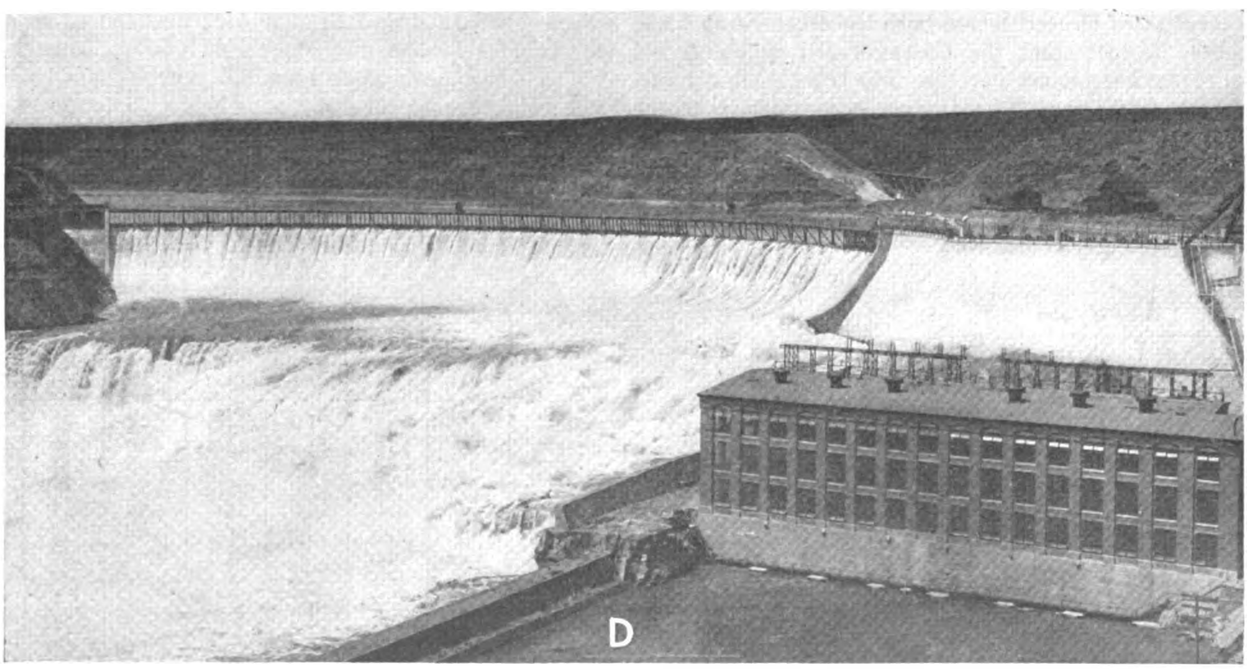
Name of Plant	Year Completed*	Rating Kw.	Average Head, Ft.	Storage, Acre-Ft.	Dam		Average Water Flow (Sec.-Ft.)		Kw. per Sec.-Ft.	Load Factor	
					Height, Ft.	Length, Ft.	Available	Used		1919	Theoretical with System Fully Loaded
Great Falls	1916	60,000	150	3,000	72	1,250	4,487	3,147	9.00	48	56
Holter	1918	40,000	103	73,000	100	1,350	3,622	1,534	6.70	19	41
Rainbow	1910 & 1916	35,000	111	1,000	36	1,145	4,487	3,221	6.40	53	80
Thompson Falls	1916	30,000	56	4,200	35	1,000	15,809	5,458	....	45	..
Hauser Lake	1911 & 1914	18,000	65	46,000	65	720	3,430	2,432	3.66	56	66
Madison No. 2	1906	10,000	108	36,000††	44	183	1,651	944	6.70	63	100
Canyon Ferry	1891 & 1901	7,500	34	40,000	40	490	3,431	2,194	2.13	35	61
Black Eagle	1913	3,000	43	....	18	745	....	852	2.50	56	100
Big Hole	1898	3,000	60	†	...	....	....	....	....	10*	..
Madison No. 1	1901 & 1907	2,000	55	....	...	....	....	....	3.35	6**	100
Livingston	1906 & 1908	1,500	24	None	...	....	....	....	....	59	..
Billings No. 1	1907	1,080	17	None	...	....	....	....	....	76	..
Lewiston No. 1	1906	450	62	....	...	....	176	66	.....	64	..

* Big Hole did not operate during February, March, April, May and September.
** Madison No. 1 operated only 544 hours during year.
† Sufficient for daily variations in load.
†† Does not include 325,000 acre-ft. in Hebgen Reservoir just above plant.

Four of the Thirteen Developed Water Powers in Montana







A—Holter, the newest and second largest plant, with a storage of 73,000 acre-ft., provided by a dam 100 ft. high by 1,356 ft. long. B—Canyon Ferry, the oldest plant, having a storage of 40,000 acre-ft. C—Hauser Lake, an 18,000-kw. plant with 46,000 acre-ft. storage. D—Great Falls development, 60,000 kw., the largest on the Montana system.

the western edge of Montana, but in a very convenient position to serve the western end of the Missoula division of the Chicago, Milwaukee & St. Paul Railway and the Cœur d'Alene mining district in northern Idaho. The Livingston and Billings plants are on the Yellowstone River, Lewiston on Big Spring Creek, a tributary of the Missouri. Big Hole is on the river of the same name, Madison Nos. 1 and 2 are on the Madison River, which empties into the Missouri, discharging water through Canyon Ferry, Hauser Lake, Holter, Black Eagle, Rainbow Falls and Great Falls. Thus the last eight plants all benefit from Hebgen reservoir, on the Madison River, just above Madison No. 1, with its storage of 325,000 acre-ft. (399,750,000 cu.m.) and utilize the same water except for what may drain into the river between plants. These plants serve the bulk of the industrial load around Butte, Anaconda and Great Falls. Although Big Hole, Livingston, Billings and Lewiston can contribute their share through the interconnections provided, they are principally to serve loads on the outskirts of the Montana power system.

Great Falls station, which has the highest rating, 60,000 kw., and highest head, 150 ft. (45 m.), of all the plants on the system, is one of the modern installations, having been completed in 1916 (See Table III). While it has only 3,000 acre-ft. (3,690,000 cu.m.) of storage immediately available, it is below all other plants on the Missouri River and hence can utilize all water passing through them as well as take advantage of their storage, which amounts to 524,000 acre-ft. (536,000,000 cu.m.), including the Hebgen reservoir. Of course it takes time for the water from upstream reservoirs to reach it (about two days from Holter and seven days from Hebgen), but the storage at Canyon Ferry, Hauser Lake and Holter is great enough—169,000 acre-ft. (207,000,000 cu.m.)—to carry the maximum rating of this plant until water from Hebgen reservoir reaches it. Usually peak loads are taken first by the three plants above, and when the water reaches Great Falls the load is shifted or shared with this and other plants in its vicinity, namely Black Eagle and Rainbow. Great Falls has six vertical single-runner wheels driving 10,000-kw., 6,600-volt generators, from which the voltage is stepped up to 100,000 volts.

HOLTER—THE NEWEST PLANT.

Holter, the newest station of the system (completed in July 1, 1918), is next in rating (40,000 kw. to 50,000 kw., depending on operating conditions) and has the largest individual storage, 73,000 acre-ft. (89,700,000 cu.m.), with the exception of the Hebgen reservoir. It also has the highest and longest dam, its height being 110 ft. (33 m.) and its length 1,350 ft. (411 m.). Simplicity is the principal feature of the plant. It is built on the downstream face of the dam, thereby reducing substructure expense and simplifying the penstocks. Four vertical single-runner waterwheels drive 12,500-kw., 6,600-volt generators. Whereas double buses and the corresponding complement of switching were used in some of the earlier plants, Holter employs single high-tension and low-tension buses. Each generator is connected through an oil switch and disconnecting switches with a step-up transformer. Any generator may also be connected with a 6,600-volt bus to feed through some other transformer if necessary. The high-tension bus makes it possible for any transformer to feed through any outgoing line. The switching positions are normally such that each generator and its transformers feed one line. Both of the buses contain sectionalizing switches, and a tie containing an air-break start switch is provided between the two principal out-going lines, making the system still more flexible. This is the first plant on the system to use three-phase transformers, the units being rated at 12,000 kw. to 16,000 kw. The transformers are on the same level as the generators, the 6,600-volt switches are on the mezzanine floor, the 100,000-volt switches are on the next floor,

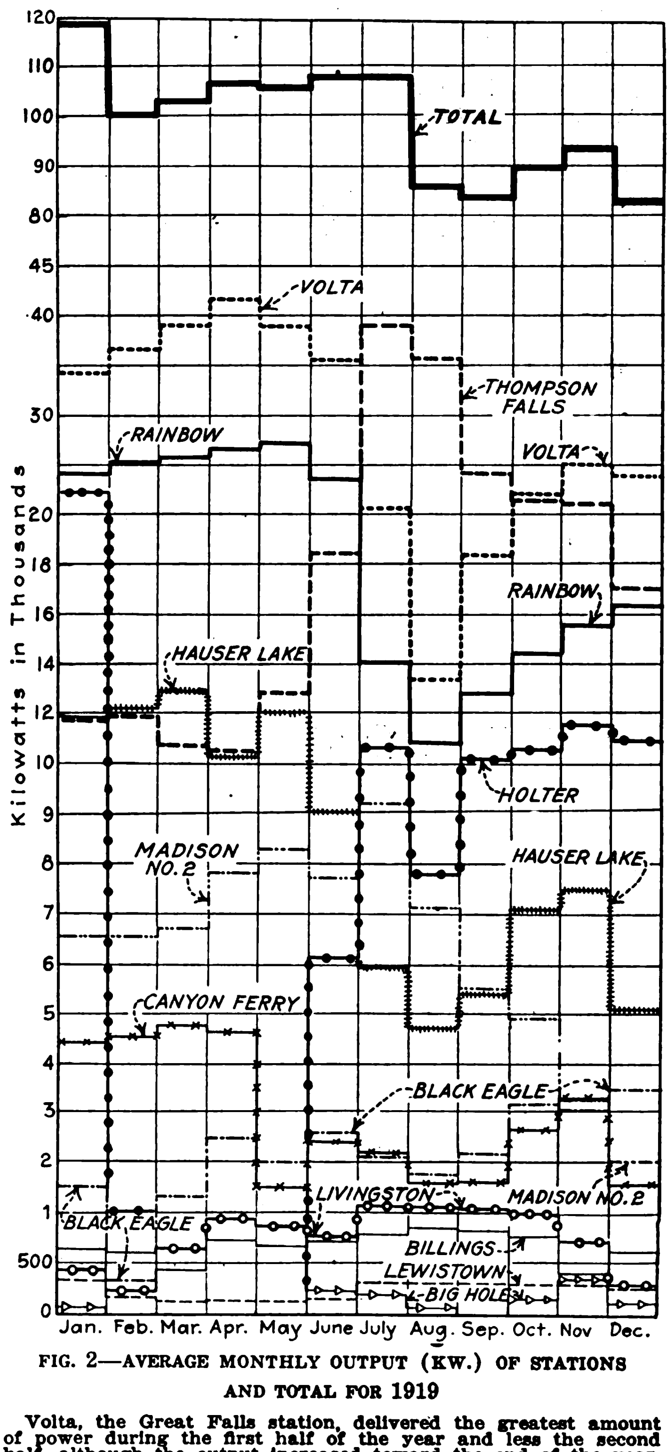


FIG. 2—AVERAGE MONTHLY OUTPUT (KW.) OF STATIONS AND TOTAL FOR 1919

Volta, the Great Falls station, delivered the greatest amount of power during the first half of the year and less the second half, although the output increased toward the end of the year. Rainbow Falls was operated in a similar manner. Thompson Falls' output was weak the first half, strong during the middle of the year, but declined again toward the end. Hauser Lake was strong the first half but weak the last half. Canyon Ferry's output was strongest the first four months, and weak the remainder of the year, owing to replacing waterwheels. Madison No. 2 was strong the first half, increasing to the middle of the year, then declining. Black Eagle was weak the first part, but gradually increased the last half. The load on Billings was relatively uniform, whereas power was on and off at Big Hole. Holter was strongest the first month, then was off five months and fairly strong the rest of the year.

and the 100-kv. bus is on the second mezzanine. On the roof are lightning arresters, air-break disconnecting switches and line-tie switches.

Aside from its features of design, the plant is novel in that it lies between the centers of industrial load and has enough storage and generator capacity to carry any peak loads that may fall on any section of the system. With Canyon Ferry and Hauser Lake just above, it has 169,000 acre-ft. (207,000,000 cu.m.) of water immediately available, which would enable it to carry full load for a remarkably long time (see Table III).

This plant cost about $4,000,000, divided as shown in the accompanying circle diagrams (Figs. 5, 6 and 7). This cost refers to prices before 1918, when the plant was started. Two years and four months were required to complete the plant. If the cost of the transmission lines and reservoir and their share of the expense to develop a market are included, the cost per kilowatt installed would be nearer what a company just starting business would have to figure on under the same conditions.

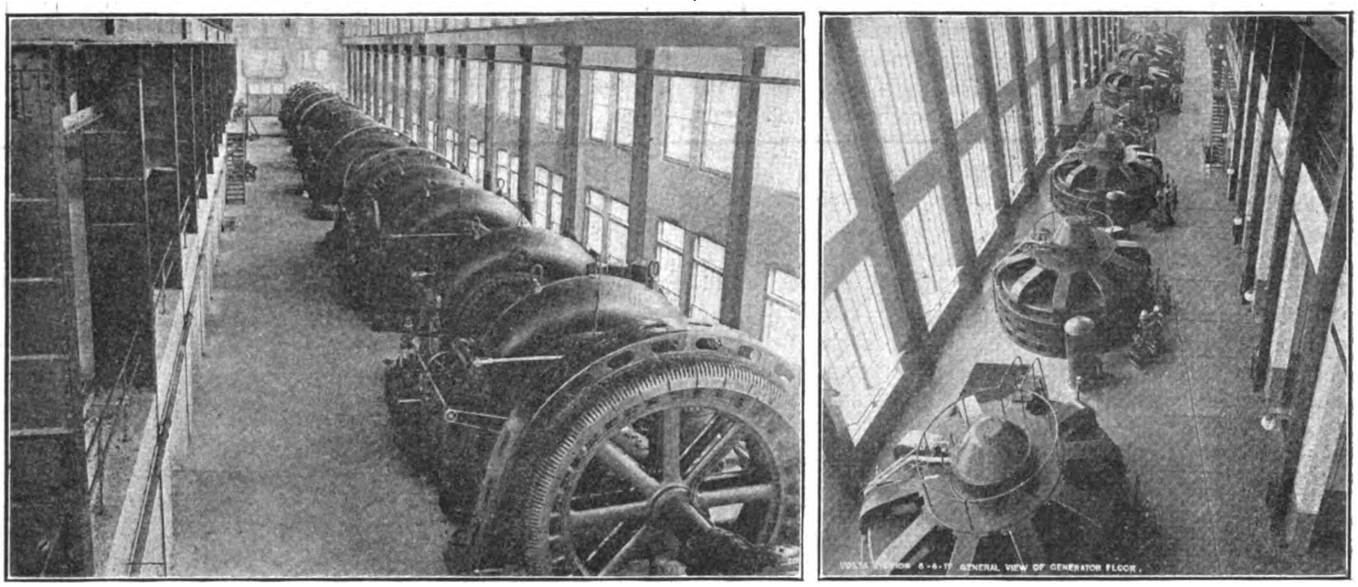
Rainbow Falls is third in rating (35,000 kw.). It contains six horizontal 4,200-kw., 6,600-volt waterwheel-driven generators and two 5,000-kw. units. This represents the older practice of the company—from 1910 to 1916.

Thompson Falls is the fourth largest plant (30,000 kw.) and contains six vertical 5,000-kw., 6,600-volt waterwheel-driven generators. It is on the Clark Fork of the Columbia River and has the largest average river flow—15,809 cu.ft. (442 cu.m.) per second—available. The plant is not connected with the rest of the Montana system except through the Chicago, Milwaukee & St. Paul Railway 110,000-volt bus, through which line some energy is being transferred to supplement the other stations in the system.

The remaining plants were built before 1914.

By referring to Table III it will be noted that four of the plants listed have large storage reservoirs, and these are all on the Missouri River and its tributary the Madison River. The total storage represented on this river system is 199,000 acre-ft. (244,000,000 cu.m.) at the various power plants and 325,000 acre-ft. (399,000,000 cu.m.) more at the Hebgen reservoir, making a total of 524,000 acre-ft. (536,000,000 cu.m.). One acre-foot (1,230 cu.m.) of water will produce a flow of 1 sec.-ft. (0.028 cu.m. per second) for twelve hours. This storage is sufficient, therefore, to increase the flow of the Missouri River at Great Falls by 2,000 sec.-ft. (56 cu.m. per second) for a period of 132 days, or nearly four and one-half months.

Before these storage reservoirs were built the minimum flow of the Missouri River at Great Falls was about 2,200 sec.-ft. (61 cu.m. per second). With the storage reservoirs in operation the minimum has been increased to virtually 4,500 sec.-ft. (126 cu.m. per second). At the various plants on the Missouri and Madison Rivers above Great Falls the amount of available storage is somewhat less, but the natural flow of the rivers also is somewhat less, so that approximately the same ratio holds as regards the increased flow made available by storage. In other words, the minimum flow of the river, and hence the continuous power available, has been practically doubled by the construction of the Hebgen reservoir and the several storage reservoirs at the various plants on the Madison and Missouri Rivers.



OLD AND NEW PRACTICE OF THE MONTANA COMPANY IN THE GENERATOR ROOM

The amount of river regulation made possible is perhaps the most noteworthy feature of the Montana Power Company's system, doubling as it does the power which otherwise would have been available and doing away entirely with the necessity of any steam auxiliary power.

The great advantage of having the principal plants of the system on the same river is very apparent on account of the fact that each unit of storage is not only available for the plant at which the storage pond is formed but also for all the plants down river from the plant in question. Thus, as the system of rivers increased in natural flow from source to mouth, so with the series of plants developed on the system, the available storage increases also in approximately the same proportion.

With a system of this kind the plants are connected in series on the hydraulic end and in parallel on the electrical end. This means that in order to use the available water with the greatest economy loads are adjusted on the several plants on the system in such a way that the load on each plant is just sufficient to use a quantity of water which, passed on to each of the succeeding

TABLE IV—DATA REGARDING PRINCIPAL MONTANA TRANSMISSION LINES*

Route	Size of Wire	No. of Circuits	Miles
100,000-Volt Lines:			
Great Falls (g) to Rainbow (g) and Zinc Plant.....	4/0	1	4
Great Falls (g) to Morel (r) and Anaconda via Holter (r).....	4/0	1	143
Branch to Gold Creek (r).....	2/0	1	15
Grieat Falls (g) to Two Dot (r) and Harlowton (j)..	115,000	1	114
Ranbow (g) to Great Falls—Morel line.....	circ.mil	1	4
Rainbow (g) to Butte (j) via East Helena (j).....	1/0	2	125
Butte (j) to Anaconda.....	1/0	1	23
Holter (g) to East Helena (j).....	115,000 circ.mil	1	31
East Helena (j) to Josephine (r) via Townsend (j)....	115,000 circ.mil	1	55
Madison Nos. 1 and 2 (g) to Butte (j) via Piedmont (r) and Janney (r).....	1/0	1	62
Thompson Falls (g) to East Portal (r) and Coeur d'Alene.....	7 No. 9 & 2/0	2	23
65,000-Volt Lines:			
Hauser Lake (g) and Canyon Ferry (g) to Butte (j) via Boulder (j).....	105,000 circ.mil	2	68
Boulder (j) to Townsend (j).....	4	1	36
Butte to Deer Lodge.....	4	1	16
50,000-Volt Lines:			
Rainbow (g) to Conrad.....	3 & 3 No. 9 G. I.	1	94
Rainbow (g) to Havre.....	4	1	104
Rainbow (g) to Harlowtown (j) via Lewiston (g)....	3	1	168
Harlowton (j) to Carpenter Creek, via Lavina (j)...	1	1	...
Billings (g) to Lavina (j).....	1	1	...
Billings (g) to Livingston (g) via Park City (j).....	3	1	112
Park City (j) to Bridges.....	3	1	...
Livingston (g) to Madison No. 2 via Hot Springs (j)	3	1	73
Madison Nos. 1 and 2 (g) to Three Forks (j).....	3	1	29
Madison Nos. 1 and 2 (g) to Twin Bridges.....	4	1	49
Thompson Falls (g) to Plains.....	3	1	...

* (g) Means generating station. (j) Junction. (r) Railroad substation.

plants below on the river, will produce in the aggregate the total amount of power required from the system. If the natural flow at any time is greater than that required by the power demand on the system, it is stored and saved until such time as the power demand calls for water in excess of the natural flow. At times when the system is fully loaded considerable care is exercised by the load dispatcher in the manipulation of the rivers so that every second-foot is fully utilized and no water at any plant spilled over the dam.

A time interval of about seven days is required for water released from storage at the Hebgen dam to reach the furthermost plant of the system at Great Falls. If an unlooked-for increase in load occurs, this is taken care of immediately by the necessary draft of water from the local reservoirs at each plant. At the same time, however, the required additional amount of water is released from the Hebgen dam, and during the following week as this increased flow reaches the various plants in succession the amount of water which was temporarily taken from the local reservoirs is replaced so that the head at each plant is maintained at nearly its maximum point. Although this continual adjustment and manipulation of the rivers requires some little skill, yet it has been found by experience that very little difficulty is encountered in making the necessary adjustments for the maximum efficiency of operation of the system as a whole.

TABLE V—GENERAL STATISTICS

	1919	1918
Generator rating (kw.).....	212,340	200,855
Maximum load (kw.).....	152,800	162,900
Average load (kw.).....	98,858	126,498
Energy generated (kw.-hr.).....	863,960,624	1,106,663,860
Load factor (yearly).....	65	74
Load factor (average monthly).....	77	82
Connected load (hp.).....	315,909	304,541
Loss in transmission and distribution.....	17	14
Consumption (kw.-hr.).....	720,681,439	951,901,714
Number customers served*.....	44,505	....
Area of territory, miles.....	260x300	....
Miles of transmission line.....	1,922	....
Miles of power wire.....	6,031	....
Miles of distribution wire.....	4,113	....

* Excluding large mines, smelters, refineries and railroads.

The tying together of the plants electrically and the possibility of perfectly free interchange of power without the usual prejudice or bias which exists where interconnection is made between different companies makes it possible to utilize to the greatest extent possible all such plants as naturally would be unable to maintain a continuous or reliable supply of power. Some of the older and smaller plants of the system, such as those at Big Hole, Livingston and Billings, are subject to extremely low water during certain periods of the year, so that their output is reduced to less than 25 per cent of their rated capacity. Such plants if operated singly would be of virtually no value whatever in carrying a commercial load. Tied in with the rest of the system, however, they can be operated all the year round so as to use all water available, and the kilowatt-hours they furnish are just as valuable as if they were furnished 365 days in the year. Practically speaking, their interconnection electrically with the other and larger plants

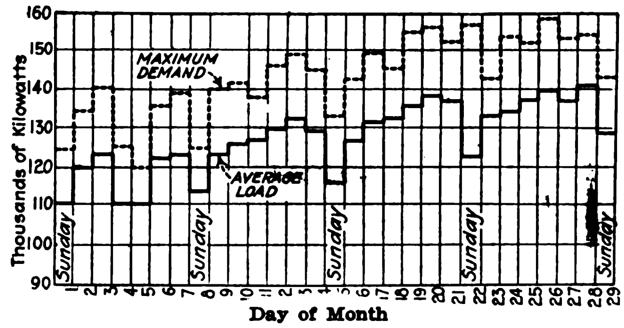


FIG. 3—AVERAGE AND MAXIMUM DEMANDS BY DAYS FOR FEBRUARY, 1920

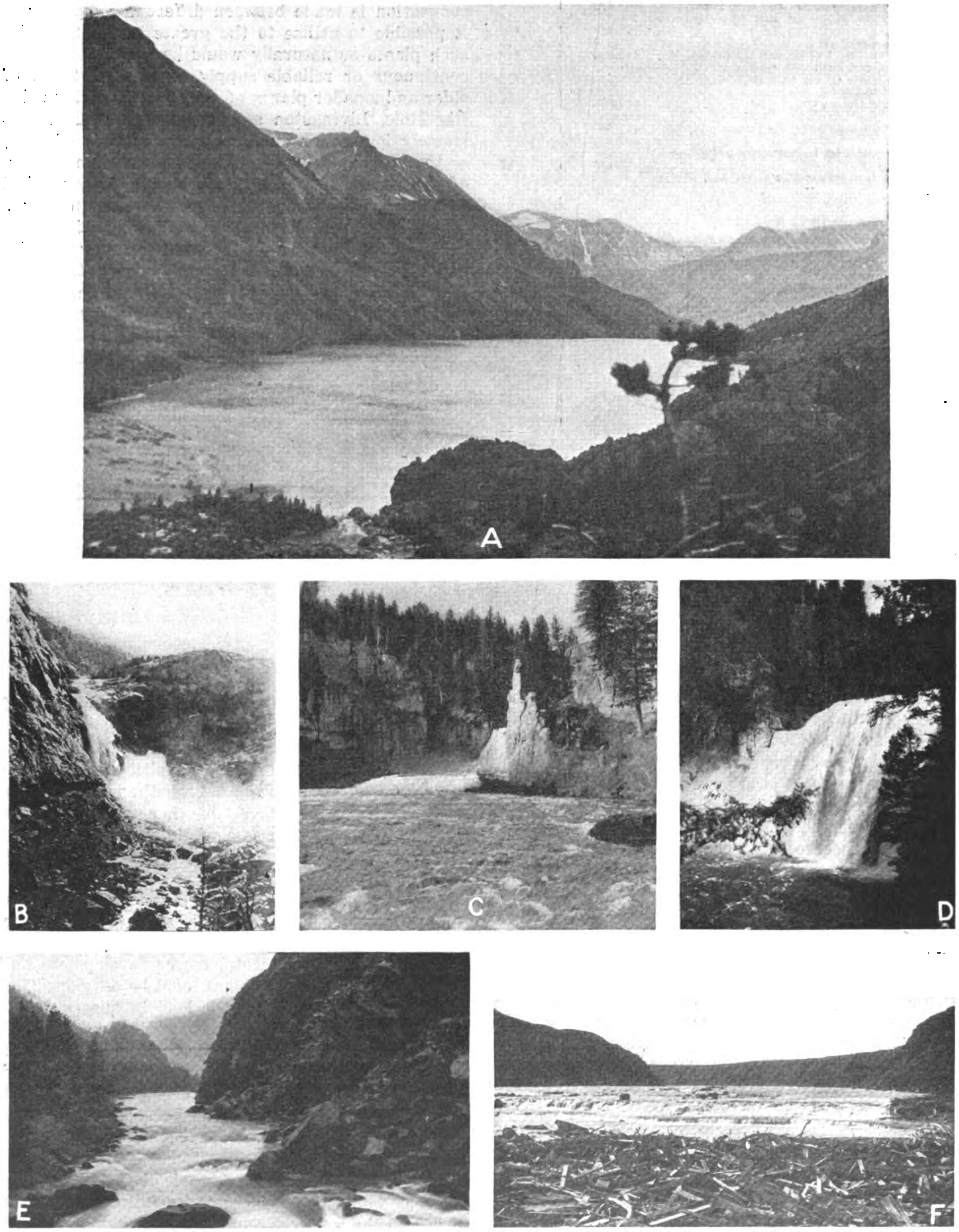
Note the high load factor, marked decreases on Sunday, non-uniformity of weekly load but general increase.

is equivalent to supplying them with their share of the storage which is available at the other plants.

To sum the matter up, it can be said that the series hydraulic connection and the parallel electrical connection of the plants in Montana, together with the storage which has been made available, have made the effective capacity of the system as a whole at least twice what it would be if the various units of the system were separate and independent.

With the present system as a nucleus, the Montana Power Company is now very advantageously situated as regards the development of additional water-power sites. In the case of a single water-power development built to carry a certain load, the plant must be developed for the anticipated load factor of the load in question, regardless of the natural advantages or disadvantages of the site. With a system such as that of the Montana Power Company to tie into, a new development can be made to operate at any load factor that may be considered desirable; for example, a high-head plant involving the use of a long pipe line, where the pipe line represents the larger percentage of the investment, would naturally be developed to operate at a high load factor so that the pipe line would be operated at its full capacity continuously and the greatest number of kilowatt-hours during the year obtained from a given investment. On the other hand, a low-head or medium-head plant, in which the head is developed by means of a dam and short penstocks, would naturally be developed for a comparatively low load factor so that the storage made available by the dam could be utilized to carry peak loads and the ad-

Some Undeveloped Water Powers in Montana



A—Mystic Lake, which will probably be used to furnish 26,000 acre-ft. of storage for an 1,100-ft. head development of 10,000 kw. B—The falls below the lake, which will furnish part of the head. C and D—Three falls in Snake River which would furnish a natural head for a 22,500-kw. development. E—Site on the Madison River where 13,500 kw. can be developed. F—Point on Missouri River below Great Falls where dam can be built to impound water for 28,500-kw. development; a 60-ft. dam 1,000 ft. long would be required for such a rating.

ditional investment required for this peak load capacity would be only that represented by additional generators and waterwheels.

One thing that has to be taken into consideration in utilizing the reservoirs is the time required for the water released to reach stations downstream. For instance, the Hebgen reservoir is 300 miles (480 km.) above Rainbow, so it requires seven days for water to travel between the two places. Likewise, Holter is five days (water travel) from Hebgen. However, the storage immediately available above this plant, Hauser Lake and Canyon Ferry, is sufficient to carry full load on each plant until water from the Hebgen reservoir reaches them. Hence peak loads can be thrown onto these three plants simultaneously.

As indicated by the map, page 1056, and Table VI, the generating stations are so located and the transmission system so laid out that the centers of industrial load—Butte, Anaconda, Helena and Great Falls—have several sources of energy as well as several channels through which to receive it.

For instance, Anaconda can receive energy over the Great Falls-Anaconda line, the two Rainbow-Anaconda lines or the two lines from Hauser Lake and Canyon Ferry to Butte. Butte, in turn, can be served from the same lines. Some help may also be received in the Butte and Anaconda districts from Big Hole and Madison Nos. 1 and 2. Helena district is fed from Holter, Canyon Ferry, Rainbow Falls and indirectly from Great Falls. Great Falls district is immediately in the vicinity of Rainbow Falls, Great Falls and Black Eagle and may also be fed from Holter as well as other plants connected to the system. Holter, being situated between the big load centers, can transmit energy to them very economically when the nearby plants become overloaded and, besides, is well equipped to take peak loads, as mentioned before. The value of interconnection has been particularly appreciated in the Butte-Anaconda district, where, owing to the several sources of energy and the various lines over which it can be transmitted and the fact that they run over different routes and are not likely to be affected by disturbances simultaneously, there is practically no opportunity for any load center to be without energy. In fact, the mines, which have to consider reliability of service more than any other users, perhaps, have not because of past experience deemed it necessary to have any standby generating equipment.

CONTINUITY OF SERVICE ASSURED BY NETWORK

Because the many transmission lines mentioned tap a 100,000-volt bus line along the Chicago, Milwaukee & St. Paul Railway at seven points, the Montana Power Company is able to give the railroad absolutely reliable service. Several of these tie-in points can be fed from more than one transmission line. For instance, Two Dot can receive energy from Great Falls directly or Rainbow and other plants indirectly; Josephine can be fed from East Helena, which is a junction point for several main transmission lines; Piedmont and Janney tap a main line between Madison Nos. 1 and 2 and Butte and hence can receive energy from two directions and several stations; Morel is fed directly by Great Falls and Holter over one line and may be connected with other plants over this and another line; Gold Creek also taps a main line that can be fed from two directions; East Portal receives energy over duplicate lines from Thompson Falls. The 100,000-volt bus line affords still another channel for transfer of energy.

During the war the policy of the Montana Power Company was to postpone all except absolutely necessary construction (Holter, as mentioned before, was built during the war). No large construction work was done during 1919 either. The principal addition was a line from Harlowton to Roundup and Carpenter Creek coal district and a tie line from this line to Billings.

As may be observed from Fig. 1, showing the monthly peak loads, average loads and station capacity, there was a slight slump in business immediately after the beginning of the war and another severe decline in business in the last half of 1917, due to a mine strike. The signing of the armistice and the simultaneous drop in the

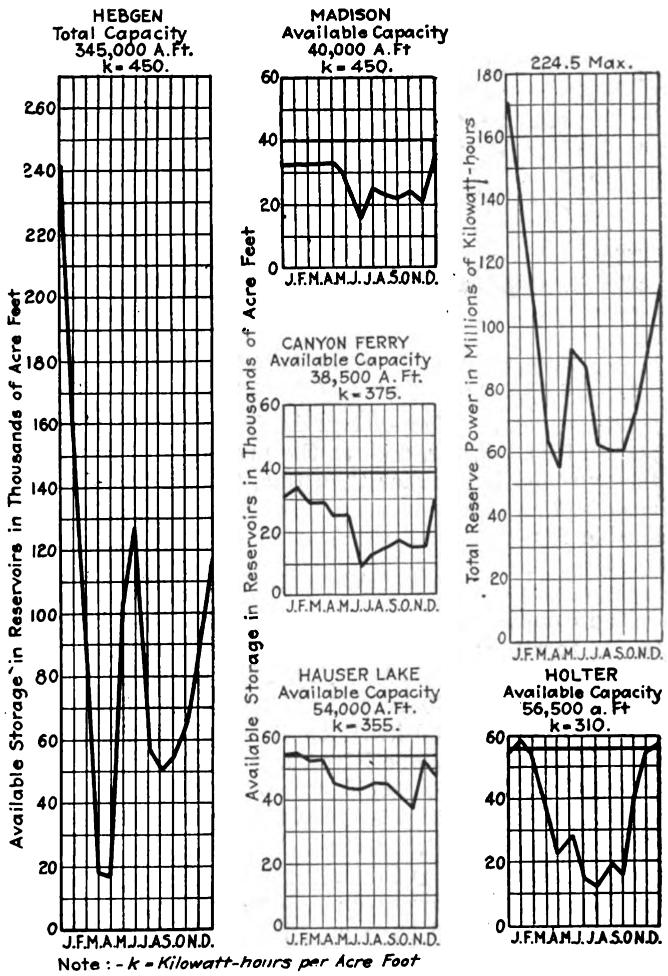


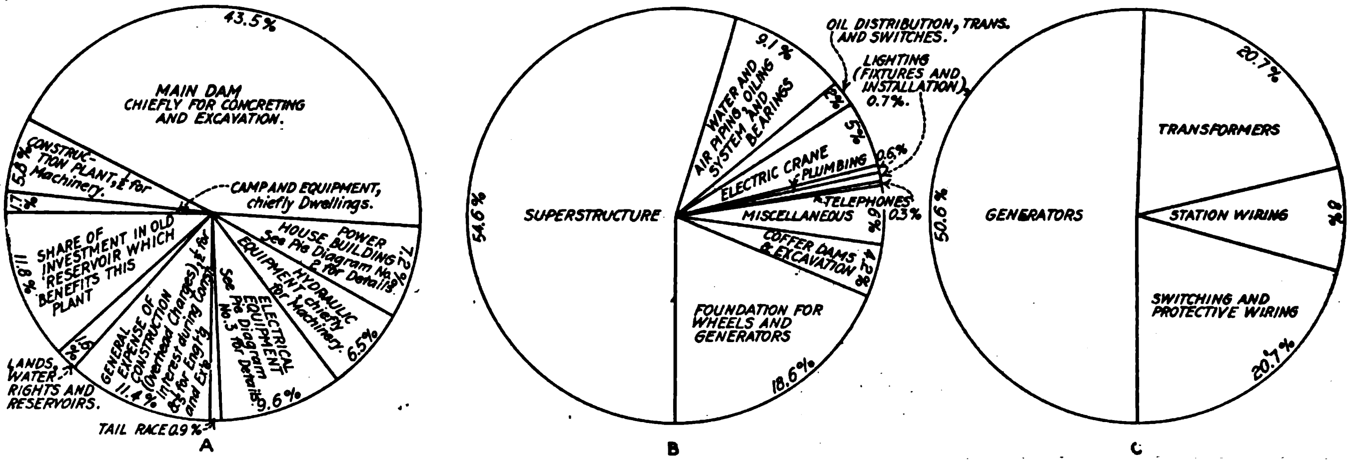
FIG. 4—AMOUNTS OF STORAGE AVAILABLE IN HEBGEN, MADISON, CANYON FERRY, HAUSER LAKE AND HOLTER RESERVOIRS AT DIFFERENT PERIODS OF 1919, THE DRIEST YEAR IN A CONSIDERABLE PERIOD, WITH TOTAL EQUIVALENT ENERGY IN RESERVE

copper market had a very marked effect, but the load is now increasing at a greater rate than before.

The loads are now about what they were in 1918, the average and maximum demands for February, 1920, being shown in Fig. 3. As will be noted, the load factor is very high. There is no uniformity in the weekly load curves except for the Sunday decline and the general increase in load. Copper and zinc mines and reduction plants have increased operations, silver mining has revived, and ferromanganese has shown special activity. Besides the natural rate of growth in established Montana industries, the development of new industries which will use large amounts of electrical energy, such as electric steel and brass production, is looked for. Owing to the high cost of harvesting natural ice there has been quite a boom in artificial ice production by electricity. Several opportunities to electrify railroads still remain. The Northern Pacific and the Great Northern provide the most favorable opportunities and are now considering electrification, while the Chicago, Burlington & Quincy and the Oregon Short Line also operate the state.

It is probable that the existing system will be able to handle the normal increase in load for one or two (860,000 cu.m.). After developing Mystic Lake, the Montana Power Company will next consider the sites around Great Falls, namely, Black Eagle, Great Falls C and Sheep Creek. Most of these power sites are shown on page 1048 and on the map, page 1056.

As in the past, the policy will be followed of so laying out future transmission lines that service shall be available to almost any industry that may be established in the State, that as many towns as possible may be



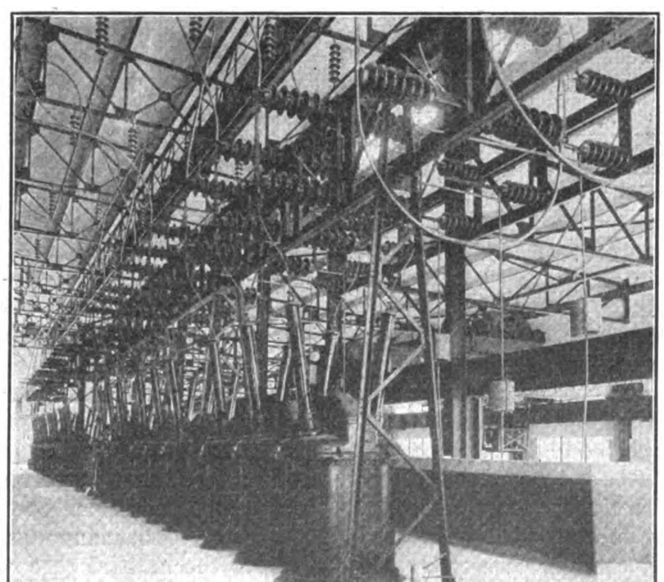
FIGS. 5, 6 AND 7—DISTRIBUTION OF INVESTMENT IN THE MONTANA POWER COMPANY'S LATEST PLANT, HOLTER
A—Major classification of 40,000-kw. plant. B—Itemization of investment in power house. C—Electrical equipment.

years to come. The system is designed for about 70 per cent load factor, and, as the present load has a load factor somewhat higher than this, there is considerable peak-load capacity available, which is particularly desirable for railroad electrification.

Undeveloped Water-Power Sites

The company has several desirable water-power sites in its territory that remain to be developed, namely, Great Falls C (28,500 kw.), Sheep Creek (28,500 kw.), Snake River (22,500 kw.), Madison No. 3 (13,500 kw.), Mystic Lake (10,000 kw.), on Rosebud Creek, a tributary of the Yellowstone River, and Black Eagle (10,000 kw.). Great Falls C would probably be developed for a 70-ft. (2.1-m.) head and would require a dam 60 ft. (18 m.) high by 1,000 ft. (300 m.) long. Sheep Creek would probably operate on a similar head and have a similar length of dam, but it would not have to be higher than 45 ft. (13.5 m.).

Mystic Lake, with an 1,100-ft. (330-m.) natural head available and 26,000 acre-ft. (32,000,000 cu.m.) of storage, is the most promising site in the eastern part of the State and will in all probability be the next to be developed. A 15-ft. (4.5-m.) dam and about 2 miles (3.2 km.) of penstock will be required. Black Eagle will probably be developed for a 42-ft. (12.6-m.) head by utilizing a 24-ft. (7.2-m) dam about 750 ft. (225 m.) long already built, impounding about 700 acre-ft.



SWITCHING EQUIPMENT IN THE MOST MODERN STATION, HOLTER

reached, the most reliable service provided and development of water-power sites facilitated.

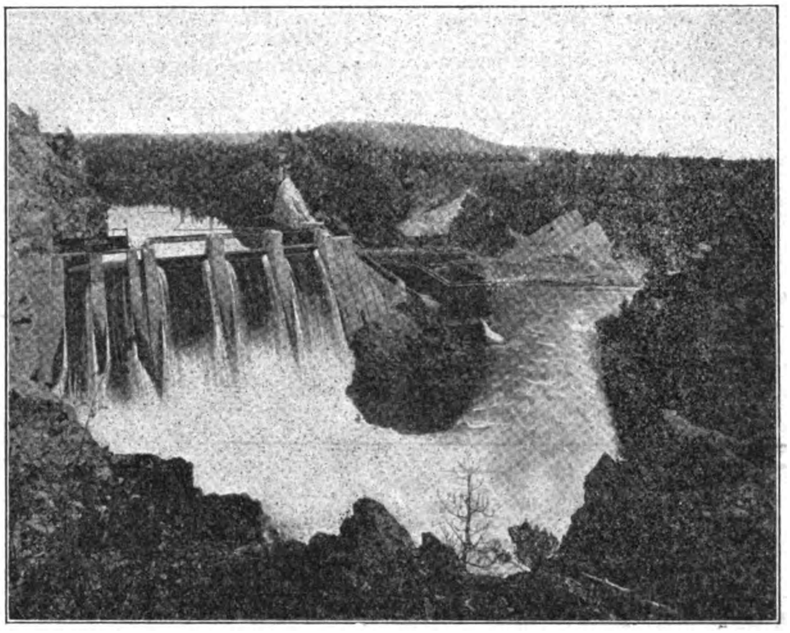
For example, if the Great Northern electrifies, a line might be built along the right-of-way from Havre at the east end to the state line on the west and fed at Havre, Cut Bank, Whitefish and Troy. Havre could be served from all existing plants through the present line to Havre, after being reinforced. Cut Bank and Whitefish could be served by lines from Thompson Falls. Mystic Lake would in all likelihood be connected with the Bozeman-Billings line, reinforcing that system, which runs along the Northern Pacific Railway. The transmission lines from Thompson Falls to the Cœur d'Alene mining district run very close to lines of the Washington Water Power Company, but there is no immediate need of interconnection. All of these interconnections will depend on conditions making them economically possible not only as to investment but as to operating expense. In general it costs about 15 cents per kilowatt-year per mile to transmit energy, which is a rough basis on which it is possible to make a rough determination as to whether it is better to utilize local energy or transmit it from a distance.

The foregoing information has been obtained with the courteous co-operation of John D. Ryan, president of the Montana Power Company; F. M. Kerr, vice-president and general manager; H. H. Cochrane, chief engineer, and others.

Giving Service in Agricultural Districts

Sparsely Settled Communities That Would Ordinarily Be Considered Uneconomical to Serve Are Being Fed by the Washington Water Power Company, Which Also Serves Two Other Systems and an Electrified Railroad

INCREASED economy, production, convenience and comfort made possible by electric service are evident everywhere, but these benefits are particularly marked where the large cities are widely separated and the towns sparsely settled and far from sources of fuel. This is particularly true in that section of the State of Washington east of the Big Bend in the Columbia River which is served by the Washington Water Power Company. There industry, as usually understood in most parts of the country, is not so predominant as agricultural pursuits, which are naturally spread over greater expanses of territory and are therefore more dependent on electric service from a large interconnected system because the carrying charges on fuel make its price almost prohibitive. In that section electricity has been made available at a moderate price through an abundant natural resource—water power—and water storage and interconnection of various plants make it possible to give a more reliable and economical service than could be furnished by individual plants. Furthermore, the service can be rendered without any steam reserve, which would add considerably to the cost of service.



LONG LAKE DAM AND 46,700-KW. PLANT OF WASHINGTON WATER POWER COMPANY AT LOWER END OF LONG LAKE. THIS IS THE NEWEST AND LARGEST OF ITS FOUR STATIONS

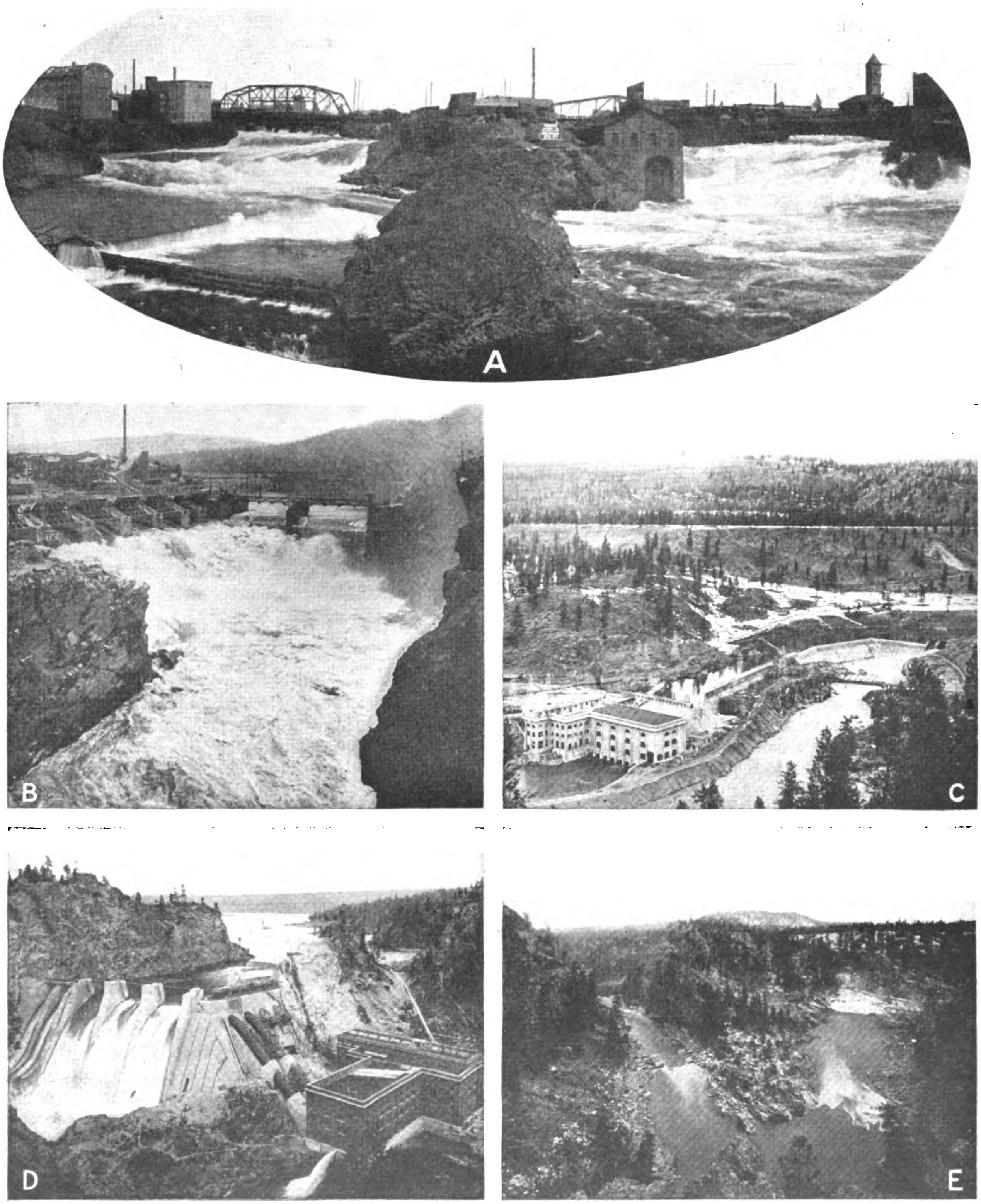
Development of the System

As shown by the map on page 1056 the lines of the Washington Water Power Company now cover a territory about 100 miles (160 km.) in both directions, east and west, and a like distance north and south, but this system started from a nucleus centered in Spokane and grew by gradually extending lines to markets in the neighborhood which would justify the investment and losses in transmission lines. The initial hydro-electric station was situated at Spokane on the Spokane River (see Table I and Fig. 1). As the load further increased another hydro-electric plant was erected upstream in 1906 near Lake Cœur d'Alene, with its enormous storage area of 45 sq. miles (116 sq. km.). Because of slack flow in the river at certain periods of the year it was necessary to build a steam reserve plant at Spokane in 1907 to supplement the existing hydro-electric plants, but more especially to supply energy during the interval before the development of more water power. Meanwhile the transmission system had been extended and the benefits of electric service had become so generally recognized that it was necessary to provide additional generating capacity at Little Falls on the Spokane River. Finally Long Lake development, with its wonderful storage of 62,000 acre-ft. (76,260,000 cu.-m.), exceeded only by Lake Cœur d'Alene, was completed in 1915. Since all the hydro-electric plants were interconnected and had sufficient storage to regulate the river flow, it was possible after Long Lake was placed in operation to shut down and dismantle the old steam plant at Spokane, which had formerly been required only to compensate for slack flow anyway. This plant was not used much after 1910 and not at all after January, 1912.

Factors Which Had to Be Considered in Extending Lines

Simultaneously with the development of new water-power sites came the extension of transmission lines, first to nearby towns such as Medical Lake, southwest of Spokane; subsequently to the Cœur d'Alene lead and silver mining district in northern Idaho; north of Post Falls to the lumber district; the Palouse territory to the south, with similar agricultural pursuits, and the Big Bend country, a rich fruit-growing and wheat-raising district to the southwest of Spokane. These sections now rank in about the preceding order as far as load centers are concerned. In extending lines to each of these sections consideration had to be given to the immediate or likely revenue which could be obtained and the possibility of its paying a reasonable return on the expense of rendering the service. Sometimes a definite enough load could be seen to justify the extension; at other times sufficient revenue to warrant the extension had to be assured by the concern or community which desired service. In some instances where the transmission company could not afford to extend a line the communities or concerns desiring power wanted it sufficiently to build a line up to the Washington Water Power Company's system. In still other cases farmers who desired service and could not be served otherwise have banded together, guaranteed a satisfactory yearly revenue and have also financed part of the line. Furthermore, the farmers agree to use power for a long enough period to make the revenue at least equal the investment in the extension. Of course, after

Hydro-Electric Plants in Eastern Washington



A—Undeveloped power about 2,050 ft. above Spokane plant which is soon to be utilized. B—Control works of Post Falls plant. C—Forebay, spillway and power house of Little Falls plant. D—Largest and newest plant at Long Lake during flood stage. E—Bend in Spokane River below Long Lake at site of Long Lake plant before construction.

they have once tasted the benefits of electric service there is not much likelihood of their discontinuing it. Much of the farm and municipal pumping load is served on the flat-rate basis, but other loads are connected on the maximum-demand and energy-charge basis.

Where the power company sees an opportunity to serve several communities it finances its own trunk lines and requires the small communities only to contribute to the financing of the laterals necessary to serve

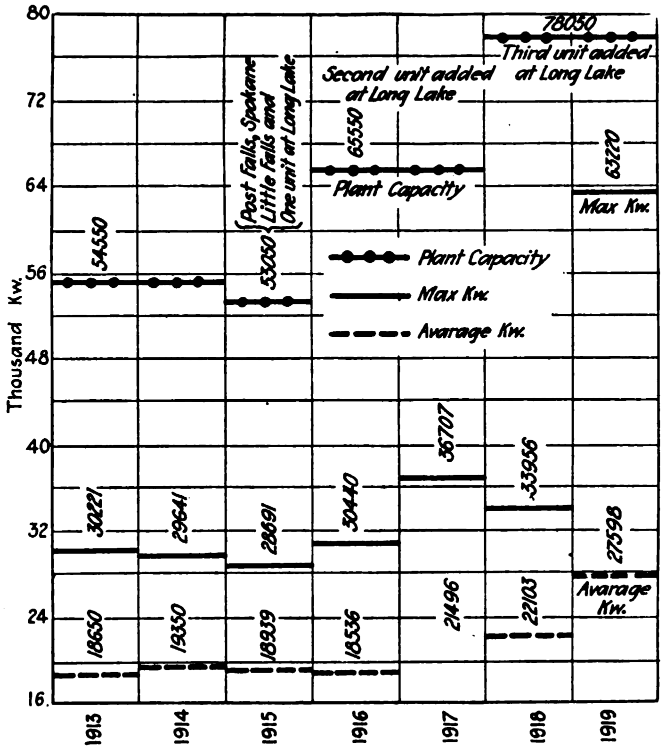


FIG. 1—PEAK LOAD, AVERAGE LOAD AND GENERATING CAPACITY OF WASHINGTON WATER POWER COMPANY FOR PAST SEVERAL YEARS

them in the manner previously described. Sometimes these trunk lines have to be built of steel wire with long spans to avoid a non-paying investment. As the loads develop, however, and the trunk lines are extended they may be converted from second-rate or third-rate construction to first class or second class to reduce the transmission losses and make them more suitable as trunk lines. Some of the lines are steel or copper-clad steel; others, of the first-class trunk-line type, are of aluminum or copper. Rural service is given only from

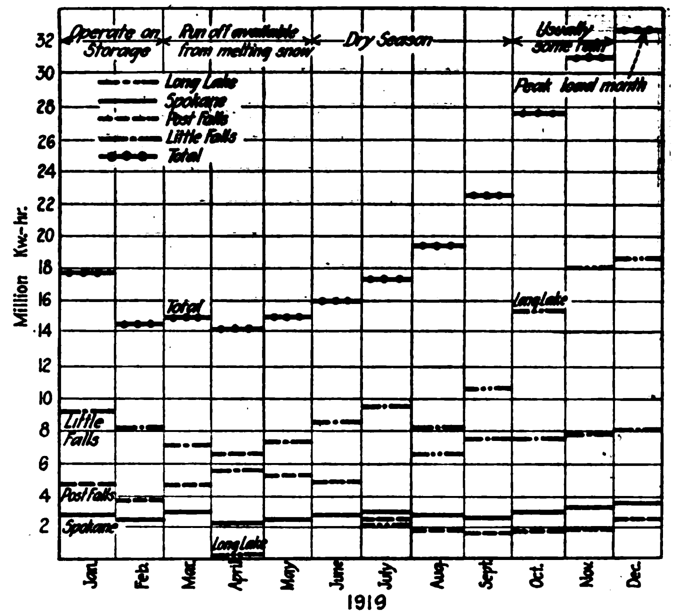


FIG. 2—AVERAGE MONTHLY LOADS FOR 1919 AND DISTRIBUTION OF LOAD BETWEEN PLANTS

The yearly average load for Little Falls was 10,725 kw.; for Long Lake, 8,110 kw.; for Post Falls, 4,840 kw., and for Spokane, 3,925 kw.

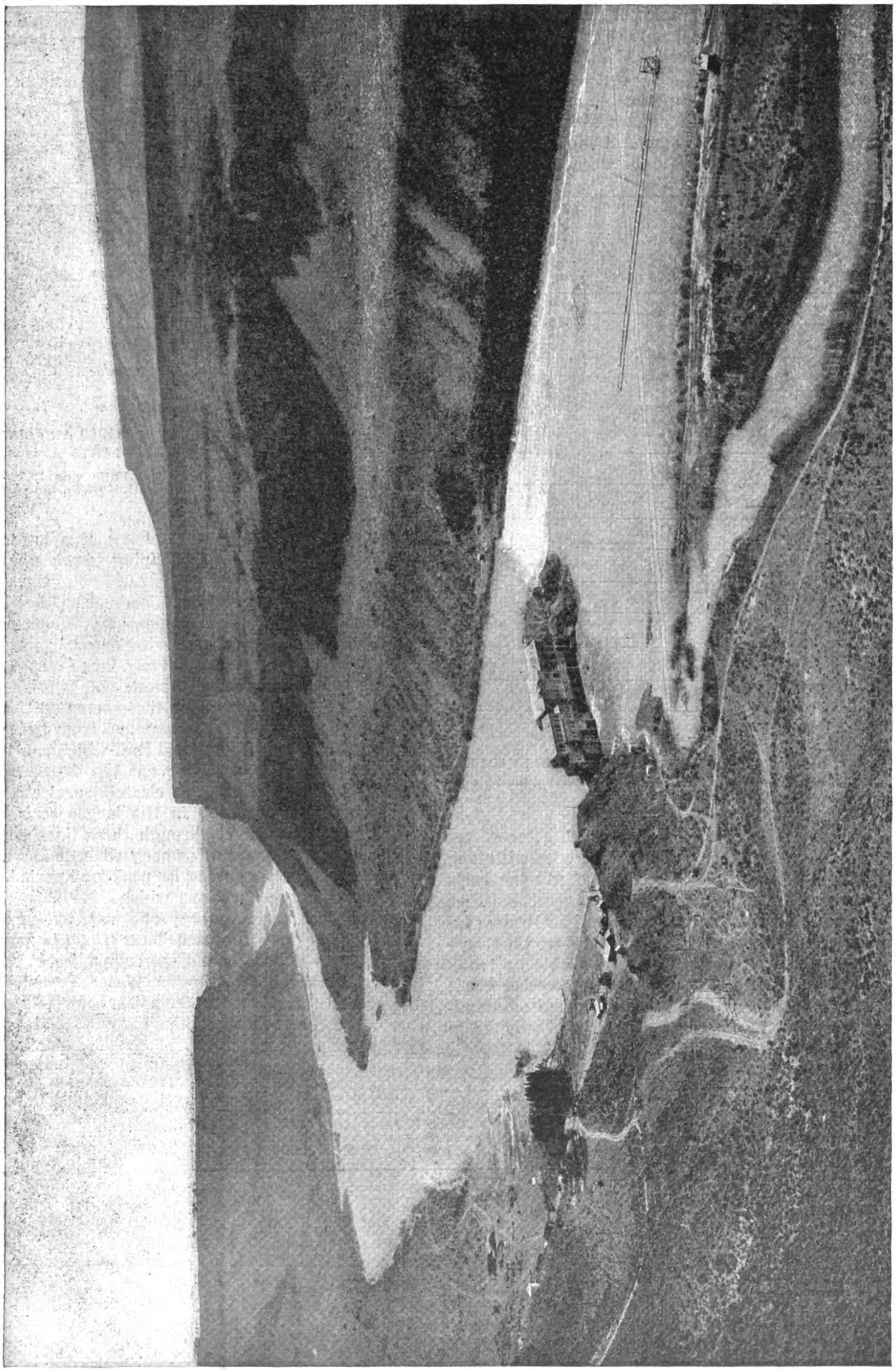
13,000-volt lines or lines operating at a lower voltage because the expense of stepping down the voltage from the 60,000-volt and 22,000-volt lines is too great to justify serving small loads from them. Where sufficient small loads develop along 60,000-volt or 22,000-volt lines that are now traversing sparsely settled territory it is possible that relatively large step-down substations may be provided at some points to feed lower-voltage bus lines from which these communities may be served. However, such a departure from present practice can come only if the total load which can be served from each bus line will warrant the expense.

Still further benefits from electric service are resulting from interconnection in the larger sense—that is between systems—since through these lines energy can be transferred from one company when it has a surplus of power to another during its peak-load period. So far the system interconnections which have been made are only for transferring energy one way, but nevertheless the tie lines may be used later for the purpose of exchange which will benefit the companies at both ends. For example, the Washington Water Power Company is now delivering energy from its Long Lake plant to the Pacific Power & Light Company at Lind (see map)

TABLE I—ENGINEERING AND OPERATING CHARACTERISTICS OF THE HYDRO-ELECTRIC PLANTS FOR 1919

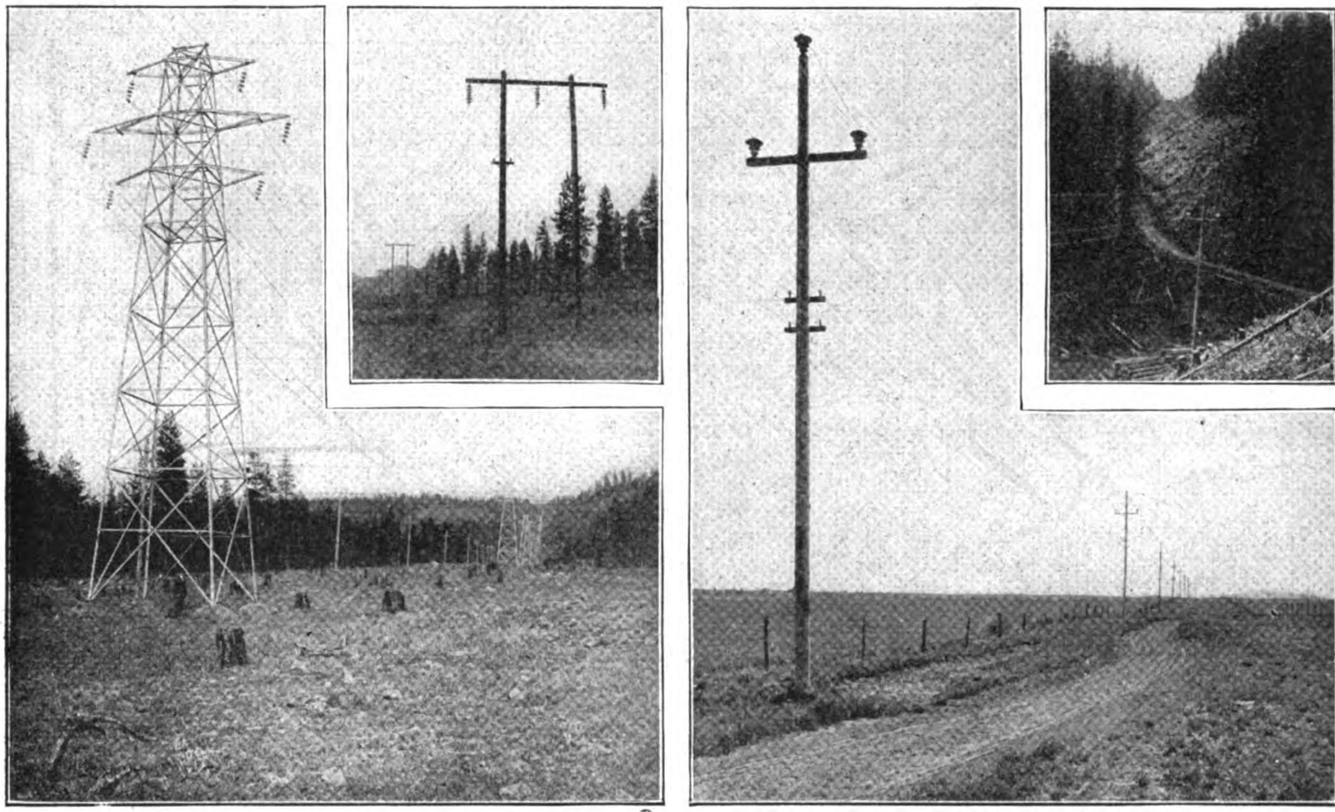
Position on Stream	Name of Plant and Location	Year Completed	Rating (Kw.)	Average Head (Ft.)	Storage (Acre-Ft.)	Dam Height Ft.	Dam Length (Ft.)	Water Flow Sec.-ft. Max.	Water Flow Sec.-ft. Min.	Water Flow Sec.-ft. Average	Kw. Per Sec.-Feet	Load[9] Factor, Per Cent. Yearly
(5)	Long Lake on Long Lake....	1915	46,700	168	62,000[3]	248	251 + 102	50,000	2,065	3,250[7]	12.0	37.4
(4)	Little Falls, Spokane River..	1910	22,800	73[1]	1,740[4]	64	600	50,000	2,065	3,250[7]	5.0	.45.8
(1)	Post Falls, Spokane River...	1906	1,250	50–56[1]	161,150[5]	52[8] 64[8] 45[8]	431 180 78	40,000	840	1,735[7]	3.5	42.4
(2)	Spokane, Spokane River......	....	8,800	75[2]	158,400[6]	19–26	360 + 90	40,000	1,300	2,500	4.0	61.9

1 At low water.
2 Can be increased to 144 ft. by taking water 2,000 ft. further upstream.
3 At 15-ft. draw-down.
4 At 10-ft. draw-down.
5 Water storage in Lake Coeur d'Alene, 158,400 acre-ft.; forebay, 2,750 acre-ft.
6 Water storage in Lake Coeur d'Alene, immediate storage sufficient only for daily variation in loads.
7 For four months in summer.
8 Three channels with the power plant at the middle one.
9 With full load on each unit.



Swan Falls Development of Idaho Power Company on Snake River, Having Rating of 9,900 Kw.

over the Intermountain Power Company line, and through this line and the Chicago, Milwaukee & St. Paul bus line is delivering energy to the Puget Sound Traction, Railway & Light Company on the extreme western side of the State. Reciprocally, if either of these companies overdevelops its system, it can return energy to the Washington Water Power Company. This has not been nor is it now essential because the Washington Water Power Company has been overdeveloped since the beginning of the European war and has had more energy than it could sell in its own territory. However, its business is fast growing and the time may come when its load will exceed what it can furnish from its existing plants. Then exchange of energy will be valuable. As a result of such exchange each of the interconnected companies can get along with less reserve generating equipment.



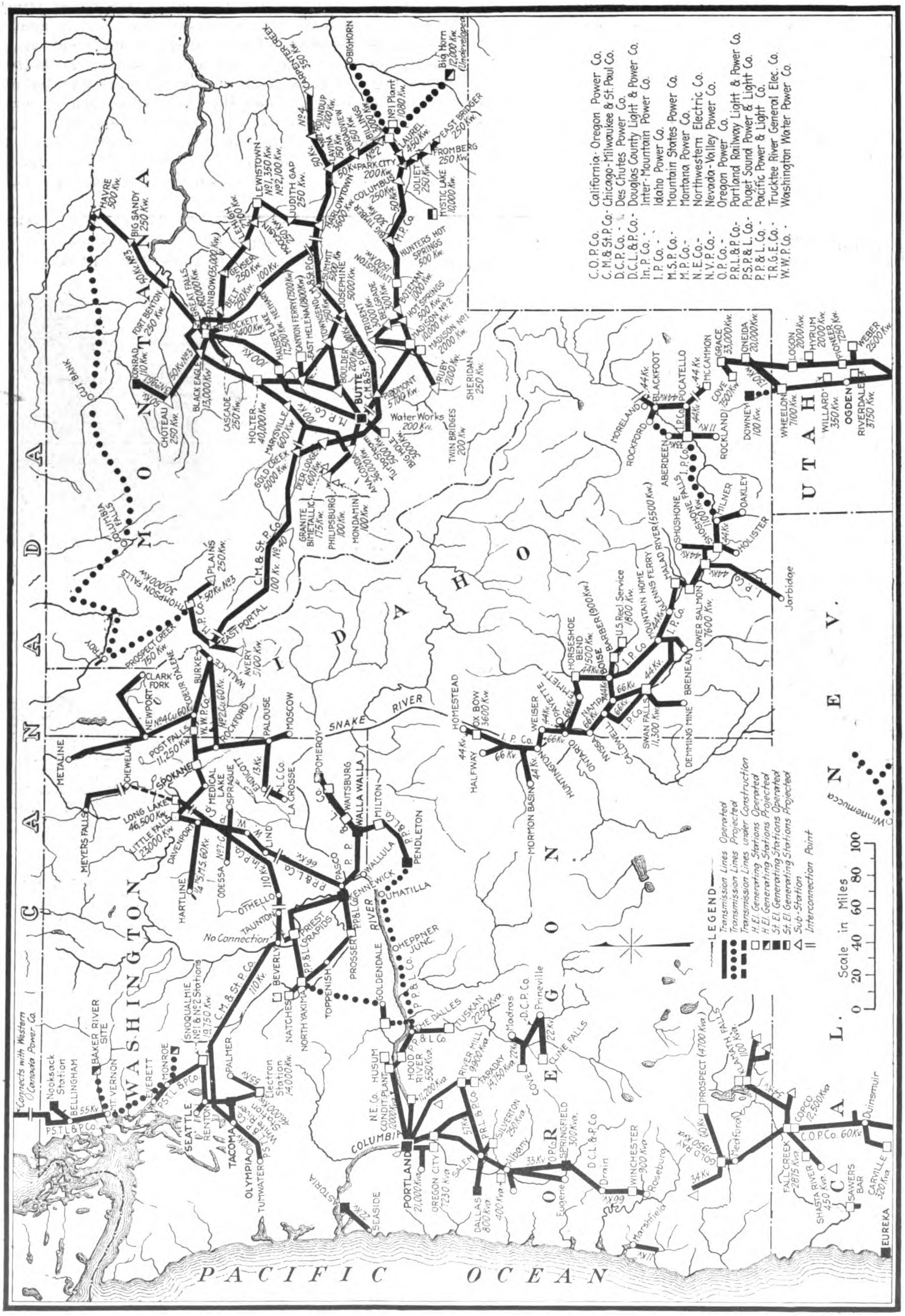
SOME MAJOR TRUNK LINES AND CIRCUITS TO LOAD CENTERS IN EASTERN WASHINGTON

On left, double-circuit 60,000-volt line connecting Little Falls and Long Lake with Spokane, the hub of the Washington Water Power System. In insert on left, single-circuit 110,000-volt line of Intermountain Power Company from Long Lake to Lind and Taunton, feeding the Pacific Power & Light Company, Chicago, Milwaukee & St. Paul Railway, and through the latter the Puget Sound Traction, Light & Power Company. On right, wood-pole 60,000-volt line feeding Big Bend country. In insert on right, Cœur d'Alene 60,000-volt transmission line of Washington Water Power Company in Fourth of July Canyon.

How Water Is Utilized to Best Advantage

The interconnection of plants that exists within the Washington Water Power Company's system enables it to give the most reliable type of service and at the same time to utilize the flow in the Spokane River and the storage in Lake Cœur d'Alene and Long Lake to the best advantage. In general during low-water season it is the practice so to operate the plants that all water is utilized. Post Falls plant, which is farthest upstream on the Spokane River of all of the four plants and consequently nearest Lake Cœur d'Alene, is operated at a uniform load which will maintain the minimum flow required in the Spokane River. This flow is sufficient to operate the plant at Spokane at near its normal generator rating. Long Lake plant, which is the next plant downstream and immediately at the outlet from Long Lake, in turn carries just sufficient load to maintain a flow at Little Falls to operate this plant at a rating that will carry the remaining load. This is the reason why the oldest plant on the system is operated at a higher load factor than the other three plants, contrary to the practice which would be followed if the stations were all steam plants. If the water discharged from Lake Cœur d'Alene raises the water at Long Lake so that there is a chance of its being spilled over the dam, then the load is redistributed and all the water is utilized. Because of the fact that it is desired to keep as much water in storage at Lake Cœur d'Alene as possible during low-water seasons, peak loads are taken by Long Lake or Little Falls. The draw-down on Long Lake during such periods is regained during light loads by collecting water from upstream. Since operation of the plants to secure the maximum use of water does not always give the best power factor and voltage regulation if uncompensated, the idle generators in each plant are used during low water for power-factor correction.

During flood season the plants are operated to insure the best voltage regulation and power factor and the least transmision loss regardless of whether the water is utilized to the best extent or not. At such times water is usually running over the spillways at each plant. During October and November enough rain usually falls to regain most of the storage "let go" during the summer, and thus ample water is available for the annual peak load, which occurs in December. From March to June run-off from melting snow is expected so that water can be stored for the dry season. The system load factor is



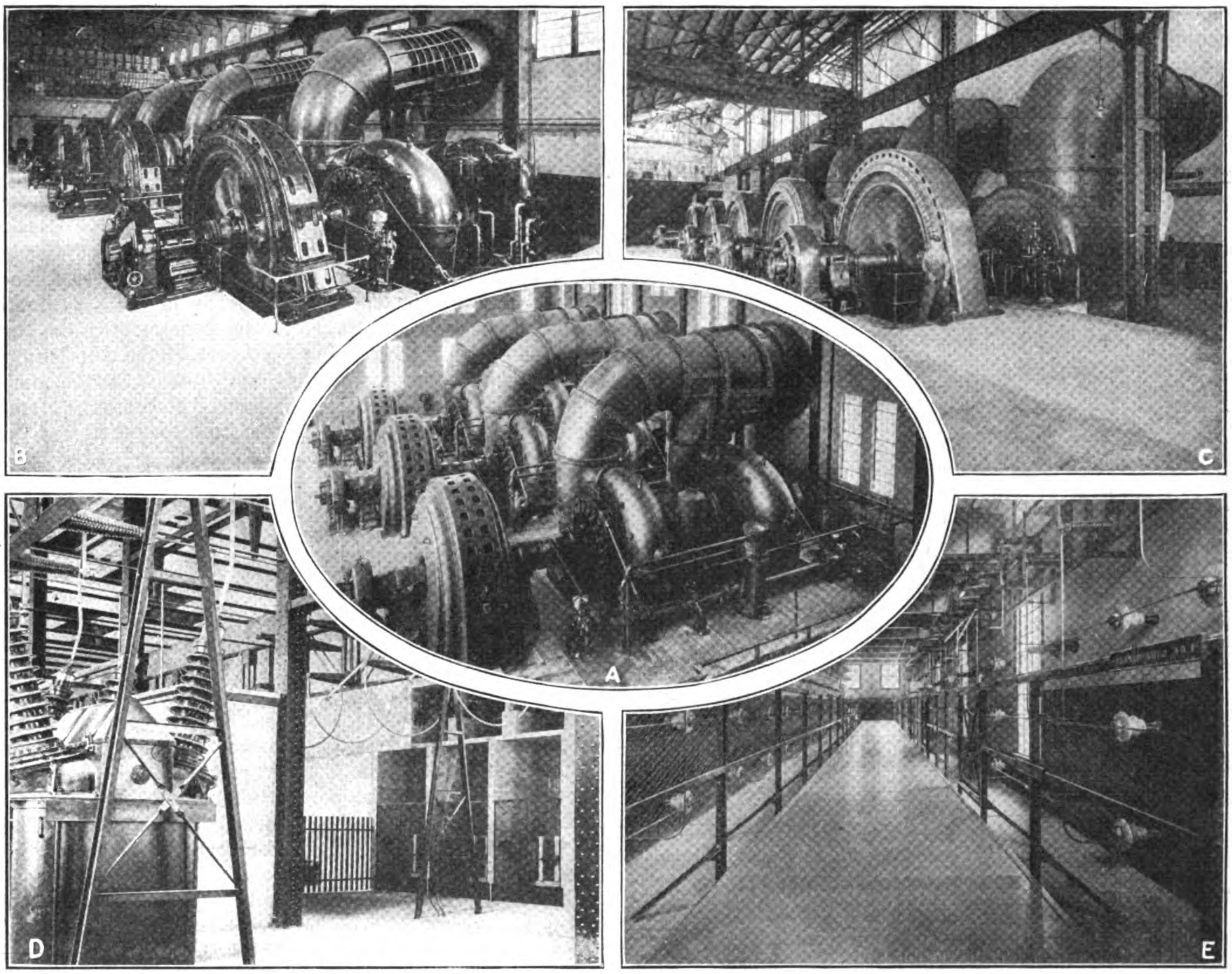
FROM EASTERN MONTANA TO THE PACIFIC TRANSMISSION LINES OF THE GREAT NORTHWEST EXTEND ALMOST WITHOUT A BREAK increasing, and as this tendency increases it will be necessary to draw down on Long Lake during the dry season to a greater extent than at present.

VALUE OF STORAGE

The full benefits of storage in Lake Cœur d'Alene have not been utilized so far, as it was unnecessary to conserve all the water during the last few years since the construction of Long Lake station has provided an excess of power capacity up to the present time.

Storage is highly desirable on practically all Western dammed. The south channel has six sliding gates with an ingenious traveling gate hoister. The north channel contains the principal control works, comprising seven Tainter gate sluiceways, one log sluice and a 110-ft. (33-m.) main sluiceway fitted with two bear-trap dams. During the spring, when high water prevails in the Tainter gates, bear traps and sluiceways are kept open.

Little Falls, the next plant to be completed, has a cyclopean concrete dam with two hand-operated relief gates of the inverse Tainter type which provide for low-water discharge. The spillway is 604 ft. (180 m.) long.



EQUIPMENT OF SOME OF THE WASHINGTON WATER POWER COMPANY'S HYDRO-ELECTRIC PLANTS

A—Three 13,900-kva. blower-cooled generators at the Long Lake station driven by double-runner waterwheels. B—Four similar but lower-head waterwheel-driven generators at Little Falls. C—Five double-runner waterwheel-driven generators at Post Falls. D—110,000-volt switch room at Long Lake with reactor compartments in background. E—Half of 60,000-volt bus room at next to newest station of the Washington Water Power Company at Little Falls.

rivers which have their source in the mountains as they are subject to wide variation in flow in successive months and years.

FEATURES OF HYDRO-ELECTRIC PLANTS

The three latest hydro-electric plants have been described quite fully in former issues of the ELECTRICAL WORLD.* Some of the general features brought up to date are given in Table I and outlined below.

Post Falls plant, which is 10 miles (16 km.) below Lake Cœur d'Alene, is built across the middle of three channels at this point and the other channels are The penstocks are closed by motor-operated headgates bearing on rollers. Four 5,500-kva. generators driven by horizontal twin-runner waterwheels are provided.

The Long Lake development, the most modern of the four plants, has a dam which is unique in at least two particulars. The water spills over the dam itself, making it one of the highest spillway dams in existence. At times of flood about 19 ft. (5.7 m.) of water flows over the crest. Six vertical-lift waste gates are mounted on the crest of the spillway to hold the low-water level at the same level as during high water. The total length of spillway through the gates is 150 ft. (45 m.).

Three generators driven by 22,500-hp. waterwheels,

*May 23 and 30, 1908; June 22, 1912; May 29, 1915.

the largest in existence when the plant was completed, are installed, the third unit being placed in operation last year. While the generators were rated at only 18,900 kva. each, tests proved they would exceed this rating so that with the forced-air ventilation provided they would carry 17,400 kw. maximum at 90 per cent power factor. The waterwheels are designed to just carry this load easily. Instead of having the oil pumps driven from the shaft, as is done at the Little Falls plant, they are driven by motors. The open-tank oil system is employed.

The buses and switching equipment are laid out in such a way that, while each generator and its corresponding transformer ordinarily operate as a unit, they can be operated in a number of other ways if the occasion demands it. To permit this flexibility of operation a single sectionalized low-tension bus is provided that can be formed into a loop bus by a cable running from one end of it to the other. Between each two sections of the bus is a 10 per cent reactor that can be inserted or cut out of circuit as desired. While each generator normally feeds into its corresponding transformer

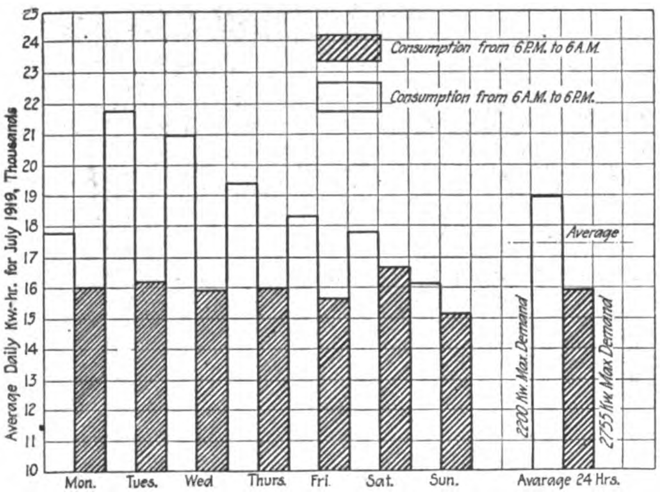


FIG. 3—EFFECT OF RANGE AND WATER HEATER LOAD ON RESIDENTIAL LOAD IN SPOKANE (JULY, 1919)

through an oil switch, it can be connected with its section of the low-tension bus and thence with any other transformer. This required three low-tension switches per generator installed. These are of the H-6 type.

Additional flexibility is provided by a loop-type high-tension bus with four oil switches per transformer. Through these any transformer may be connected with its own feeder or with any other feeder. Both 60,000-volt and 110,000-volt lines are supplied, and type K-15 and type K-36 oil switches are used respectively.

Reverse-power relays are used on the generators and transformers, selective relays between the generators and transformers, and inverse-time-limit relays on the outgoing lines. While the generator neutrals are not grounded now, they will be eventually and balanced protection will be provided.

The low-tension bus and switch layout is very interesting because it enables almost any desirable connection, permitting convenient placing of any apparatus that may be required and ready access to it. Two vertical tiers of bus compartments are placed parallel to each other with an aisle between and the oil switches overhead. In addition to the advantages mentioned, this obviates having switches and buses on different floors and gives a firm foundation for the switches.

TABLE II—AVAILABLE STORAGE IN RESERVOIRS

	Acre-Ft.	Sec.-Ft. Available
Coeur d'Alene	151,250	445 for 120 days.
Post Falls	2,750	Sufficient for daily load variations.
Long Lake	62,000	260 for 120 days.
Little Falls	1,740	1,000 for 20 hours.
Spokane	......	Enough for daily load fluctuations.

The transformers, which are connected delta-delta for 60,000 volts and delta-star for 110,000 volts, are installed in fireproof compartments at one end of the wheel room, with the high-tension buses overhead and the low-tension buses behind them on the wall. Over them on a mezzanine floor are the low-tension buses and switches within sight of the control board. In another section of the bus and switch house running parallel to the low-tension room are the high-tension oil switches, disconnecting switches, bus-sectionalizing reactors and low-tension current transformers. The high-tension buses, which consist of iron pipe, are run overhead between the ceiling trusses, which are designed to give sufficient ground clearance. High-tension leads to the buses and switches come from uptakes in the floor below. On the floor above are the lightning arresters, choke coils, high-tension current transformers and line "disconnects." The horn gaps, lightning-arrester "disconnects" and terminal tower for the outgoing lines installed are on the roof.

MAGNITUDE AND NATURE OF LOADS

As mentioned before, the principal load centers are at Spokane, in the Cœur d'Alene district, and in the big Bend and Palouse districts respectively. Waste power is sold to the Pacific Power & Light Company, which has a maximum demand of about 6,000 kw. An additional 15,000 hp. is transmitted over the Intermountain Power Company's 110,000-volt line to the Chicago, Milwaukee & St. Paul Railroad electrification at Taunton. All power that the railroad does not use is transmitted over its bus line to the Puget Sound Traction, Light & Power Company. Commercial power in Spokane and suburbs amounts to about 40,000 connected horsepower. The electric range load on this system, which far excels the range load on any other system, is 20,000 kw. (connected). It is worthy of attention that 17½ per cent of the rural consumers have electric kitchens—*i.e.*, electric ranges and water heaters—and that there is a service connection for every four persons. Irrigation and municipal pumping together constitute 8,000 hp., although irrigation is not so prevalent in this territory as

TABLE III—GENERAL STATISTICS REGARDING WASHINGTON WATER POWER COMPANY

	1919	1918
Generator rating (kw.)	78,050	78,050
Maximum load (kw.)	63,220	33,956
Average load (kw.)	27,598	22,103
Energy generated (kw.-hr.)	241,761,350*	193,628,500
Yearly load factor (per cent)	43.6	65.09
Average monthly load factor (per cent)	78.0	70.60
Connected motor load (hp.)	62,400	58,200
Consumption (kw.-hr.)	187,395,293	148,458,721
Miles of transmission:		
60,000-volt	654	630
22,000-volt	32	32
Miles of distribution	700†	650†

* At present rate the energy generated for 1920 will be between 350,000,000 kw.-hr. and 400,000,000 kw.-hr.
† Approximate.

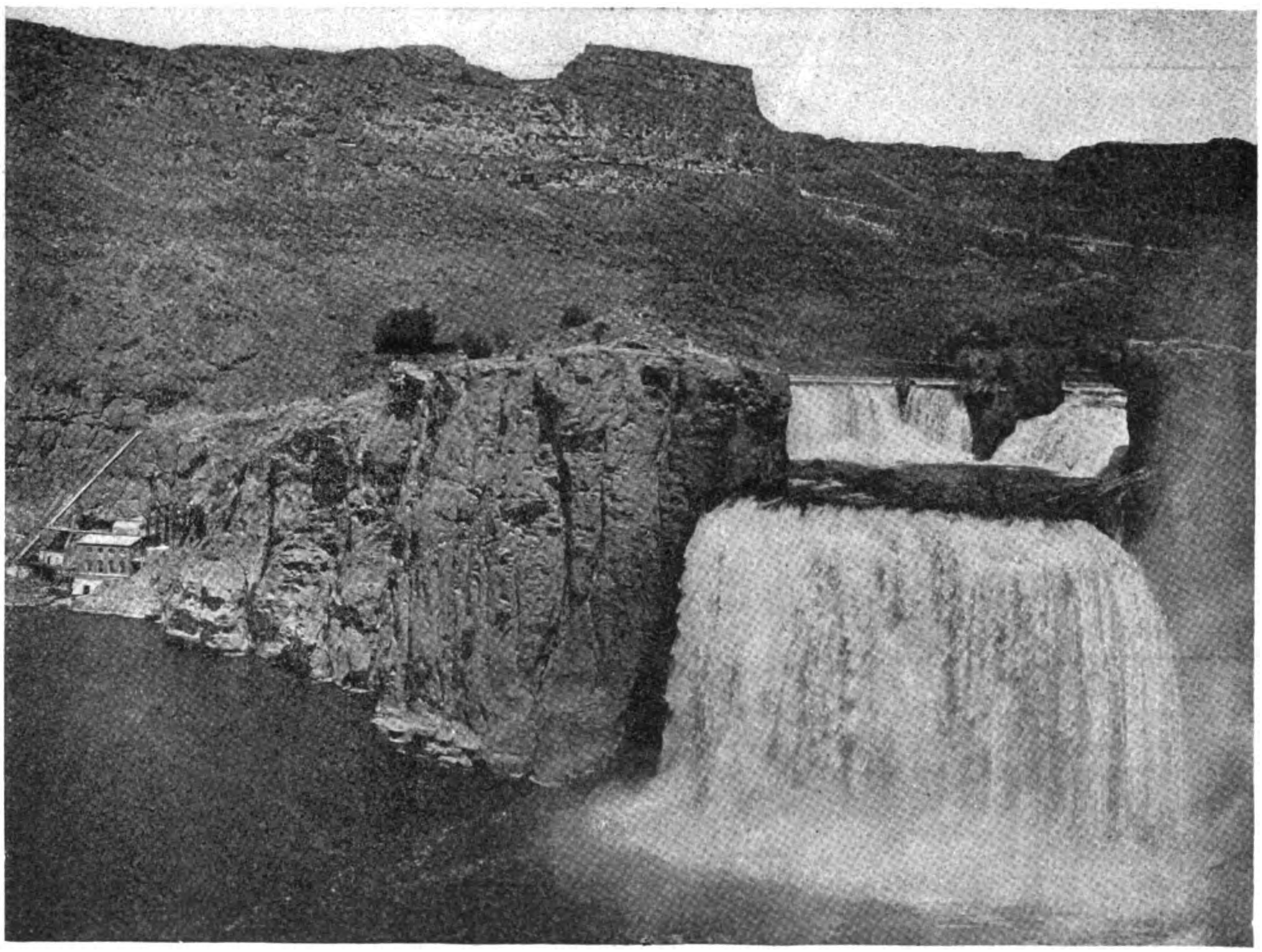
in some other parts of the West. About 4,000 kw. is supplied to the Washington Water Power Company's street railway, and connected loads in flour mills, railroad shops, meat-packing houses and lumber mills are about 3,000, 2,000, 1,500 and 1,000 kw. respectively.

PAST BUSINESS AND FUTURE OUTLOOK

Unlike many territories, eastern Washington was hard hit during the war because it had practically no war industries, men migrated to other sections and business in general was curtailed. As a result the electric service business suffered. Immediately after the armistice, however, electric service picked up, and it has increased rapidly ever since except for slight setbacks due to curtailment of mining in the Cœur d'Alene district owing to market prices and labor conditions. The future outlook is quite promising, and in addition to the natural growth in business it is expected that new loads will develop. For instance, some magnesite mines have been started north of Spokane, and the load may be particularly attractive if the operator converts this mineral to magnesium electrolytically. Pulp and paper industries are developing, and more activity can be expected because of the abundance of wood available and the composition wood products that can be marketed. Flour-mill loads are developing rapidly, and, since this section ranks as a great wheat-growing country, they promise to be still more attractive. In the territory Armour has built a meat-packing plant which is the only one of his plants driven entirely by central-station power, and a meat-packing center is expected to develop around it. Lumber-finishing mills are already being served, but until some use is found for the scrap lumber from sawmills which will prevent its being burned the opportunities for increasing service to such mills are rather slight.

UNDEVELOPED WATER POWERS IN VICINITY

As loads increase it will be feasible to develop other water powers in which Washington abounds, but at present most of the undeveloped sites do not have a sufficient market to justify their development. Among the water powers available are those at Priest Rapids and Kettle Falls, on the Columbia River; Z Canyon, on the Pend Oreille River; Salmon River, Clearwater River, Clark Fork of the Columbia River, Kootenai River, Priest River, other sites on the Spokane River, and possibly Lake Chelan if some of the engineering obstacles now apparent can be removed. Development of any of these sites will benefit all companies now operating in this territory if system interconnection is still further developed.

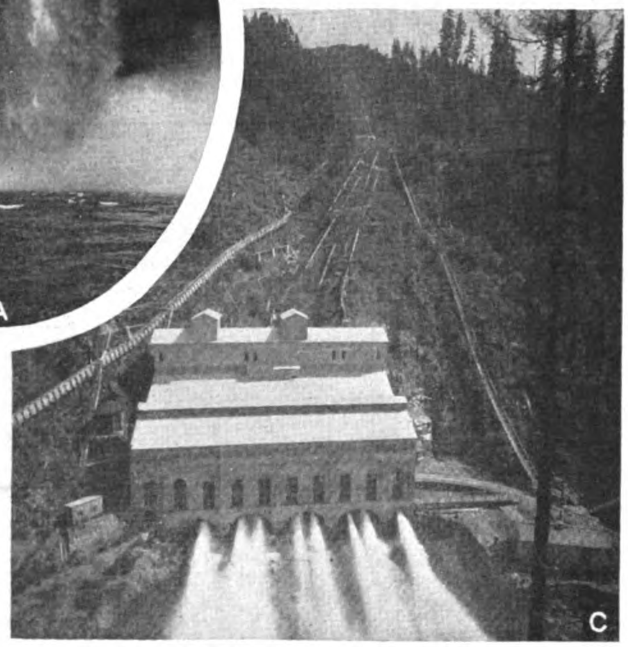


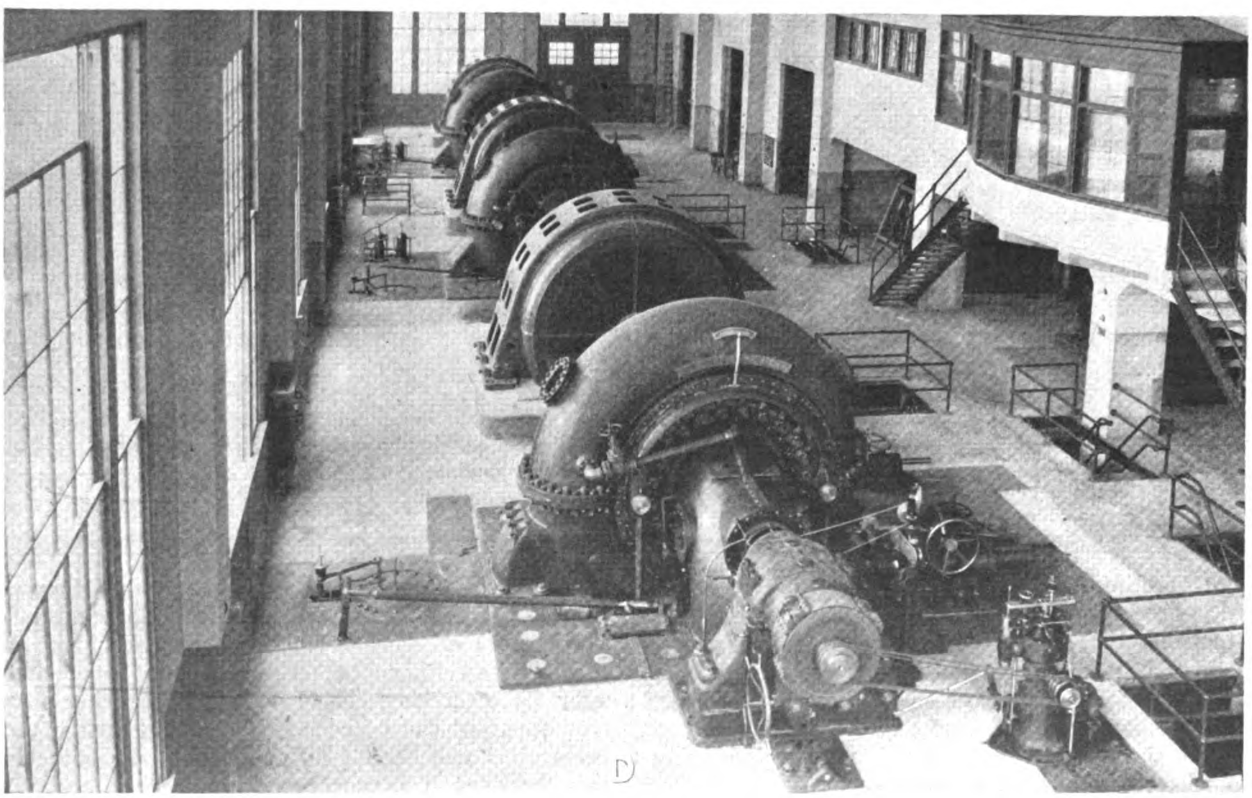
SHOSHONE FALLS DEVELOPMENT OF IDAHO POWER COMPANY ON SNAKE RIVER.
STATION AT LEFT, OPERATED UNDER HEAD OF 210 FT.

The information for this engineering study was kindly contributed by members of the Washington Water Power Company, of which D. L. Huntington is president, W. E. Coman is vice-president and general manager and V. H. Greisser is chief engineer.

Water Powers That Provide Energy for Western Washington

Interior of 46,000-kw. Station on White River at Dieringer





A—Snoqualmie Falls furnishes a 286-ft. head for about 20,000 kw. in generators underground on each side of the falls; in summer very little water goes over the falls.

B—Flume connecting Puyallup River with Electron plant; Mount Rainier, the source of the Puyallup and White Rivers, can be seen in the background of this illustration.

C—Electron, which is connected with bus at White River station, operates on head of 865 ft.

D—T-wheel room of White River station, the largest and most modern hydro-electric plant of the Puget Sound Company.

Hydro-Electric Service West of Cascades

Although Competing with Municipal Plants, the Puget Sound Power & Light Company Has Been Able to Maintain a Firm Foothold by Reason of the High Degree of Service Reliability Assured

THAT portion of Washington west of the Cascade Range is as unlike the eastern part of the State in climate, topography, commercial activity, and hence electrical development, as day is from night. The rainfall is much heavier, there are no wide expanses of level land for agricultural development, the proximity to the ocean gives to the cities more of the trading character, and industry is more predominant. This section is provided with electric service almost entirely by the Puget Sound Power & Light Company, which has two distinct transmission systems, one extending northeast and southeast from Bellingham, the other taking in the territory on Puget Sound including Everett, Seattle, Tacoma and Olympia.

The company has an unusually diversified load such as results from serving prosperous seaport cities which do not have any single dominating industry that takes a large amount of power. For example, in Bellingham there are salmon canneries, cement mills, can factories, lumber and shingle mills, interurban lines, and rural light and power, with prospects of considerable mining load some day. Everett is essentially a manufacturing city producing lumber and its products. The principal load as far as magnitude is concerned, however, is that derived from the paper mills. Tacoma, which is at the head of ocean navigation on Puget Sound, offers excellent wharfage facilities for railway and steamship terminals, and these apply electricity in various ways. The chief industry is lumber, with flour milling ranking next. A large smelter, a shipbuilding yard and a street railway system are served with electricity, and energy is sold in bulk to the municipal plant in this city.

Seattle, the largest load center in western Washington, is the leading port on Puget Sound and has an enormous import as well as export trade. The largest single load in this territory is electric traction (about 20,000 kw.), the remainder being made up of (1) iron and steel-working shops, (2) coal mines, (3) lumber, box and paper mills, (4) office buildings, department stores, hotels and clubs, (5) flour milling, (6) shipbuilding, (7) can making and canning, (8) dock operations, (9) brick, tile and clay, (10) oxygen production, and (11) entertainment places, ranking about in the order of the groups named. The magnitudes of a few of these loads are given in the accompanying table with the average yearly load factors. Load factors, however, are no indication of the value of the loads to this company nor to a good many others, since the diversity factor is very high. Recently a large load (10,000 kw.) in the form of a contract with the Intermountain Power Company to serve the Chicago, Milwaukee & St. Paul electrified road has been acquired.

Hydro-Electric Plants in Seattle District

Because of the greater magnitude and importance of the load in the southern district, the principal generating plants have been developed in connection with this district. There are three hydro-electric plants. The oldest, rated at 11,000 kw., is at Snoqualmie Falls; the next newest is at Electron and is rated at 14,000 kw., and the most modern is at Dieringer, on the White River, with a rating of 46,000 kw. A second plant was built at Snoqualmie Falls in 1910 with a rating of 8,750 kw. Some of the characteristics of these plants are given in Table II. It may be noted that Electron has the highest head—865 ft. (263 m.) and develops the most power per second-foot (46.5 kw.), whereas White River has the largest storage—56,000 acre-ft. (68,880,000 cu.m.). Snoqualmie Falls has the highest river flow, however, and operates at the best yearly load factor and also most economically. Impulse wheels are used in both the Electron and Snoqualmie Falls plants, whereas center-flow, end-discharge Francis wheels are employed at White River.

Connected with the southern system are also two steam* plants with a combined rating of 26,500 kw., the principal one, situated at Georgetown, having a rating of 23,000 kw. This plant is used chiefly to compensate for deficiencies in water flow and must stand ready to take an emergency load any time.

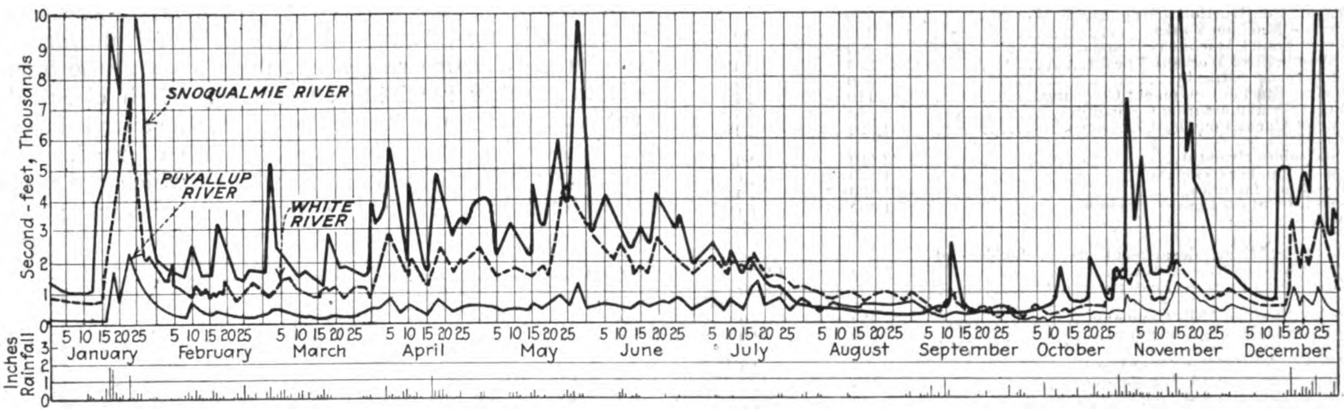


FIG. 1—VARIATIONS IN FLOW OF SNOQUALMIE, WHITE AND PUYALLUP RIVERS, WHICH FEED THE PRINCIPAL HYDRO-ELECTRIC STATIONS OF THE PUGET SOUND POWER & LIGHT COMPANY, FOR YEAR 1919

*The Puget Sound company was a pioneer in the burning of powdered coal and is still conducting extensive investigations in connection with its use in steam-heating plants. However, the company has not utilized coal in this form in its generating stations and will not do so until it feels that the experimental stage has been passed. Results of experience with powdered coal have been published in the ELECTRICAL WORLD.

Additional power is received over the Intermountain Power Company's connection with the Chicago, Milwaukee & St. Paul Railroad and the Long Lake development of the Washington Water Power Company when the railroad does not utilize all the power for which it has contracted. In the northern district is an 1,800-kw. hydro-electric plant on the Nooksack River. Power is also obtained across the Canadian border from the Western Power Company of Canada.

How Lines Are Laid Out to Assure Reliable Service

The method of serving the territory under consideration is best indicated by the transmission map on page 1056. As shown, a 55-kv. line runs from the Nooksack plant to Bellingham, which also receives energy from the Western Power Company of Canada on the north. A line running south to Burlington and branching to Mount Vernon and Contrete serves towns to the southeast. Lines operating at 11,000 volts run south from Mount Vernon, but a gap now exists between their southern extremities and the southern system.

The southern system is laid out so that the load centers are amply assured of reliable service from all or any of the three hydro-electric plants—Snoqualmie Falls, White River and Electron—more than one circuit running to each city. Seattle is particularly well provided with service facilities. For example, it may receive energy over two lines from Snoqualmie or White River and over another pair of circuits from the latter plant as well. White River in turn is reinforced by having Electron connected with its buses by two direct lines and one loop line to the east of White River, so that the two plants operate practically as one generating station. Additional flexibility in service is afforded by having a tie line between two of the transmission lines to Seattle. By this means if anything happens to either the load can be transferred to the other.

Not only is Seattle provided with four paths of energy and a local steam plant but these lines are so connected with substations that there is no likelihood of service being interrupted. One pair of transmission circuits goes to one receiving substation and the other pair to another receiving substation. Each circuit is kept isolated from its mate by sectionalized buses, which may be closed, however, in case of need. The remaining substations have two buses which are separately energized from the two main receiving stations but may be connected if necessary. Ordinarily

TABLE I—NATURE AND MAGNITUDE OF PRINCIPAL LOADS IN SEATTLE DISTRICT, SHOWING DIVERSITY

Load	Demand Kw.	Load Factor (per Cent)
Pacific Coast Steel Company	2,250	40
Washington Iron Works	700	28
Pacific Construction & Engineering Works	250	33
Seattle Machine Works	150	30
Puget Sound Machinery Company	200	24
Olympic Steel Works (off peak)	273	30
Steel furnaces (peak)	350	20
Hofeus Steel & Equipment Company	110	24
Vulcan Manufacturing Company	250	23
Pacific Car & Foundry Company	1,000	30
Coal mines (twenty)	4,800	50
Canal Lumber Company	1,000	21
Wood-box factories	1,500	20
Everett Pulp & Paper Company	1,092	65
Northern Pulp & Paper Company	600	40
Office buildings, department stores, hotels and clubs	2,500	14–52
Theatres and places of entertainment	800	10–40
Fisher Flouring Mills Company	2,250	60
Hammond Milling Company	550	50
Ballard Shipbuilding Company	50	20
Elliott Bay Shipbuilding Company	125	22
S. F. Duthie Shipbuilding Company	1,300	32
American Can Company	180	29
*National Fruit Canning Company	30	11½
*Fruit canneries	600	20
*San Juan Fish & Packing Company	225	44
Seattle Can Company	125	25
O. & W. R. R. & N. C. dock	50	20
Pacific Coast Steamship Company	70	32
Grand Trunk dock	30	15
Colman dock	50	19
East Waterway dock and warehouse	100	21
Todd dry docks	790	19
Denny Renton Clay & Coal Company	515	10
Seattle Brick & Tile Company	25	19
Seattle Oxygen Company	180	90
Air Reduction Company	125	50
Linde Air Products Company	225	74
Washington Burdette Oxygen Company	175	55

*Works three months of year.

TABLE II—CHARACTERISTICS OF PRINCIPAL HYDRO-ELECTRIC STATIONS OF PUGET SOUND POWER & LIGHT COMPANY.

Name and Location of Plant	Snoqualmie Falls		White River	Electron
Year completed	No. 1–1898	No. 2–1910	1911	1903
Rating	11,000	8,750	46,000	14,000
Average head, ft	225		440	865
Storage, acre-ft	350		56,000	88
Value of storage (kw.-days per acre-feet)	7.16*		13.6†	23.4*
Height of dam	20		Diversion dam only	Diversion dam only
Length of dam	217			
Water flow (sec.-ft.) max.	26,880		11,566	3,200
Water flow (sec.-ft.) min.	350		300	120
Water flow (sec.-ft.) average	3,000		2,450	600
Kw. per sec.-ft.‡	14.2		27	46.5
Yearly load factor, per cent	67.1		45.1	49.3
Ranks as regards operating cost:				
(a) Per kw. installed	1		3	2
(b) Per kw.-hr	1		3	2

*Storage for daily fluctuations in load only.
†As measured at intake of storage reservoir and used within 15 days. Evaporation and seepage in three months' time is 17 per cent.
‡Mean water level and at full-load efficiency.

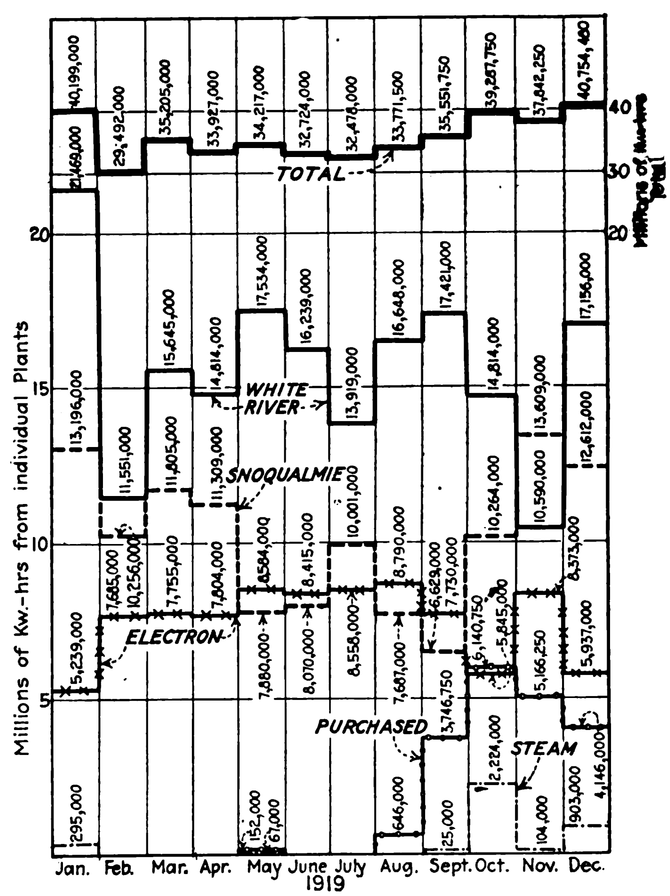


FIG. 2—DIVISION OF YEARLY OUTPUT BETWEEN PLANTS OF PUGET SOUND COMPANY

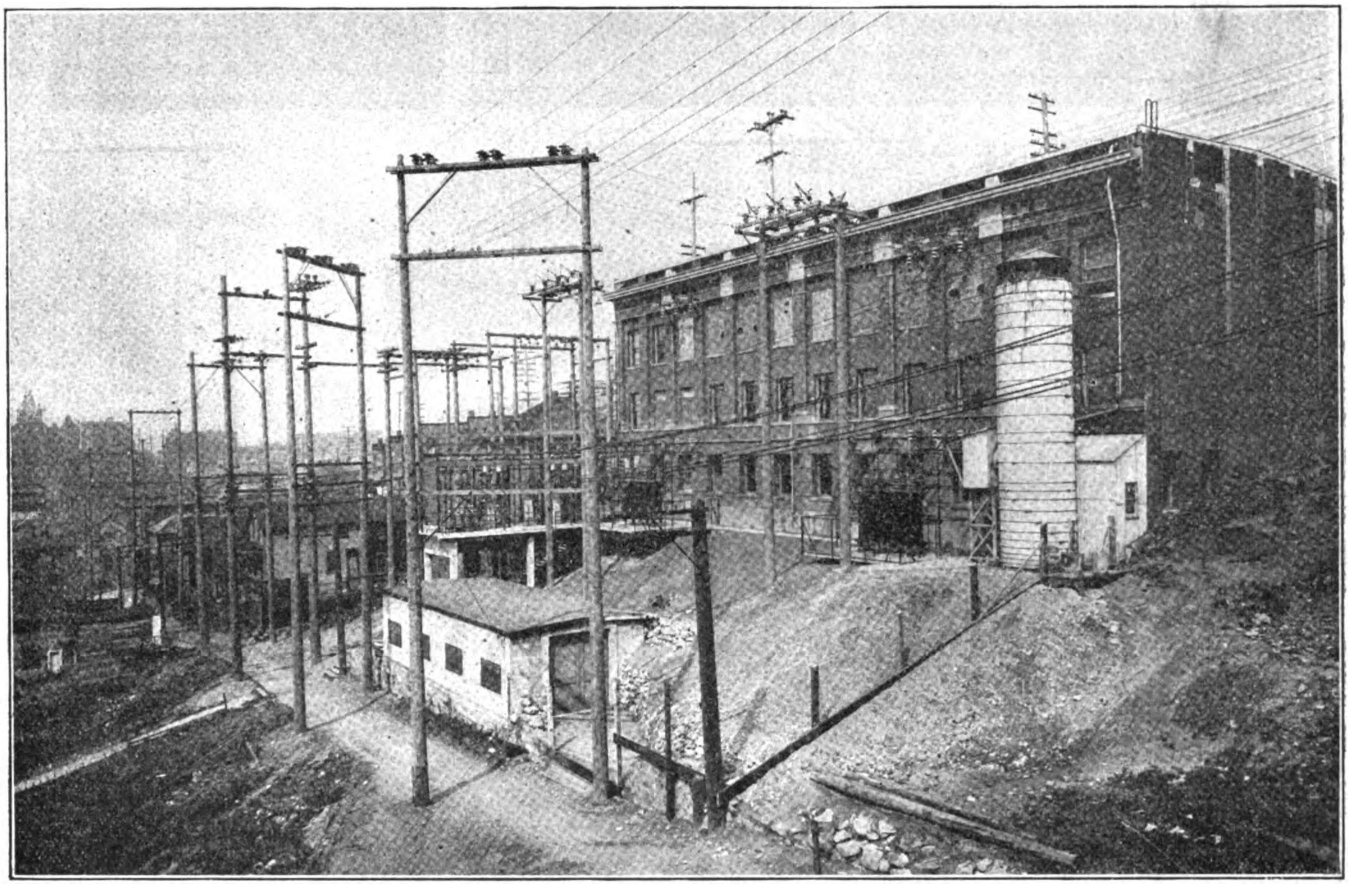
the high-tension feeders are kept isolated and the system is paralleled only on the low-tension side. Tie feeders are provided between all the substations and kept alive at one end to permit interconnecting when necessary.

Reliability of service is still further assured by relays. In the outgoing feeders at generating stations there are overload relays, and in all incoming feeders there are reverse-power relays. The overload relays in the lines from White River to Seattle are set for ten seconds definite time, while those in lines to Tacoma are set for three seconds. The overload relays at Electron are set for five seconds and those at Snoqualmie for eight seconds. Thus Seattle service will be the last to be interrupted, Electron letting go first, Snoqualmie second and White River, the largest plant, last.

Reliable service to both Tacoma and Everett is assured by duplicate transmission lines which are isolated at the receiving ends but arranged so either can energize any bus. The coal mines are served by a line running from Electron to Palmer which is tapped at Buckley by another transmission line from White River. A very effective line-inspection system has been in use for some time, and it also reduces the likelihood of interruption to service.

Possible Interconnections of Future

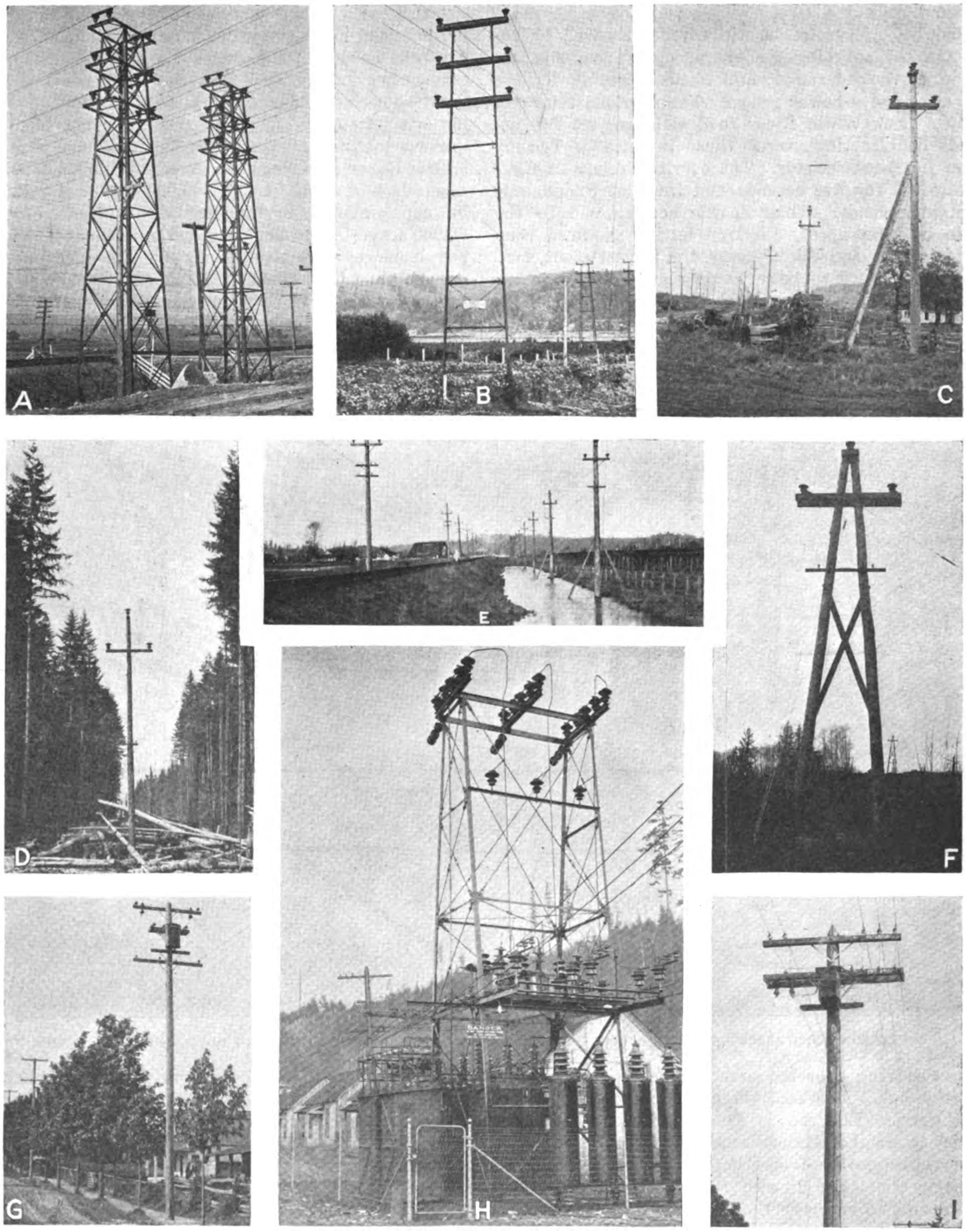
As can be seen from studying the maps, it will be possible to close some gaps and make loop circuits if enough benefits will be gained thereby. In some territories, especially in Seattle proper and between Everett and Mount Vernon, it is possible that as the 13,000-volt lines are extended they may tie together the northern and southern systems, although this capacity would not be sufficient to permit great exchanges of energy. A more effective tie would be afforded by running a 110,000-volt line between Mount Vernon in the northern system and Snoqualmie Falls in the southern system, but this will become feasible and economical only as the financial necessity which now faces all public utilities—the need of higher rates—is relieved and markets for energy are developed in the Bellingham districts great enough to make advantageous its connection with the southern district. Until then it is not likely that the water-power rights which the company now owns on the Baker River will be developed. This site has a possibility of 30,000 kw. to 45,000 kw. that may later be supplemented by another development of about 30,000 kw. Unless sufficient revenue can be earned to pay a more attractive return on the investment required, this development as well as others will doubtless have to wait. When the Baker River site is developed it will in all probability be connected with the 110,000-volt trunk line previously mentioned, the route now considered being indicated on the map. To the east of the Baker River site is the Skagit River development which is now under construction by the city of Seattle.



JEFFERSON SUBSTATION OF PUGET SOUND COMPANY, SHOWING INCOMING 55-KV. AND OUTGOING 13-KV. LINES

In the southern district to the east of the proposed trunk line, at Index, on the Skykomish River, is another water-power site that can develop 10,000 kw. to 20,000 kw. Natural head can be utilized and the plant could be connected with the 110,000-volt trunk line. Farther south, on the upper White River above Buckley, is still another water-power site which can develop about 60,000 kw. by running a penstock several miles upstream. This plant could be connected with the present White River plant.

Types of Transmission Line Construction Used by Puget Sound Company



A—Steel-tower lines at railroad crossing carrying four 55-kv. circuits from White River Station.

B—Flexible steel towers carrying White River lines.

C—Wood-pole lines from Electron to White River.

D—Line to Everett run through timbered tracts where excessive prices asked for cutting trees prohibited as wide right-of-way as would be desirable.

E—Two wood-pole 55-kv. lines along interurban line feeding Seattle.

F—Another 55-kv. line to Everett showing construction employed for 600 to 1,200-ft. spans in rough country and at river crossings.

G—Single-phase 13,800-volt line on top crossarm feeds 13,800/230-115-volt transformer which is connected with three-wire crossarm below.

H—Steel tower substation serving coal mine. This substation is typical of those feeding the larger coal mines in western Washington.

I—A single-phase 6,600-volt line on the left side of crossarm feeds 6,600/230-115-volt transformer that is connected with three-wire secondary on right.

Just south of Olympia around Tenino is the northern terminal of a transmission line belonging to a company that connects with Vancouver. Vancouver in turn is connected with Portland, and from that system there is only a short gap to the lines of the Pacific Gas & Electric Company with its ramifications, interconnections and possible future connections. It is looking too far into the future, though, to think of the gaps mentioned being closed, because the benefits which would accrue would be negligible under present conditions, distances between generating centers being too great. Such interconnections could permit only small interchanges of energy, and the annual charges on lines large enough to permit large power interchanges would make the energy cost more than it could be purchased for locally.

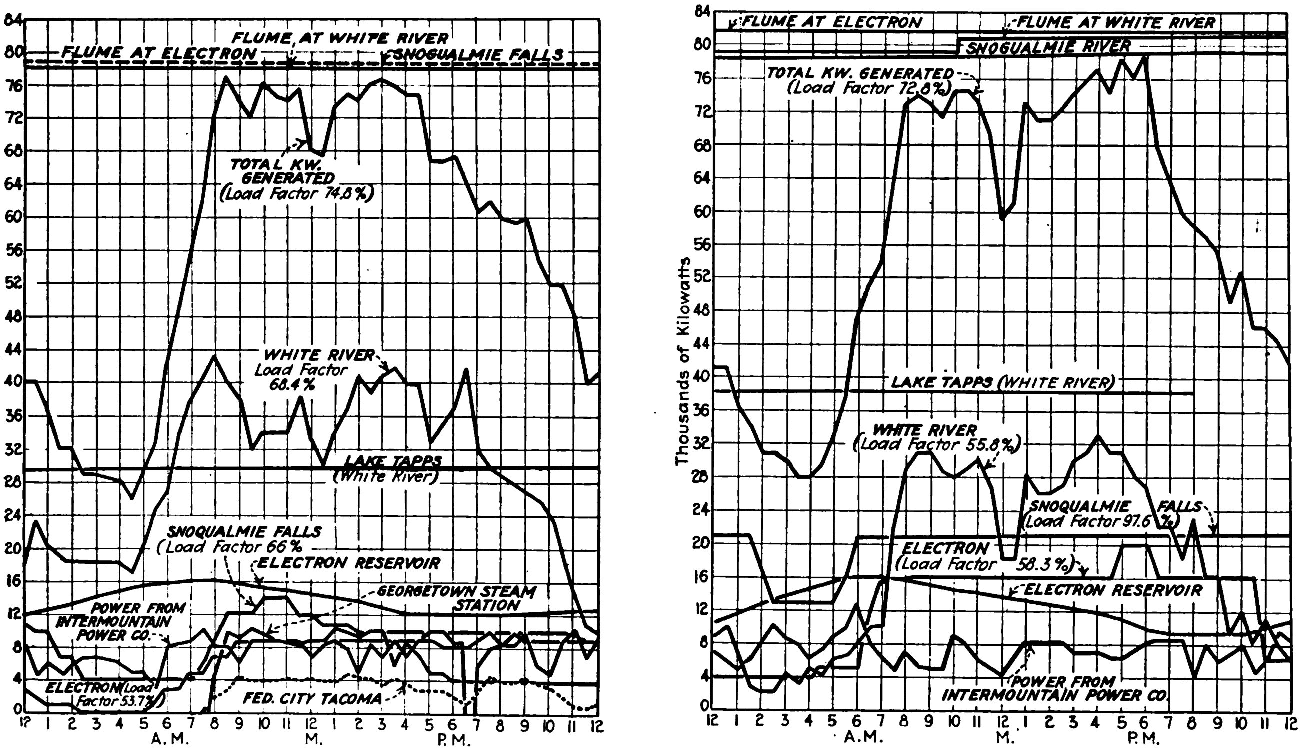
Men on the Pacific Coast do believe, however, that it will be feasible some day to have a coastal trunk line into which all generating stations can feed and from which energy can be taken in bulk for distribution. The problems connected with this plan are not so much technical as financial, since a main question is how the charges for line usage, rates for energy, etc., can be equitably fixed.

How Load Is Divided Between Stations

The operation of water-power plants with relation to each other is a problem that is handled differently in different territories, but stream-flow conditions exist in this country that may be interesting and the fundamental principles involved in operation can be applied anywhere. The three principal plants—Snoqualmie Falls, White River and Electron—take water from three streams quite different in characteristics.

The Snoqualmie River, which feeds Snoqualmie Falls, is a clear-water stream which receives its water from melting snows and rains and none from melting glaciers. It has a very large drainage area covered with heavy timber that regulates the run-off to a great extent. The dry season ordinarily occurs during August, September and October, and the rains are heaviest in winter. On the other hand, Puyallup River, which feeds Electron, rises on the western side of Mount Rainier—14,526 ft. (4,420 m.) high—and receives its water principally from melting glaciers. Of course, it also receives some water from melting snow and rains. As a result the greatest amount of water is discharged through this river when the temperature on the slopes of Mount Rainier is high enough to melt the glaciers. The flow subsides when the glaciers quit melting, but by this time Snoqualmie River begins to benefit from rains.

White River tributaries rise on the north side of Mount Rainier, but at a lower level than Puyallup River. As a result White River has characteristics between those of Snoqualmie River and Puyallup River, receiving water from melting snow, rain and melting glaciers. The rains build up the flow during the winter when snow and glaciers are not melting. As spring progresses the snow melts, and when the warm summer weather occurs the glaciers melt. Thus, except for a short period, usually during October, the river flow is relatively high. The flow in each river is given for the year 1919 in Fig. 1.

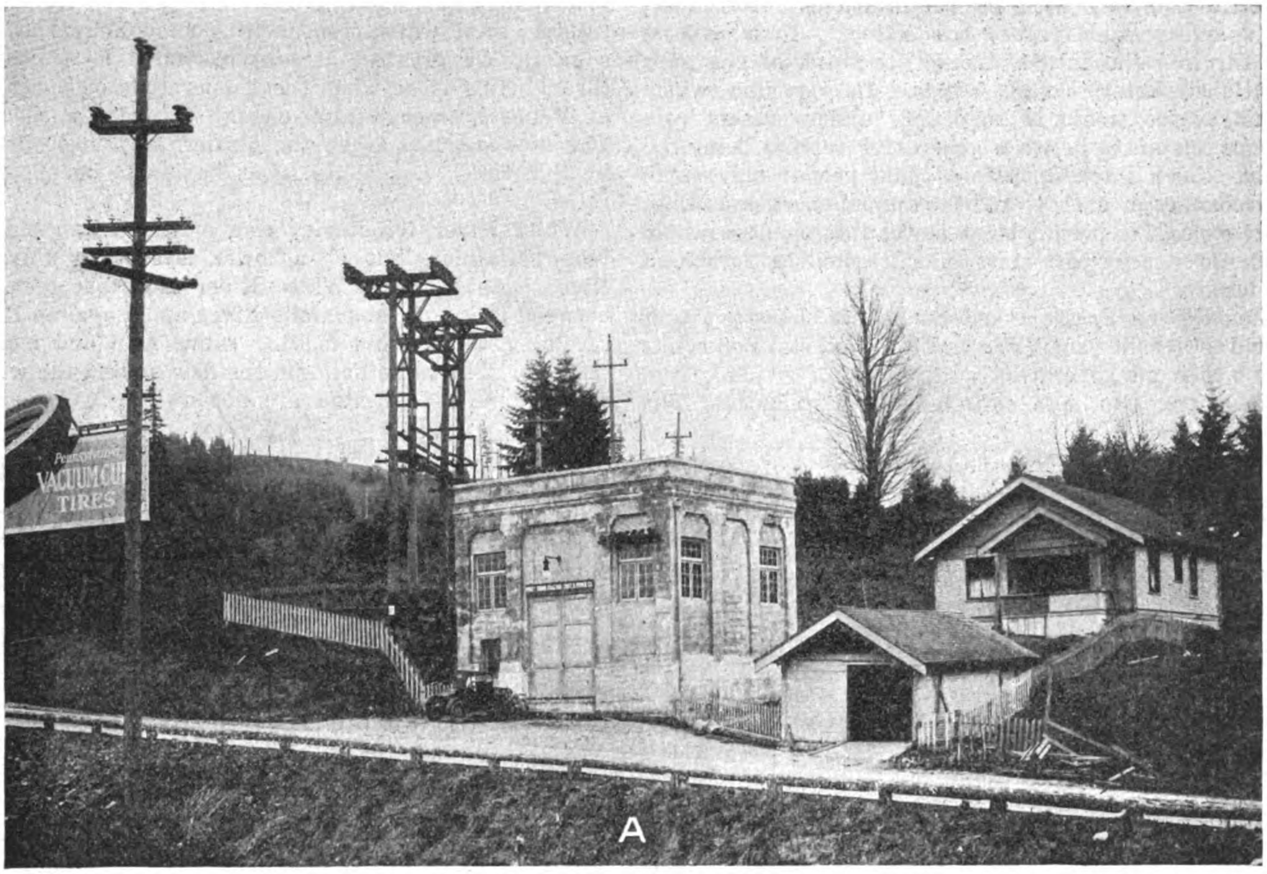


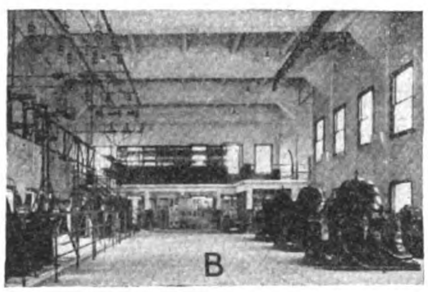
FIGS. 3 AND 4—PUGET SOUND COMPANY PLANT LOADS FOR TYPICAL LOW AND HIGH FLOW DAYS (OCT. 10 AND NOV. 17, 1919)

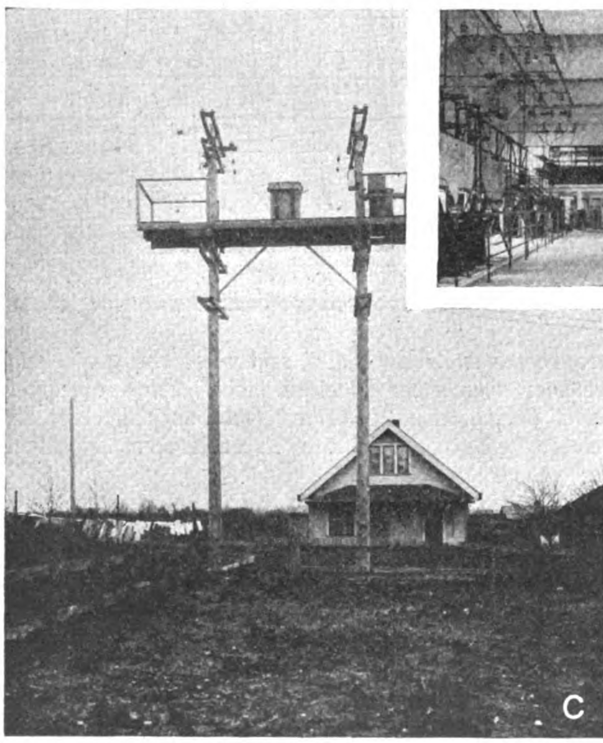
To show how the plants utilize these stream characteristics to the best advantage, the division of total load between plants is given for the year 1919 (Fig. 2) and also for typical high-water and low-water days (Figs. 3 and 4). In studying these curves reference should be made to Table II, which gives the average heads, water flow and storage at each plant.

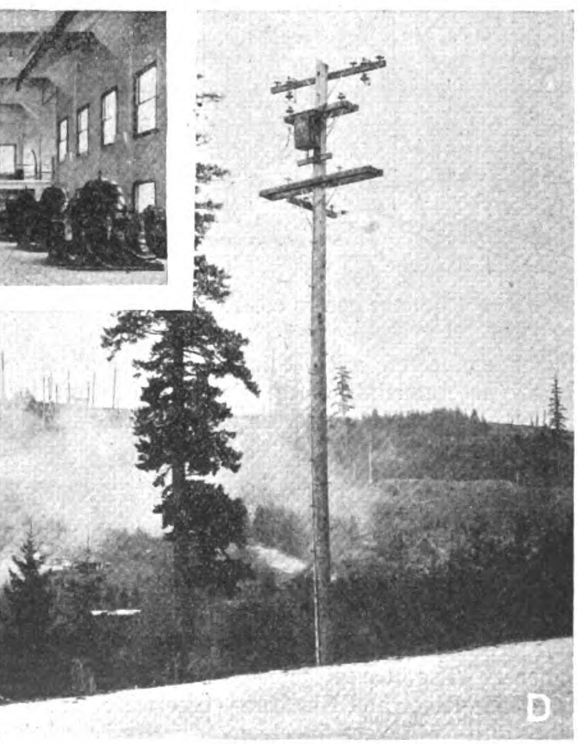
The storage at the White River plant is equivalent to 18,000,000 kw.-hr., while that at Snoqualmie and Electron is only 60,000 kw.-hr., just enough for daily fluctuations in load. For this reason White River storage is allowed to accumulate as much water as possible during the wet season, and Snoqualmie and Electron are used to carry their maximum loads. Of course,

Distribution Features in Rural Sections Fed by Puget Sound Power & Light Company









A—Bothell substation transforms 1,500 kva. from 55,000 volts to 13,800 volts, feeding small towns and rural sections within 15 miles radius; shows cottage and garage for district agent.

B—Main operating floor of Jefferson substation.

C—Pole-top 13,800/2,300-volt transformers and automatic voltage regulator. The structure is designed for three ultimate units of 100 kva.

D—13,800/130-volt transformation for scattered rural distribution.

TABLE III—VOLTAGE OF PRINCIPAL LINES OF PUGET SOUND POWER & LIGHT COMPANY, WITH SIZES OF CONDUCTORS

	Voltage	Size of Conductor
Nooksack (g)—Bellingham (g)	55	No. 2 copper equivalent
Western Canada Power Company—Bellingham (g)	55	No. 2 copper equivalent
Bellingham (g)—Mount Vernon via Burlington (j)	55	No. 1 copper equivalent
Burlington (j)—concrete	55	No. 1 copper equivalent
Mount Vernon—La Conner	13	
Mount Vernon—Stanwood	13	
Snoqualmie Nos. 1 and 2 (g)—Everett	55	No. 4 copper
Snoqualmie Nos. 1 and 2 (g)—Everett via Mo-Aleer Lake	55	No. 4 copper
Loop around Seattle	13	
Snoqualmie (g)—Renton (j)	55	Two 4/0 aluminum
Renton (j)—Seattle	55	Two 4/0 aluminum equiv.
Electron (j)—White River (g)	55	Two 4/0 copper
White R (g)—Renton (j)	55	Two 4/0 copper equiv.
White River (g)—Buckley (j)	55	No. 4 copper
Electron (g)—Buckley (j)	55	No. 4 copper
Buckley (j) to Palmer	55	
White River (g) to Tacoma Smelter and Olympia	55	2/0 aluminum No. 4 copper
White River (g) to Tacoma	55	2/0 aluminum
White River (g) to Seattle	55	Two 4/0 copper
Tap to Tacoma	55	Two No. 1 copper, No. 1/0 copper
Tie between Renton Junction—White River—Seattle; White River-Renton	55	4/0 copper equivalent
Georgetown (g) connected with one of White River-Seattle lines	..	

(g) Indicates generating station; (j) indicates junction point.

as much of the water that cannot be stored as possible is used to generate power at White River during high-flow season because it is the largest plant. Electron can develop the most power per second-foot, however. During low water Snoqualmie and Electron are operated to utilize as much water as possible, White River is operated to carry a fairly uniform load, and the fluctuations in total load are carried by the steam plant at Georgetown. It is usually necessary to start drawing down White River storage (Lake Tapps) in the last part of August or the first part of September. If there are prospects of a prolonged dry season, less water is drawn off and the steam plant is operated at a heavier load. Fortunately, as pointed out before, the low-flow period in Puyallup River occurs later than in the other two rivers, so that the Electron plant can help to make up any deficiency in the dry season. Power from the Intermountain Power Company cannot be depended on for help during low water because of the fact that the Puget Sound Company receives only surplus power.

The division of load for typical low-flow and high-flow days is better shown by Figs. 3 and 4. On the dry day, it may be noted, Electron and Snoqualmie were loaded for as much as they would carry, the reservoirs being drawn down during the day and allowed to fill up at night. However, White River had to carry

TABLE IV—GENERAL STATISTICS REGARDING PUGET SOUND POWER & LIGHT COMPANY

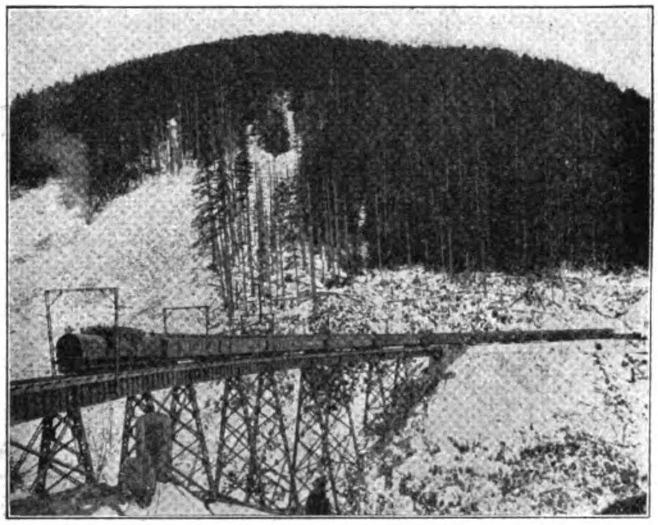
	1919	1918
Generator rating	119,500	109,500
Maximum load	101,400	99,200
Average load	51,500	48,700
Energy generated (kw.-hr.)	447,576,000	423,092,000
*Load factor (yearly)	50 75	49.1
Average (monthly), per cent	63.6	63.8
Connected motor load	100.200	86,300
Loss in transmission, transformation and distribution	96,638,000	87,129.000
Consumption (kw.-hr.)	358,000,000	338,200,000
Miles of transmission	....	....
55,000 volts	566	566
13,000 volts	181	160

* Supplied power to Tacoma for short periods, thus increasing maximum demand and reducing load factor.

the base load and Georgetown steam station had to help. The situation was made more serious than usual by the fact that the Tacoma municipal plant required emergency service on this day. On the high-flow day Electron and Snoqualmie were able to carry larger loads and White River could be operated at less load to allow its reservoir to store water. The idle generator capacity at White River can be used to correct for power factor during the high-flow season.

Prospects of Future Development

The prospects are that the central-station load in western Washington will become still more diversified because, as was pointed out before, Seattle handles an enormous amount of import and export trade which will either directly or indirectly affect electric service development. Besides, as manufacturers find that their markets in the Far West and in foreign places easily



TRAIN ON THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY'S OTHELLO-TACOMA ELECTRIFIED DIVISION, FORMALLY OPENED FOR SERVICE MARCH 5, 1920.

reached from the Pacific Coast ports justify locating factories in the Far West the territory around Seattle is quite certain to become an industrial center, its excellent ports and transcontinental railroad facilities and its delightful climate conducing to its being worked at a high efficiency the year round.

Already large parts of the wool, cotton, silk, rubber and flax that are brought into Seattle are being converted into finished products in the city's mills, and more textile plants are likely to be established there because the humidity is almost ideal for textile manufacture. A great many automobiles are used on the Coast, and the demand for rubber tires has warranted their manufacture in the West. Automobile assembling plants with their electric japanning ovens are also being located there. Steel shipbuilding, which was stimulated by the war, is continuing.

Lumbering has always been a predominant industry in the Northwest, and as the supplies of timber elsewhere in the world become depleted, which is fast occurring, this industry will increase in importance. Timber will not become exhausted if proper protection from fire is given to second growth and if it is made financially possible to hold cut-over timber lands until the second growth is ready for cutting. While the logging industry has not been served extensively by central stations so far, because of the fact that "hogged" fuel can be used by logging companies to generate power more economically, the operation of lumber, shingle and lath mills is quite generally performed by electric service from central stations. Paper making, which is also dependent on a supply of wood for some grades, is an important and growing industry.

Much of the level land in western Washington is already used for dairy purposes, and as timber land is logged off more grazing space will be available for cattle. At present large milk-condensing and canning plants, which are electrically operated, are situated at Auburn, Kent, Stanwood, Mount Vernon, Ferndale, Lyndon and Everson. Since these have developed in the last six years, it can be imagined what the size of this industry will be in the next few years with the facilities for cattle grazing increased.

Coal Mines Use Central-Station Energy

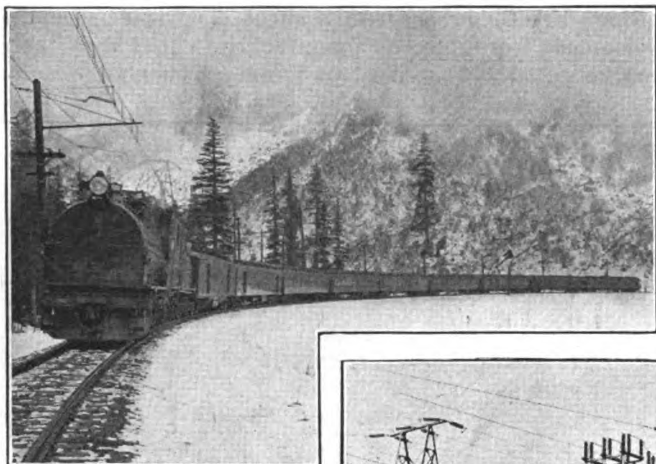
In the northwestern section of the State are enormous deposits of limestone, clay, talc and magnetite. Portland cement is already made in large quantities near the Baker River site. Brick and tile are being manufactured by the aid of electricity, and some magnetite mines have been opened. When some means of economically making aluminum out of clay is developed there should be an attractive electrolytic load for the transmission company. Practically all of the coal mines in western Washington are electrically operated now. The operators have shut down their isolated plants because it was not unusual to have two or three breakdowns a week lasting as long as six hours each. Now they secure reliable, uninterrupted service from the Puget Sound company over lines which are fed from two plants.

Fish canning is an important industry, but the load is light and lasts only three months of the year. Flour mills are fast developing, and electricity is being used at ship terminals for unloading and loading vessels, transporting material in trucks and similar purposes.

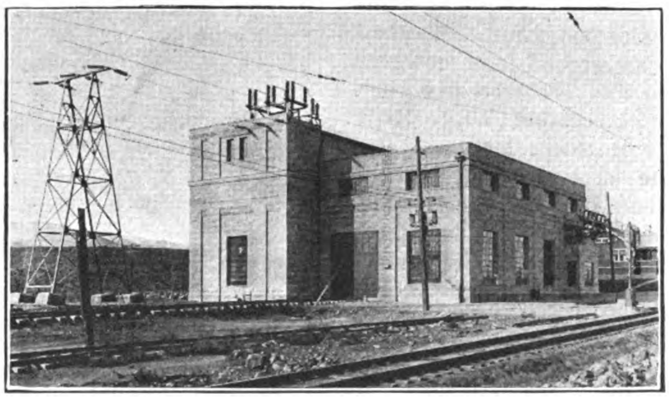
Electrification of Railroads

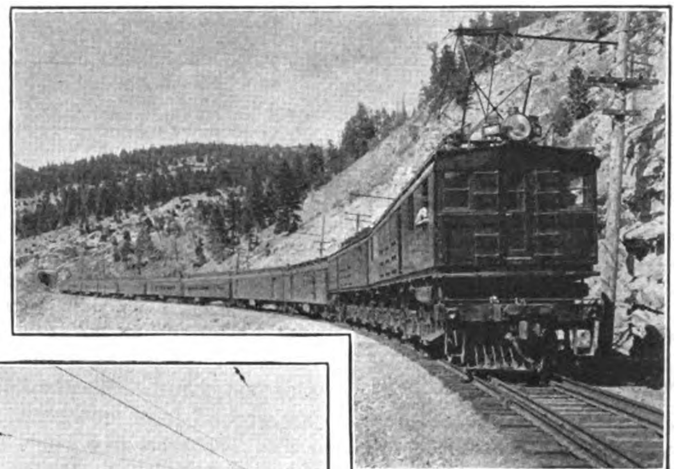
The contract to supply the Chicago, Milwaukee & St. Paul Railway with part of the energy for the Othello-Tacoma electrification constitutes quite a large load (10,000 kw. maximum demand). As more electric locomotives are placed in operation the energy required will increase. Several other railroads enter Seattle, and as these electrify their mountain divisions it is quite likely that they will have to call on the Puget Sound Power & Light Company for energy west of the Cascades, because it appears hardly wise to depend absolutely on transmission lines from the East over the high, windswept territory.

Information for this article was kindly contributed by engineers of the Puget Sound Power & Light Company, Seattle, of which A. W. Leonard is president, W. H. McGrath vice-president, G. E. Quinan chief engineer, John Harisberger general superintendent, S. C. Lindsay electrical engineer, M. T. Crawford superintendent of transmission and distribution, and H. J. Gille sales manager.



At left, Olympian Express, the first train to be propelled over Cascade Range under electric power. The division is served by the Puget Sound Power & Light Company and Washington Water Power Company through lines of the Intermountain Company.





At right, train being hauled across Rocky Mountain division of C., M. & St. P. R.R. by electric locomotive of a different type served by Montana Power Company. In center, one of the substations feeding the C., M. & St. P. R.R. electrification.

ELECTRIC LOCOMOTIVES ON TWO DIVISIONS OF C., M. & ST. P. R.R. OPERATED FROM CENTRAL-STATION TRANSMISSION LINES

THE *cost of steam power is steadily increasing. Power can be developed at far less cost by water. Energy developed by hydraulic plants and converted into electricity can be distributed cheaply and over wide areas. Applications of electricity are multiplying. Demand for electricity, for industrial purposes through motors, for electrochemical use and for domestic convenience is growing with great rapidity. Beyond this, there is the unquestionable fact that trunk lines of railways are certain to depend in the not distant future on electric locomotives wherever energy can be obtained at a reasonable price.*—PRESIDENT DODGE *of the International Paper Company.*