checked and to apply the air brake to bring it down to the speed required. It is then again allowed to accelerate and then again checked; but with regenerative braking the speed is uniform and there is no grinding of brakes and no annoyance to passengers in consequence. In the practical operation of the transcontinental trains of the Milwaukee Company over the Rocky Mountain grades, eastbound, the train is brought to the summit at a speed of about 23 to 25 miles per hour and after pitching over the summit, as soon as the train reaches a speed of 30 miles per hour, regenerative braking is started and, without the slightest knowledge on the part of the passenger, the train is held uniformly at 30 miles per hour down the 22 miles of 2 per cent grade. There is no difficulty in obtaining a speed of 60 miles per hour on level grades with 10 all-steel cars, and woe to the competitor who attempts a speed trial with one of our transcontinental trains.

The Milwaukee railroad decided on two innovations for geared locomotives, first that the trolley potential should be 3000 volts and second that there should be a full guiding truck at both ends of the locomotive. A great deal of doubt was expressed by electrical engineers as to the feasibility of collecting current at so high a voltage, but, by the use of the sliding pantograph there has not been the slightest difficulty in this matter and absolutely no sparking, and eight months of continual use has demonstrated that there has been no appreciable wear on the trolley wire. The use of the guiding trucks aside from all questions of safety has resulted in a locomotive which at the highest speeds rides almost as smoothly as a Pullman car

Electrification has been such a tremendous success on the Milwaukee road that it is difficult to state the results without seeming exaggeration, but I think it quite within the fact to say that the Milwaukee road has forgotten that the Continental Divide exists.

THE MONTANA POWER COMPANY AND ITS PART IN THE ELECTRIFICATION OF RAILWAYS

By John D. Ryan

President Montana Power Company

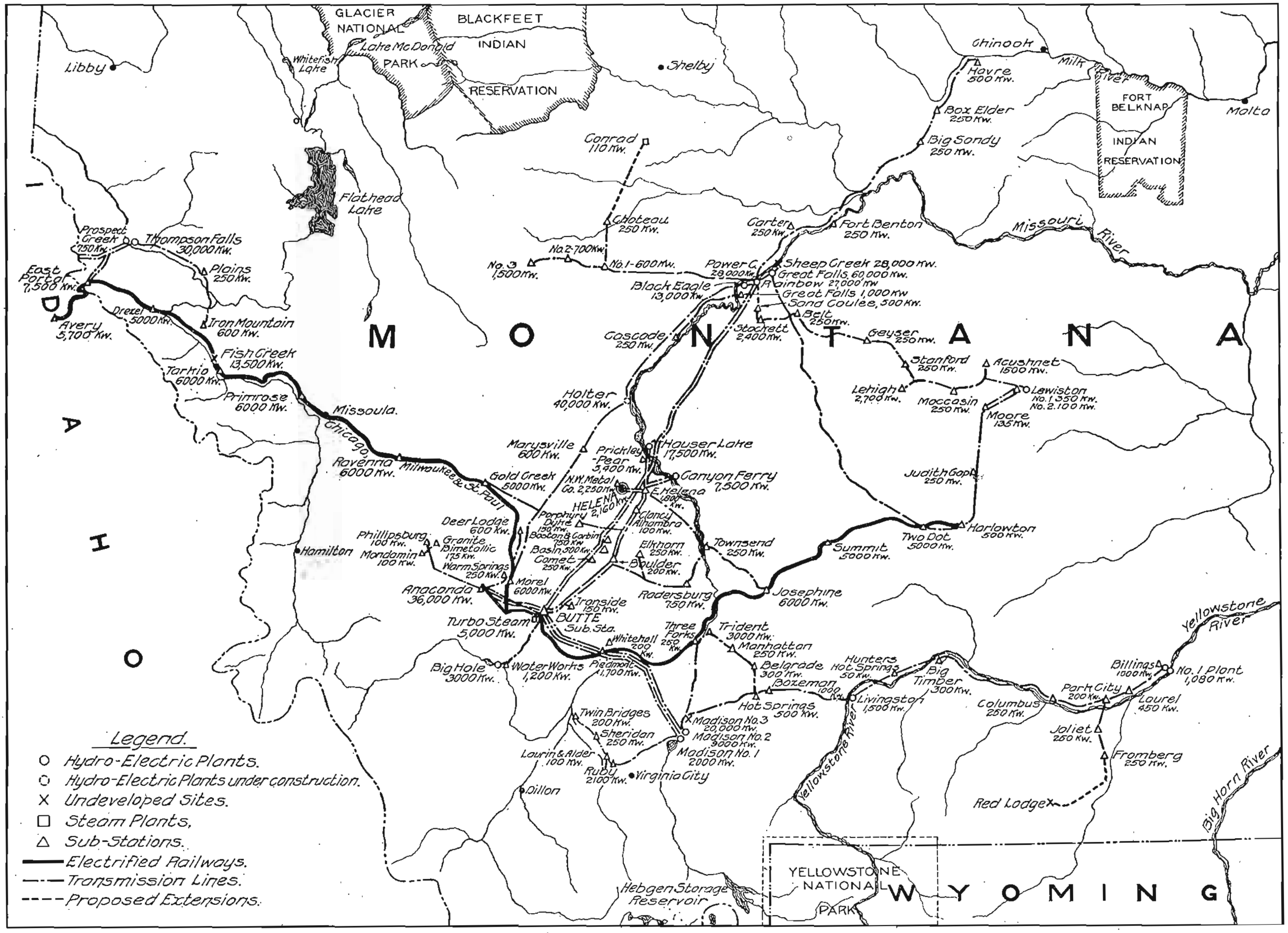
Mr. Ryan's article will be of special importance to engineers interested in the absolute continuity of service, the achievements of the Montana Power Company in this direction being wonderful. The general layout and tying together of the system is described and many of the interesting features noted. Both the B., A. & P., and the C., M. & St. P. Railways are supplied with electric energy from the Montana Power System, and in some of the opening paragraphs the author notes the successful results obtained.—Editor.

The development of water powers and the transmission of electrical energy had reached a point in Montana about the year 1912 where electricity began to force itself upon the attention of railway managers as a substitute for steam in railway operation.

More than a dozen hydro-electric plants had been connected with a great system of high tension wires to supply the fast growing needs of the State for power and light. The necessity for continuous service in the operation of mines forced the consolidation of plants into one system, out of which could be drawn the energy needed when the source of direct supply might for any reason fail temporarily.

The one vital need for railway operation is continuity of power, and the experience of the Butte mines and ore reduction plants at Anaconda and Great Falls had proved that, given the plant capacity, located at several points on different rivers, draining different water sheds and connected with ample transmission lines traversing different sections of the territory covered, as safe and certain a supply of power can be assured as by isolated steam plants, or any other possible means. The record of continuous operation with power from the Montana system, is, I believe, unparalled and unequaled.

The Butte, Anaconda & Pacific Railway Company took the first step by electrifying its main line and principal branches, about 70 miles in all. The work was completed in the autumn of 1913. The cost was within the original estimate; the operation has been an unqualified success and the economy at least 50 per cent in excess of the promises of the engineers at the time the work was undertaken. The tonnage handled over the lines has increased over 50 per cent in three years; no difficulty has been found in moving the increase, and in the opinion of the railway



Map showing Stations and Lines of the Montana Power Company, with special reference to the electrified section of the Chicago, Milwaukee & St. Paul Railway managers the main line and two of the principal branches had reached the capacity of single track when electrification came into use.

To any railroad management called upon to move heavy traffic with limited track facilities I would commend a study of what has been and is being done on the Butte, Anaconda & Pacific Railway.

The electrification of the Chicago, Milwaukee & St. Paul was a much greater stride; the courage was there, the money was found and the electrification of 440 miles of main line is practically a finished work. What the result has been I leave to others to tell in this magazine. I am proud of the part The Montana Power Company has in the accomplishment. It developed the water powers, built the transmission lines, contracted to do all overhead work on the railway line, and turned the work over, ready for substation and motive power equipment on time and in shipshape.

The following account of the Montana Power System will show many interesting features of the plans made to ensure a continuity of service, and other factors which go to make up a modern reliable system of energy distribution.

The growth of The Montana Power Company and its predecessors has been coincident with the development of the art of high voltage transmission and typical of the rapid progress which has been made in that field.

The beginning of the present system was marked by the construction of the Big Hole plant completed in 1898 and designed to deliver 3,000 kilowatts at 15,000 volts 22 miles to Butte, for public service use. Canyon Ferry plant was built independently at about the same time to develop and transmit 3,000 kilowatts to Helena and vicinity for public service, ore concentrating and smelting uses. In 1901 Canyon Ferry was enlarged to 7,500 kilowatts, and transmission 65 miles to Butte at 50,000 volts was immediately proven economical, the first large power loads consisting of air compressor and ore concentrating machinery. Madison No. 1 plant was completed the same year.

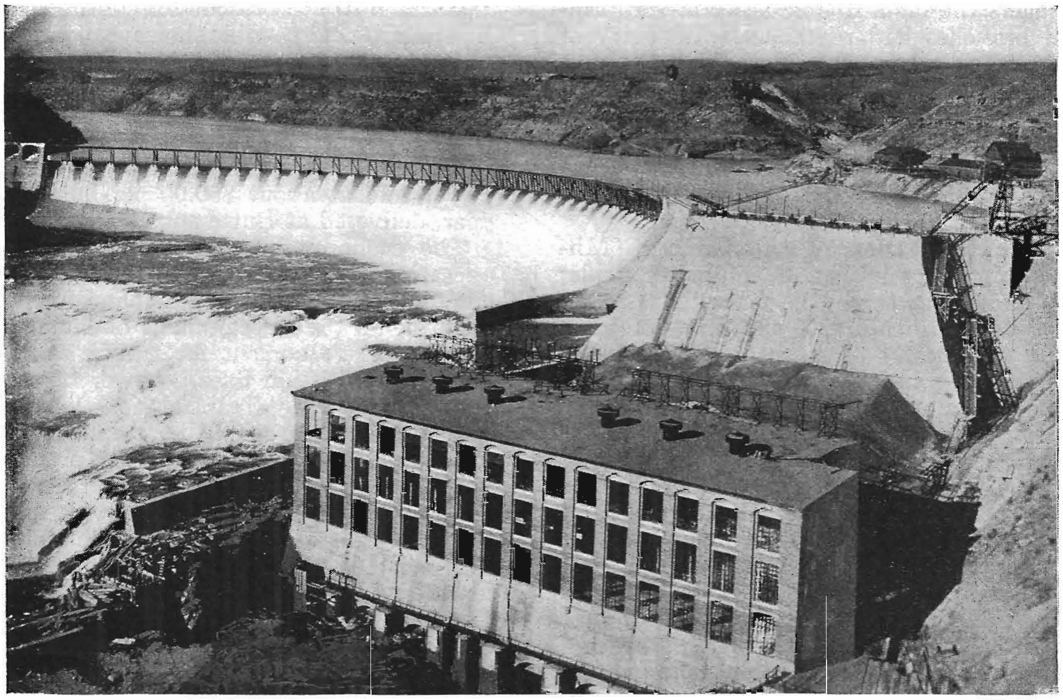
These small plants did much to establish confidence in the reliability of transmitted power. The natural caution of the mining companies, however, prevented the full adoption of electric power for urgent work such as ore hoisting and mine pumping until the construction of a 4,000 kilowatt steam reserve plant in Butte to provide for contingencies of line failures and possible shortage of power due to low water.

A steam plant was also kept in reserve for public service uses in the city of Butte. At that time steam power was costing upwards of $90.00 per horse power year, and electric power sold at about $50.00 per horse power year, delivered at Butte substations.

The economy and success attending the operation of these early hydro-electric plants created a rapidly growing demand for power, resulting in the development of larger sites, higher voltage current for transmission and longer transmission lines. Lower rates were also established. Transmission lines were extended to cities served by steam plants or small and unreliable water power plants and to many towns having no electric service at all, and low rates and good service secured even to towns of but 200 or 300 inhabitants.

In Butte the problem of mine hoisting was considered from all standpoints. There were then in operation more than a dozen steam hoisting engines rated above 2,500 horse power each of which was operating very inefficiently as to cost because of the intermittent character of the load. Direct connected motors of large capacity were not considered feasible because of their effect on the regulation of the transmission system and because of the serious inconvenience which would result from an interruption in delivery of power. This type of mine hoist, however, was adopted for sizes up to about 300 horse power. Ilgner flywheel sets were considered too expensive, not fully developed as to details of control and the energy stored in the flywheel insufficient to accomplish the necessary hoisting in case of failure of electric power. Storage battery reserves and direct current hoists were also considered and rejected as being unreliable or not ecomonical.

The Anaconda Copper Mining Company finally solved the problem for its own group of mines by converting its steam hoisting engines to air engines and providing a large storage of air in cylindrical steel tanks connected with a water pressure reservoir located on the adjacent hill at a height sufficient to maintain the working air pressure. This rendered the entire capacity of the air receivers available at practically full pressure and stored sufficient air to operate several hoists for thirty minutes in case the air compressors were not operating, and thus it was provided that the men could be taken out of the mines in case of failure of power.



Bird's-eye View of Dam and Power House at Great Falls

Hydro-Electric Power Station at Great Falls on the Missouri River
Montana Power Company

The compressors for this system of air hoisting now require eight motors of 1,200 horse power each.

Recent improvements in the control of fly-wheel hoisting sets have brought this system into favor for isolated mines, and such hoists are being used in Butte with capacities as high as 3,500 horse power.

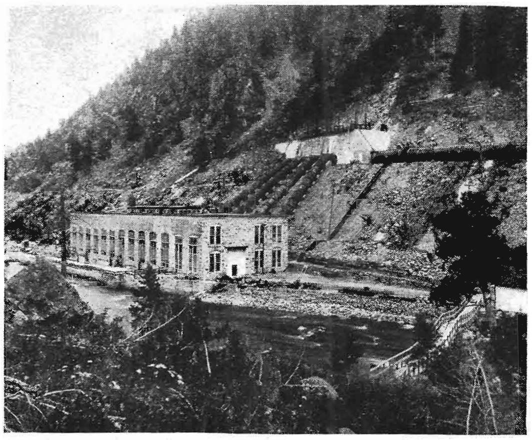
Electric power has been rapidly adopted for mine pumping and electric mine haulage. Coal mines suffering from bad boiler feed water adopted transmitted electric power as a way out of their troubles with such economy that it was adopted in other mines not so troubled. Several irrigation projects have been completed in which water is pumped to an elevation of 300 feet for orchards and a maximum of 150 feet for ordinary agricultural projects. The Power Company has been a pioneer in the introduction of electric cooking and has now nearly 1,000 stoves connected on its lines.

In 1910 the Rainbow power development at Great Falls was completed. 25,000 kilowatts were developed by the erection of a 30-foot dam and two-wheel conduits 15½ feet in diameter, which developed a total head of 110 feet by shunting the water around the Rainbow and Crooked Falls of the Missouri River. Power was transmitted to adjacent towns within a radius of 110 miles at 50,000 volts, and over duplicate steel tower lines to Butte 130 miles and Anaconda 160 miles at 100,000 volts.

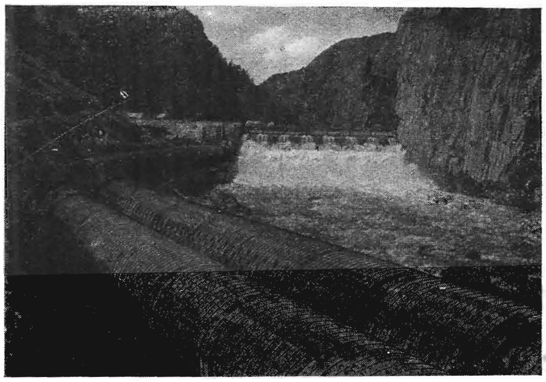
The Hauser Lake plant was completed in 1911 and transmitted power to Butte and nearby irrigation loads at 66,000 volts. At this plant a solid concrete dam secured a working head of 60 feet and created a storage reservoir about 18 miles in length.

In 1912 these various plants which had previously been operated independently of one another were physically interconnected and consolidated in The Montana Power Company. The interconnection was made between the low tension busses of the two principal substations in Butte and provision made for an interchange of about 10,000 kilowatts in either direction. The economies resulting permitted a further reduction in rates, reserve steam plants were shut down and have been operated since only temporarily, when the growth of load has outstripped the construction of new plants.

In 1913 active construction was started on the 60,000-kilowatt development at the "Great Falls of the Missouri" and a 30,000-kilowatt development at Thompson Falls on Clark's Fork of the Columbia. These plants were intended to supply the necessary power for the operation of the Chicago, Milwaukee & St. Paul Railway through the Rocky



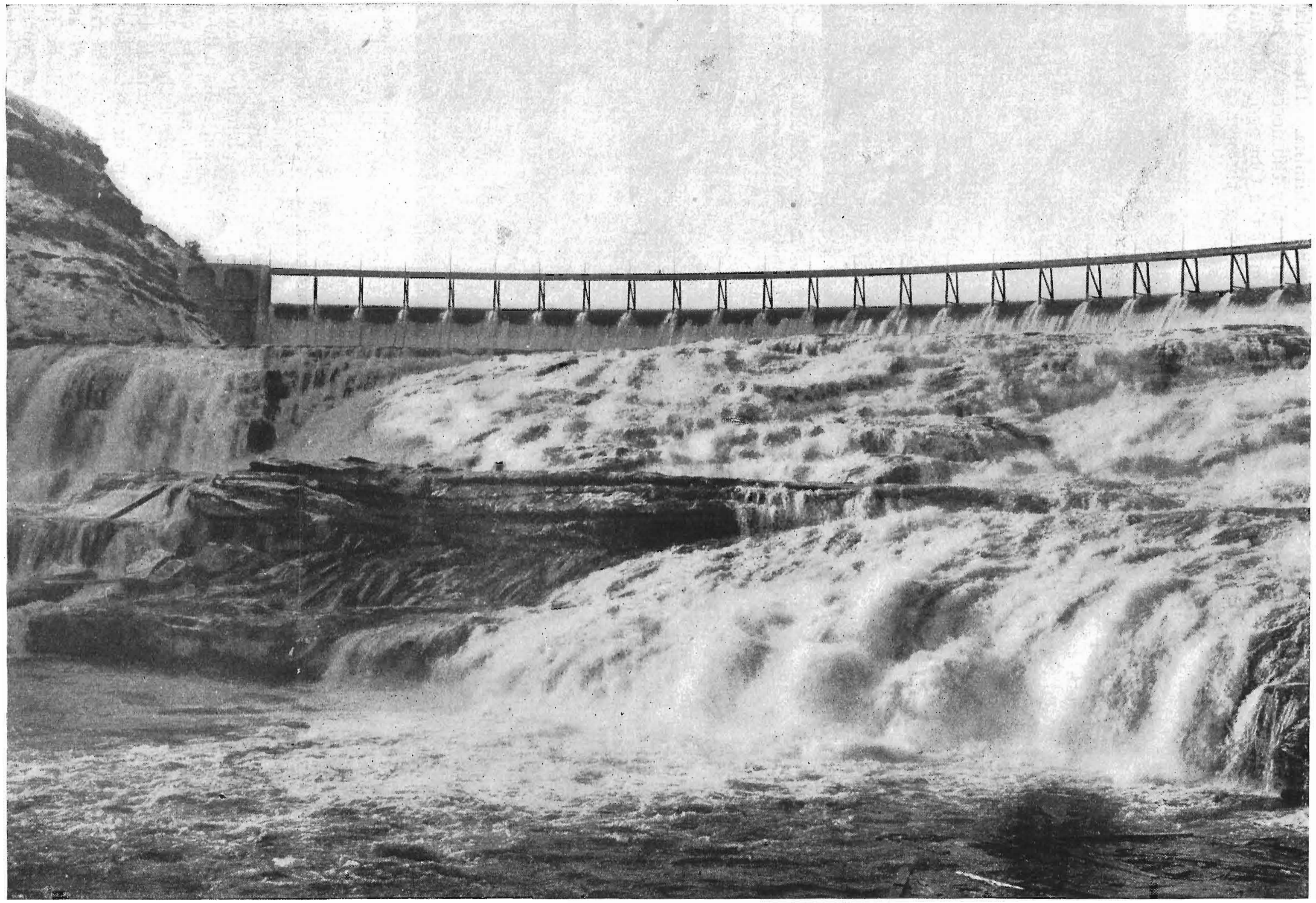
Madison No. 2 Power House and Regulating Reservoir 110 ft. Head, 10,000-kw. Capacity



Madison River Dam, 34 ft. High and Stave Penstocks 12 ft. Diameter

Mountains, and to take care of the general growth of business. At the Great Falls Development at 70-foot concrete dam, close to the brink of the Great Falls, and steel penstocks about 300 feet in length developed 150-foot head. At Thompson Falls a 30-foot dam above the falls and a short canal developed 50-foot head. Both of these plants have sufficient local storage to enable them to operate at 65 per cent daily load-factor utilizing the entire low water flow of the river.

On account of the rapidly increasing demand for power these plants will be fully loaded sooner than expected, so that work on a 40,000-kilowatt development at Holter on



The Great Falls of the Missouri River
Dam of the Montana Power Company in Background

TABLE I

COMPLETED HYDRO-ELECTRIC PLANTS

Rainbow Falls on Missouri River, completed 1910	25,000 kw.
Additions under way 1916	10,000 kw.
Black Eagle Falls on Missouri River, partly reconstructed 1913	3,000 kw.
Hauser Lake on Missouri River, completed 1911, enlarged 1914	18,000 kw.
Canyon Ferry on Missouri River, completed 1898, enlarged 1901	7,500 kw.
Madison No. 1 on Madison River, completed 1901, remodeled 1907	2,000 kw.
Madison No. 2 on Madison River, completed 1906	10,000 kw.
Big Hole on Big Hole River, completed 1898	3,000 kw.
Livingston on Yellowstone River, completed 1906, enlarged 1908	1,500 kw.
Billings No. 1 on Yellowstone River, completed 1907	1,080 kw.
Lewistown on Spring Creek, completed 1906, remodeled 1913	450 kw.
Thompson Falls on Clarks Fork of the Columbia, completed 1916	20,000 kw.
To be added 1917	10,000 kw.
Great Falls of the Missouri River, completed 1916	60,000 kw.
Total	171,530 kw.

HYDRO-ELECTRIC PLANTS UNDER CONSTRUCTION

Holter on Missouri River	40,000 kw.

STEAM PLANTS

Butte, completed 1905	5,000 kw.
Phoenix (Butte), completed 1895	250 kw.
Billings, completed 1906	560 kw.
Conrad, completed 1910	110 kw.
Total	5,920 kw.

UNDEVELOPED SITES

Madison No. 3 on Madison River	18,500 kw.
Black Eagle on Missouri River, reconstruction, (additional)	10,000 kw.
Great Falls Site "C" on Missouri River	28,500 kw.
Below the Great Falls on Missouri River	28,500 kw.
Fish Creek on Missoula River	13,500 kw.
Snake River on Snake River, Idaho	22,500 kw.
Total	121,500 kw.

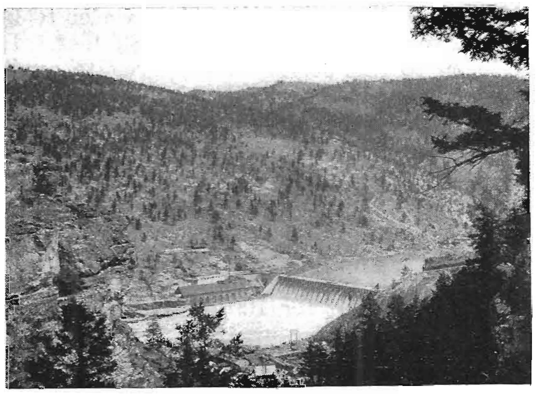
the Missouri River is being pushed for completion in 1917.

A new process of electrolytic zinc refining has been developed by the Anaconda Company and a plant has just been completed at Great Falls which will consume about 25,000 kilowatts.

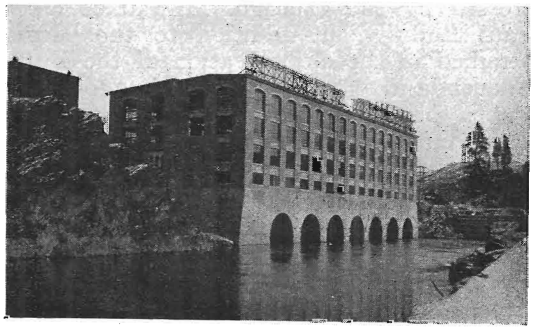
The transmission line system consists of:

Steel tower lines	340.5 miles
Pin type pole lines	635.4 miles
Suspension insulator pole lines	513.0 miles
Two pole bridge type lines	375.0 miles
	1,863.9 miles

Present standard types of construction are the two-pole towers spaced twelve to the mile for 100,000-volt construction, and a single pole, double armed structure for 45,000 to 65,000 volts. The former type has two 3/8-inch Siemens Martin steel ground wires strung above the power circuit. The latter type has one ground wire strand composed



Hauser Lake Development, 60 ft. Head, 18,000-kw. Capacity



Thompson Falls Station, 30,000 kw. in Six Units

of three No. 10 iron wires at one end of the top cross arm, all copper conductors. Telephone wires are commonly run about eight feet below the power wires on the power line poles.

Table I shows the present plant capacities and proposed capacities of undeveloped sites. Map, page 916, shows the location of plants and substations and routing of distributing transmission lines.

For many years Mr. Max Hebgen, who until his death in 1915 was Manager of The Montana Power Company, had in mind the construction of an immense storage reservoir on the head waters of the Missouri River. The consolidation of the ownership of plants