Electrical Review

With Which Is Consolidated WESTERN ELECTRICIAN and ELECTROCRAFT.

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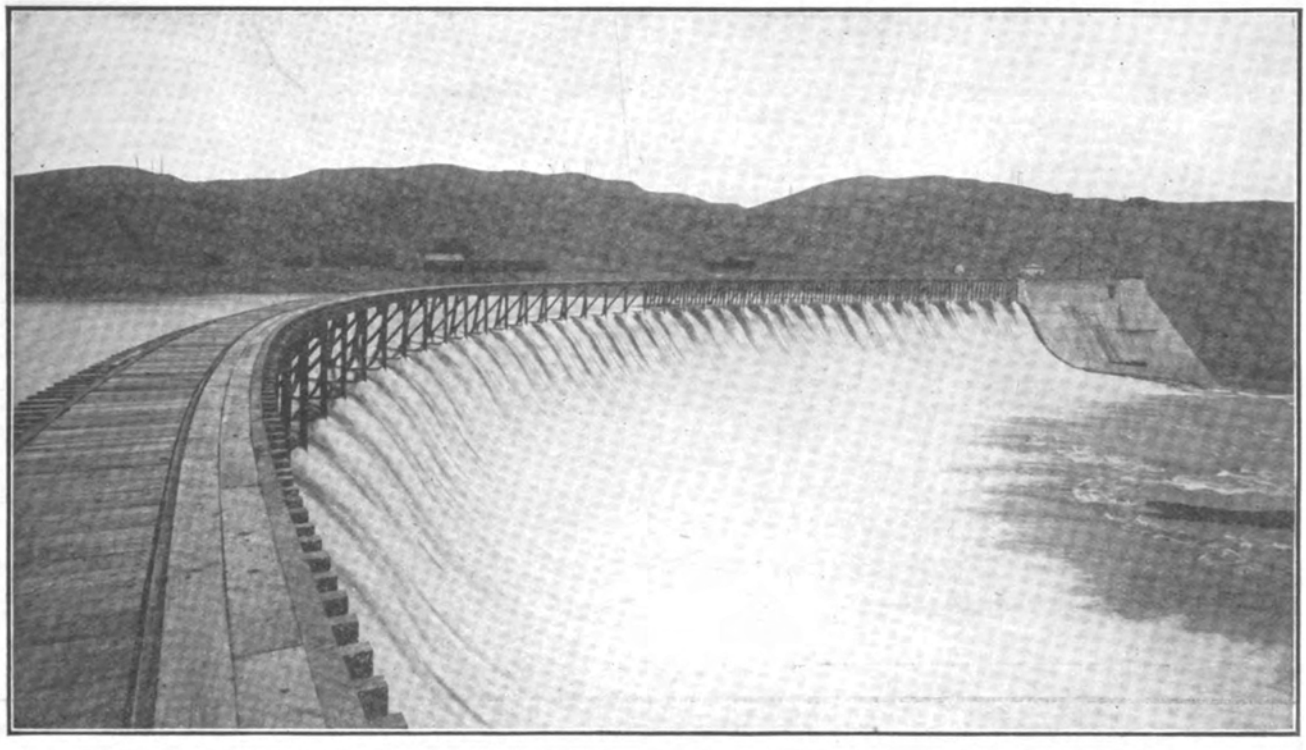


Montana Power Company's Dam at Volta, Near Great Falls.

Montana Power Company's System

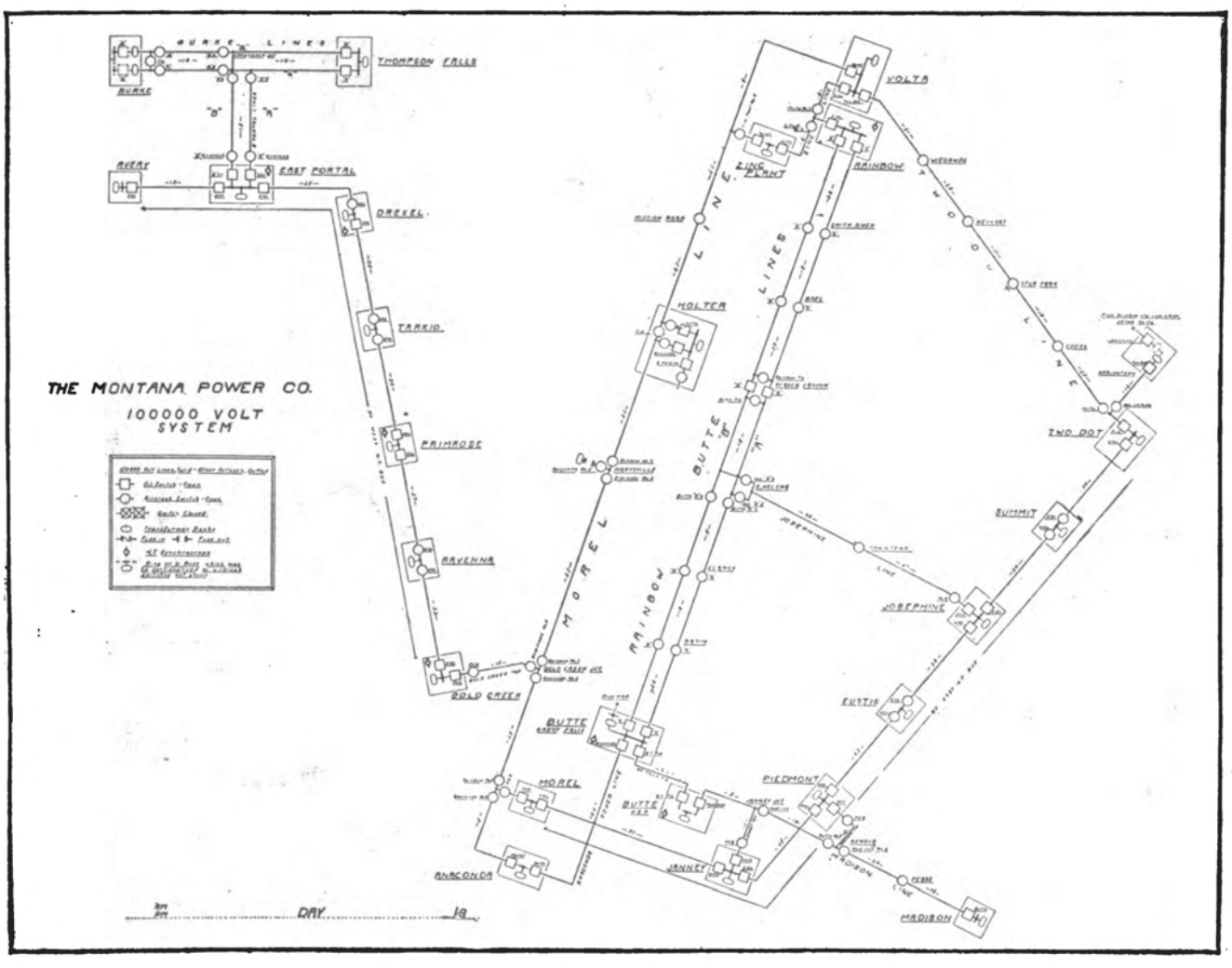
Many Hydroelectric Plants Interconnected, With Combined Generating Capacity of Over 200,000 Kilowatts—Essential Features of Each Plant—Notes on Transmission Lines and Service

By W. A. SCOTT

A VISUALIZATION of the Montana Power Company's utilities discloses 13 hydroelectric and four steam-electric plants, all tied together in one comprehensive system by means of numerous substations and over 1,800 miles of transmission lines. The hydroelectric plants in operation have a combined generating capacity of 171,530 kilowatts, and the Holter plant which is to be completed this year, will bring into the system 40,000 kilowatts more. The steam-driven plants have an aggregate capacity of 5,920 kilowatts. Thus, by the close of 1917 the company's power-producing plants will be equal to 217,450 kilowatts. The system reaches from Billings, on the east, to Thompson Falls and Montana-Idaho state line on the west; from Havre on the north to Ruby and Alder creek on the south; and supplies power to a territory 250 miles north-south by 400 miles east-west. All hydroelectric plants are situated on the Missouri River and its tributaries, except the plant at Thompson Falls, which is on the Clark fork of the Columbia, in western Montana. Those on the Missouri and its branches are closely interconnected as a power-service system, while the Thompson Falls plant and its substations are tied to the main Butte-Great Falls system only through the C. M. & St. Paul electric railway line. The transmission of power is by means of 340 miles of steel tower lines, 635 miles of pin-type pole lines, 513 miles of suspension-insulator-type pole lines, and 375 miles of two-pole bridge-type lines.

MANY PLANTS INTERCONNECTED.

This system of the Montana Power Company is the result of the merging of a number of power-serv-



Map Showing Location of Plants and Transmission Lines.

ice interests and the physical inter-connection of their several plants, and the construction of new plants to become a part of the system. These consolidations were necessary to meet a demand for continuous service for mines, mills, smelters, railroads, manufacturing plants and municipalities. Security against interruptions of service was found in arrangements to draw on the current of the numerous plants of a big system, instead of relying upon the direct supply of an individual plant. While cities and towns have expanded, and manufacturing has increased, the great demands for power, which caused such rapid power development, came from the mining industry and the railroads. The Butte, Anaconda & Pacific railroad took the initiative in utilizing electric energy for freight and passenger trains. It completed the electrification of its 70 miles of road in 1913, and provided electric locomotives for this work. The economy and efficiency of its operations by electric power exceeded expectations, and its success probably was influential in the prompt action taken by the C. M. & St. Paul railway in electrifying 440 miles of its main line between Harlowton, Montana, and Avery, Idaho. The latter company has had electrically operated trains on that part of its system since December, 1916.

Mining Companies Adopt Electric Power.

The mining companies of Butte were slow to adopt electricity for power until such problems as continuity of service, long-distance transmission and adaptability were solved; gradually these were all practically demonstrated and the electrification of mines for operating air-compressors, pumps, haulage cars, and in many cases for hoisting, was rapidly accomplished. The Anaconda Mining Company led the way to a considerable extent by installing eight electric synchronous motors of 1,200-horsepower each to operate its air-compressors. At the same time, it converted its steam hoists into air hoists, and provided for compressed-air storage in cylindrical steel tanks, which were connected to a water-pressure reservoir, the latter situated upon an adjoining hill of sufficient height to maintain a working pressure. This made the capacities of the air-receivers available at about full pressure and resulted in storing air sufficient to operate the several hoists for thirty minutes after air-compressors ceased to operate. This acts as a reserve power whereby the men may be taken out of the mines in case of the failure of power from outside sources.

In 1914 about 365,145,736 kilowatt-hours of energy were delivered to consumers of power, and for 1916 this was increased about 50 per cent. It is estimated that 95 per cent of the energy sold is being utilized for mining, industrial and railway power purposes.

Missouri River Water Storage.

The eight hydroelectric plants situated on the Missouri and Madison rivers utilize 600-feet head, the same volume of water passing successively over the dam at each plant. Of the three streams which join at Three Forks to form the Missouri River, the Madi-

son is the largest. Near the headwaters of the Madison, an earthen dam, 600 feet long, 107 feet high, having a concrete-core wall, was thrown across the stream, whereby the Hebgen reservoir was created. This reservoir is now a lake of 13,000 acres with a shore-line of 65 miles, and having a storage capacity 325,000 acre-feet. It receives the drainage of an area of 900 square miles, where there is an annual precipitation of 30 inchs. This dam and reservoir renders the flood waters available during the natural period of low water; besides it adds 87 per cent to the volume of local storage available for the plants on the Madison and Missouri. The physical combination of the eight plants on one steam, where the same water is successively used, gives an opportunity to use stored water through each plant in series.

Data on Plants.

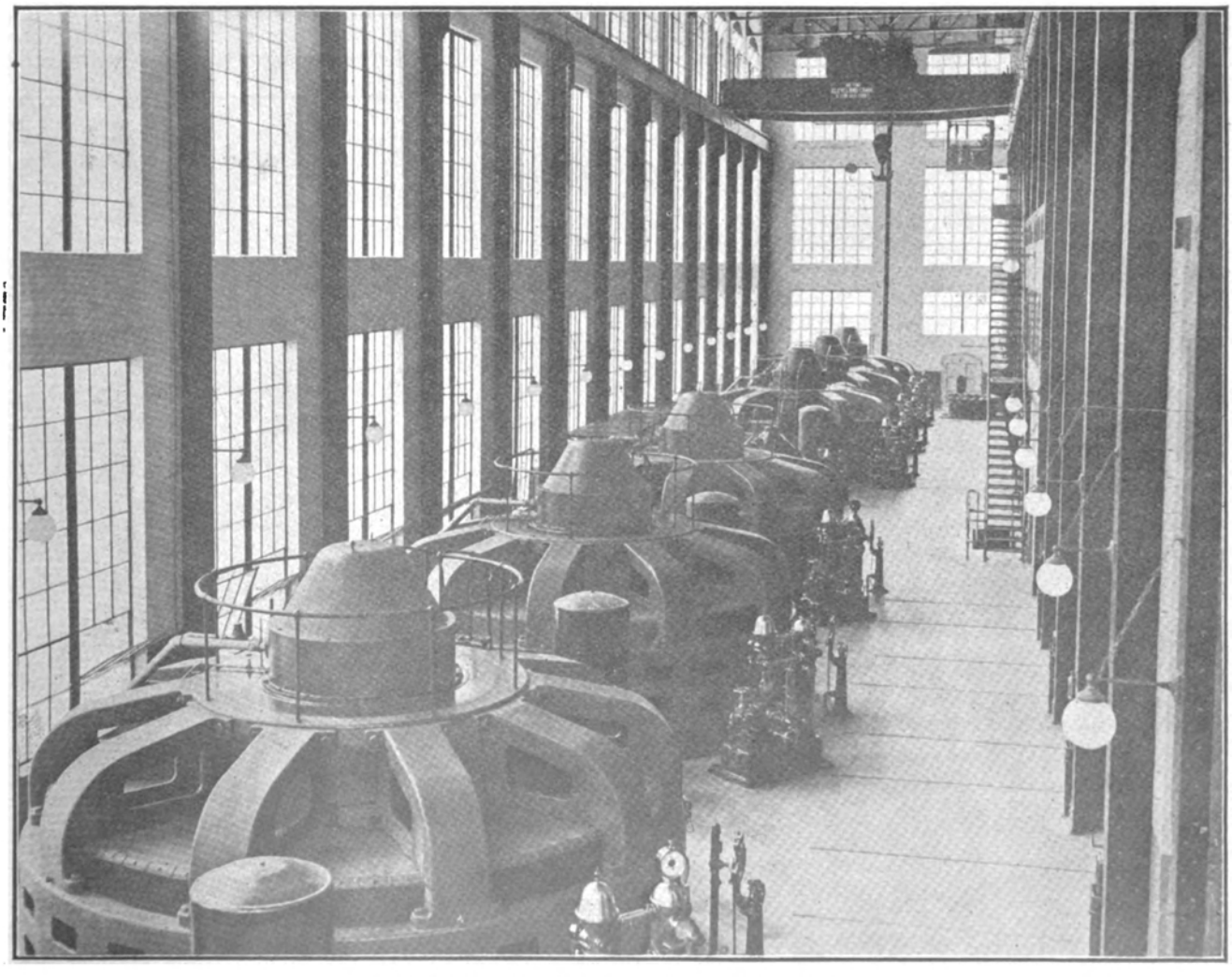
The Big Hole plant was constructed in 1898. This is situated on Big Hole River, 22 miles southwest of Butte, that stream being a tributary of the Jefferson. Here a rock-filled, timber-crib dam was built, developing 65-foot head. Steel penstocks were so placed as to carry the water to four Leffel wheels, each of which drives a 750-kilowatt generator. The current thus generated is transmitted at 15,000 volts to Butte over a cedar pole line. This was the first of the system, and the equipment is still doing good service.

Madison River Plant.

Madison River plant, in Madison canyon, consists of a rock and concrete-filled, timber-crib dam, from which two conduits, 10 feet and 12 feet diameter, respectively, extend down stream a distance of 7415 feet, discharging into a balancing basin; four steel penstocks, 9 feet diameter, carry water from this basin to four 3700-horsepower, double, horizontal Leffel turbines, each connected to a 2500-kilowatt generator. Current generated here is transmitted to Butte and other substations by two lines. The line originally built carrying 46,200 volts to Butte, is of No. 1 stranded aluminum wire, with Provo glass insulators mounted upon 21-inch locust pins. In order to deliver an increased load from this plant a steel tower line was built parallel to the first, in 1908. Conductors on this line consist of No. 0 stranded copper wire on suspended insulators, and carry 110,000 volts.

Canyon Ferry Plant.

The plant farthest upstream on the Missouri River proper is at Canyon Ferry, seventeen miles east of Helena, and was built in 1898. A rock-filled, timber-crib dam, 490 feet long, 40 feet high, built at this place, develops a 40-foot head, and stores 40,000 acre-feet. The power house contains ten 1000-horsepower double, horizontal turbines, each connected to a 750-kilowatt, 550-volt generator. The 550-volt switchboard is provided with air-brake circuit breakers and triplicate busbars to which connection is made by knife switches. Current is transmitted from here by four circuits of No. 4 solid copper wire to Helena, 17 miles distant, at 12,000 volts; and over two No. 0 stranded copper lines,



Vertical Generator Sets in Volta Plant, Great Falls.

at 70,000 volts, to Butte, 65 miles away. The 12,000-volt pole line is equipped with two-part, 4½-inch glazed porcelain insulators on 9-inch wooden pins. The 70,000-volt lines are provided with 9-inch glass insulators, on 18-inch treated wooden pins, protected by glass sleeves. The dam at this place creates a backwater reservoir 6 miles long and 1½ miles wide.

Hauser Lake Project.

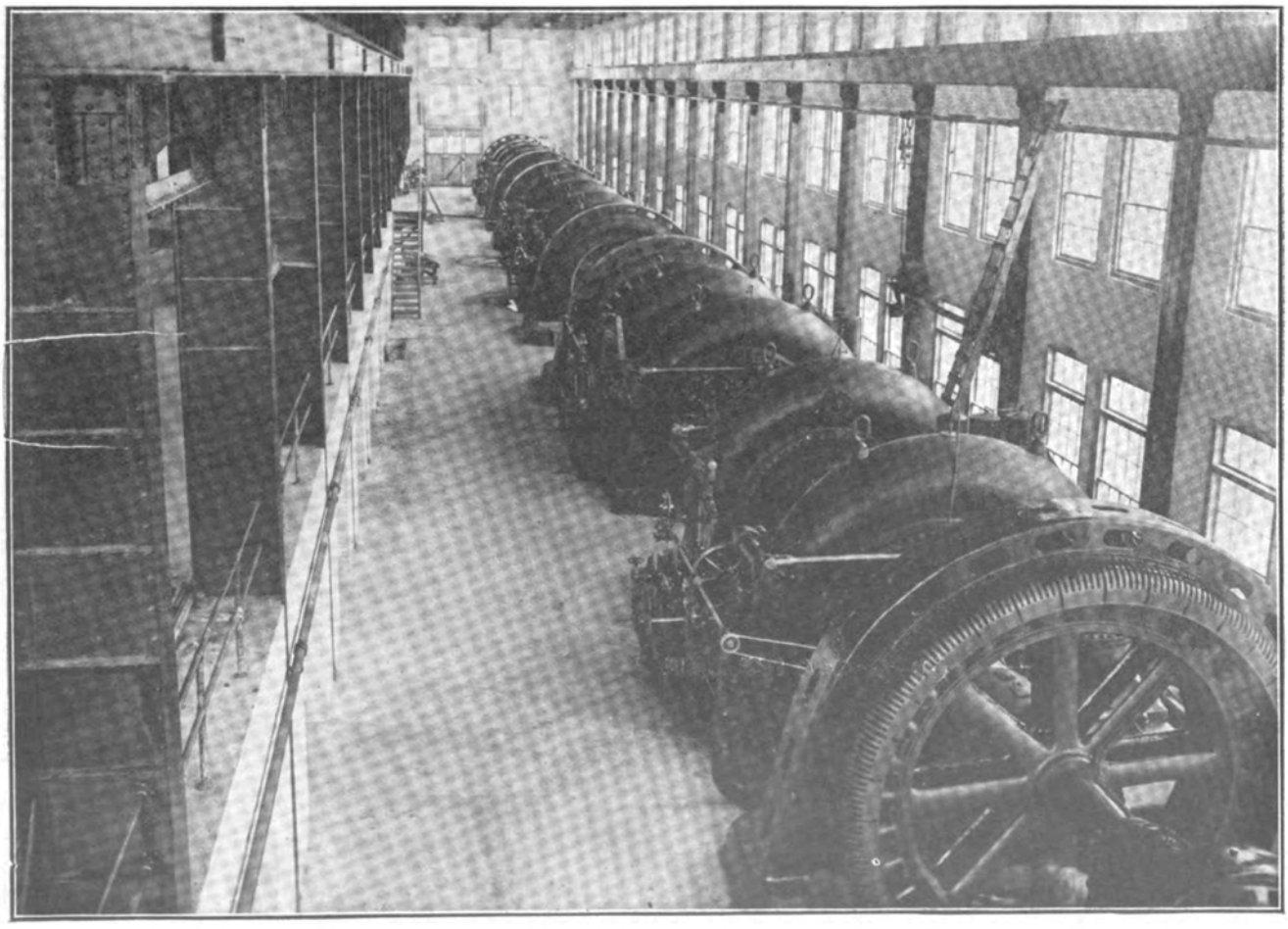
Hauser Lake development is also on Missouri River, sixteen miles down stream from Canyon Ferry. A head of 65 feet is developed here by a dam of mass concrete, 720 feet in length, with a height of 130 feet from bedrock to the top of the bridge. The backwater extends upstream to Canyon Ferry, making a storage basin of 46,000 acre-feet. The dam has removable flashboards, by which water-level 14 feet above the spillway may be maintained. Water is conveyed from the forebay to six horizontal, 4000-horsepower turbines, each driving a 2800-kilowatt generator. After the completion of Hebgen dam the Hauser Lake plant was increased by the installation of another generating unit of 3750-kilowatts capacity. Power developed here is transmitted at 66,000 volts by duplicate lines to a junction with the Canyon Ferry transmission lines at East Helena, and there interconnected with the general distribution system. At the plant the low-tension buses are in duplicate; the high-tension side of the transformers is connected through selector knife switches to a ring bus system to which the two transmission lines are connected through oil circuit-breakers.

Black Eagle Station.

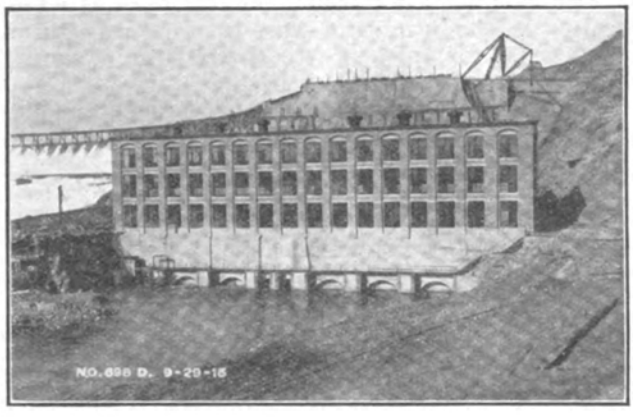
This is within the limits of the city of Great Falls, and was built in 1890, being the oldest in the company's system of plants. It has a capacity of 13,000 kilowatts, developed by 44-foot head of water. A rock-filled, timber-crib dam, with masonry abutments, was built at the crest of the falls. The original plant of 8000-horsepower was built at the north end of the dam, current from which was used by the Copper Ore Reduction Works; at the south end of the dam is a 3000-kilowatt plant for commercial service. It is stated that the old plant which serves the smelter will be replaced by a new one of 10,000 kilowatts capacity.

Rainbow Plant.

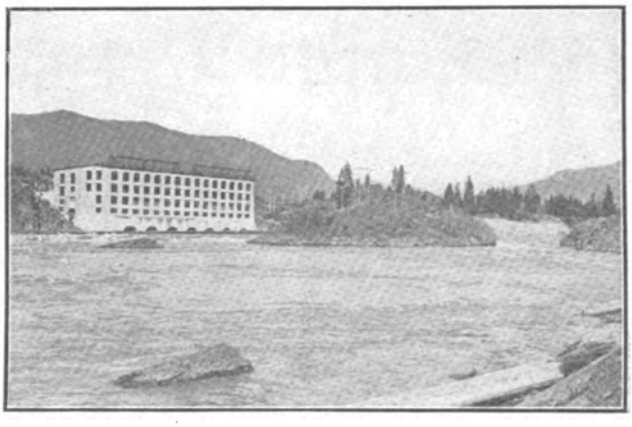
Rainbow generating station is situated at Coulter's, Rainbow and Crooked Falls, four miles below Black Eagle Falls. The plant was originally completed in 1910, and enlarged in 1916. A head of 107 feet was secured here by constructing an A-shaped rock and concrete-filled timber-crib dam on the crest of Rainbow Falls. The structure has 1140 feet of spillway, is 36 feet high, and is equipped with 10-foot removable flashboards. At each end are massive concrete abutments and sluice-gate structures. At one end is an intake forebay, from which two steel conduits, each 15½ feet diameter, 2400 feet long, conduct the water to a concrete balancing reservoir, having an area of 2½ acres; it passes from this reservoir through twelve steel pressure pipes, each 8 feet diameter and 300 feet long, to six 8000-horsepower double-runner Francis inward-flow water wheels, directly coupled to six 3500-kilowatt, 6600-volt General Electric generators. A tailrace, 1100 feet in length, excavated through solid rock, carries the water to the river below the falls. The head of 107 feet is produced by a 36-foot dam, 35-foot fall at Rainbow and a 25-foot drop at Coulter Falls, as well as the intervening rapids. Two parallel



Generator Floor, Rainbow Plant, Great Falls.



Power House at Volta—Upstream View.



Thompson Falls Power Station.

steel tower lines, carrying current at 100,000 volts, extend from Rainbow plant to Butte, a distance of 130 miles, and double-pole lines extend 72 miles west to the Sun River region, 106 miles north to Havre, and 125 miles east to Lewistown, all carrying current at 50,000 volts; also, 8000 kilowatts are transmitted to the Great Falls smelters over a 6600-volt feeder line four miles long. The lines to Havre, Lewistown and Sun River are the two-pole bridge type, with suspension insulators.

The Volta Station.

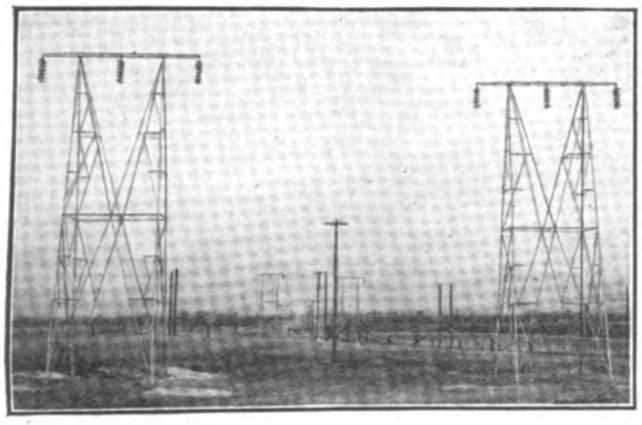
The crowning achievement of this company in central-station construction is seen at the Volta plant, situated at the Great Falls of the Missouri, about 12 miles below the city of Great Falls. A gravity concrete dam, 1250 feet in length, 72 feet in height, in the form of an arch of 563-foot radius, was constructed just above the brink of the falls; the arched form was adopted to secure the required length of spillway. The left end of the dam curves downstream, forming a forebay, through which six main penstocks, 282 feet in length, extend down to the water wheels; and two other penstocks take the same course to the exciter units. The main steel penstocks are each 12 feet 8 inches diameter at the headgates, and 8 feet diameter at the water wheels; the smaller penstocks are each 5 feet diameter at headgates and 18 inches at the wheels. The natural height of the falls is 78 feet, which, with the 72-foot height of dam, gives an operating head of 150 feet. The water wheels are the S. Morgan Smith type of vertical turbines, revolving in a horizontal plane, are 8 feet diameter, 1400-horsepower, having a speed of 200 revolutions per minute, within cast iron scroll casings. These turbines are equipped with Woodward oil-pressure governors, the motors operating in pairs, connected directly to the gate operating rings. The six generators are the General Electric vertical type, each being a 10,000-kilowatt, 6600-volt, 3-phase, 60-cycle machine. The transformers consist of twelve 6000-kilowatt-ampere single-phase units. The switching arrangement is in duplicate, there being duplicate exciter buses, and duplicate oil switches for each generator, transformer unit and each line, so that any combination can be obtained without the operator leaving the switchboard. This station can be operated as two entirely separate sections, each with its own speed and voltage control, two Tirrill regulators being provided. This arrangement of switching has been objected to, on account of complications and greater cost of installations, but the view of the operating engineer is that for a large station where maintenance of service is important and where the number of attendants are small, this arrangement greatly simplifies control and is worth the extra cost. Three transmission lines extend out from this plant, all being two-pole, bridge type lines, carrying 100,000 volts. One line runs 106 miles southeast to Two-Dot, as a feeder for the C. M. & St. Paul railway; another extends 142 miles southwest to Morel, near Anaconda, as a feeder for the same system; the third runs 10 miles up stream to the electrolytic zinc plant of the Anaconda Copper Company. The power house, a reinforced concrete structure, was specially designed to accommodate the most modern installations within. An accompanying illustration shows the six vertical generators, with oil-pressure governors for turbines, which is typical of the symmetrical arrangement throughout. The transformers are to the right of generators, each recessed in a separate apartment, the switchboards occupying the floor, above the transformers. This plant, as well as the plant at Thompson Falls, was built especially to meet the increased demand for power on account of the C. M. & St. Paul railway electrification.

Thompson Falls Development.

The plant on Clark's fork of the Columbia River, at Thompson Falls, being in the western part of the state, supplies power for that part of the Milwaukee railroad, and for a number of mines in Coeur d'Alene district, Idaho. For the latter service, the company delivers current at the Idaho state line, connecting there with transmission lines operated by several mining companies in joint arrangement. About 7500 kilowatts are supplied in that way. At Thompson Falls the river has a minimum flow of 6500 second feet, and has a natural fall of 20 feet. By constructing a concrete dam 1000 feet long, 35 feet high, above the falls, a head of 55 feet was developed. The power house is situated at a site 600 feet down stream from the dam, water being conducted thereto through a side channel and a canal excavated in solid rock. The equipment consists of six single-runner, vertical turbines, and the same number of 5000-kilowatt, 6600-volt generators. The plan of power house and switching arrangement are practically the same as those of Volta plant. Power is transmitted from the plant over 110,000-volt lines; two such lines serve the mining district referred to, and two others supply power to the C. M. & St. P. railway, the western terminus of its electrified line being at Avery, Idaho.

Holter Plant.

The plant at Holter, designed for a capacity of 40,000 kilowatts, is under construction and is to be completed by the end of 1917. The site is on the



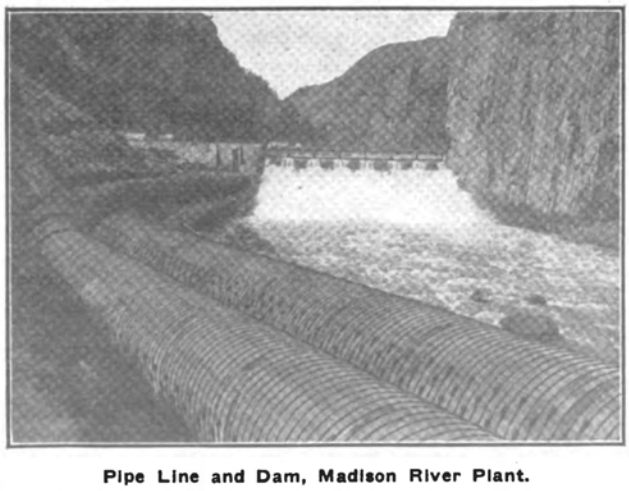
Parallel Steel Tower Transmission Lines.

Missouri River, near Wolf Creek station, thirty miles north of Helena. The location is central as to the company's system. At this site a head of 100 feet is being developed by a concrete dam, 1350 feet long, 100 feet in height, there being no natural falls on the stream. Accompanying this is a picture, showing construction work well advanced. It shows the power house at one end of the dam, the two being closely connected in construction. The dam, of mass concrete, is composed of a 1-3-5 mix, and has base width of 180 feet. The plant equipment will consist of four single-runner turbines and four Westinghouse vertical generators of 10,000 kilowatts capacity each, with the same type of transformers and switchboards as at Volta. Current will be stepped up to 100,000 volts and turned into the general system through connection with the 100,000-volt lines which extend from Great Falls to Morel and Anaconda. The water storage produced by Holter dam will extend nearly to Hauser Lake, and will constitute the third in a chain of 50 miles, the three lakes having a storage of close to 150,000 acre-feet.

Notes on Transmission Lines.

High-voltage transmission has developed with the growth of this vast power system. The standard types of lines, as now adopted, are the two-pole, bridge type, spaced 12 to the mile, for 100,000-volt transmission; and the single-pole, double-arm line for 45,000 to 65,000-volt transmission. At the peaks of the two-pole bridge-type lines are strung two 3/8-inch Siemens-Martin steel ground wires, above the power circuits. The single-pole lines have one ground wire strand of three No. 10 iron wires at one end of the top cross-arm.

Suspension insulators are used on all lines higher than 45,000 volts. Strands of three No. 8 copper wires are used as conductors for lines carrying as high as 88,000 volts; for those of 102,000 volts the minimum size is No. 0 seven-strand copper.



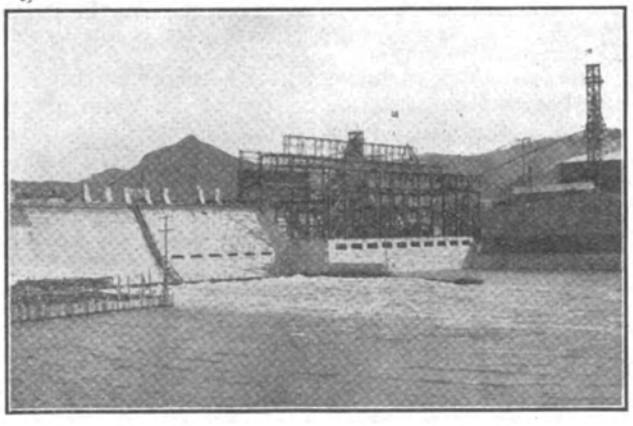
Pipe Line and Dam, Madison River Plant.

The double line of steel towers, 130 miles long, from Great Falls to Butte, are built of angle iron, each tower being 13 by 14 feet at base, the footings being six feet in the ground. Each tower has a 22-foot steel cross-arm, with three suspension insulators attached, carrying three No. 0 B. & G. 6-strand hard-drawn copper wires. These two parallel tower lines carry 100,000 volts. The average tower spacing is 672 feet, the longest span being 3034 feet. In these parallel lines a distance of 60 feet apart is maintained. The cost of each single tower line was close to $3200 per mile.

On the Volta-Morel two-pole line, 133 miles long, the average span is 440 feet. The poles of the two-pole bridge-type line are set 10½ feet apart, and each set has a cross-arm 22 feet in length, other dimensions being five by seven inches. The poles are usually purchased with butts creosoted, and are set 6½ feet in the ground.

Smaller Plants.

The company operates small hydroelectric plants at Billings, Livingston and Lewistown; and several steam-electric plants at Butte and elsewhere, maintained as sources of reserve power.



Holter Plant—Dam and Power House Under Construction.

Substations.

This power system utilizes 47 substations, having a combined capacity of 227,000 kilowatts. Three of these are at Butte, in fireproof buildings, their capacities being 13,275 kilowatts, 20,000 kilowatts and 28,800 kilowatts, respectively. Sixteen of the 47 substations are outdoors.

Lease of Underground Conduit System Approved, Pennsylvania.—Reversing a former decision, the Public Service Commission, Pennsylvania, has handed down an order approving the leasing of the conduit system of the Keystone Telephone Company, Philadelphia, by the Philadelphia Electric Company, at an annual rental of four cents a duct foot. The minimum rental will commence at $25,000 a year and increase $12,500 a year until a maximum of $100,000 is reached. The maximum rental for the use of the entire system is placed at $240,000. Upon the former application, the Commission refused to approve the proposed agreement on the ground that the rental price was too high and consumers would be forced to defray the amount.