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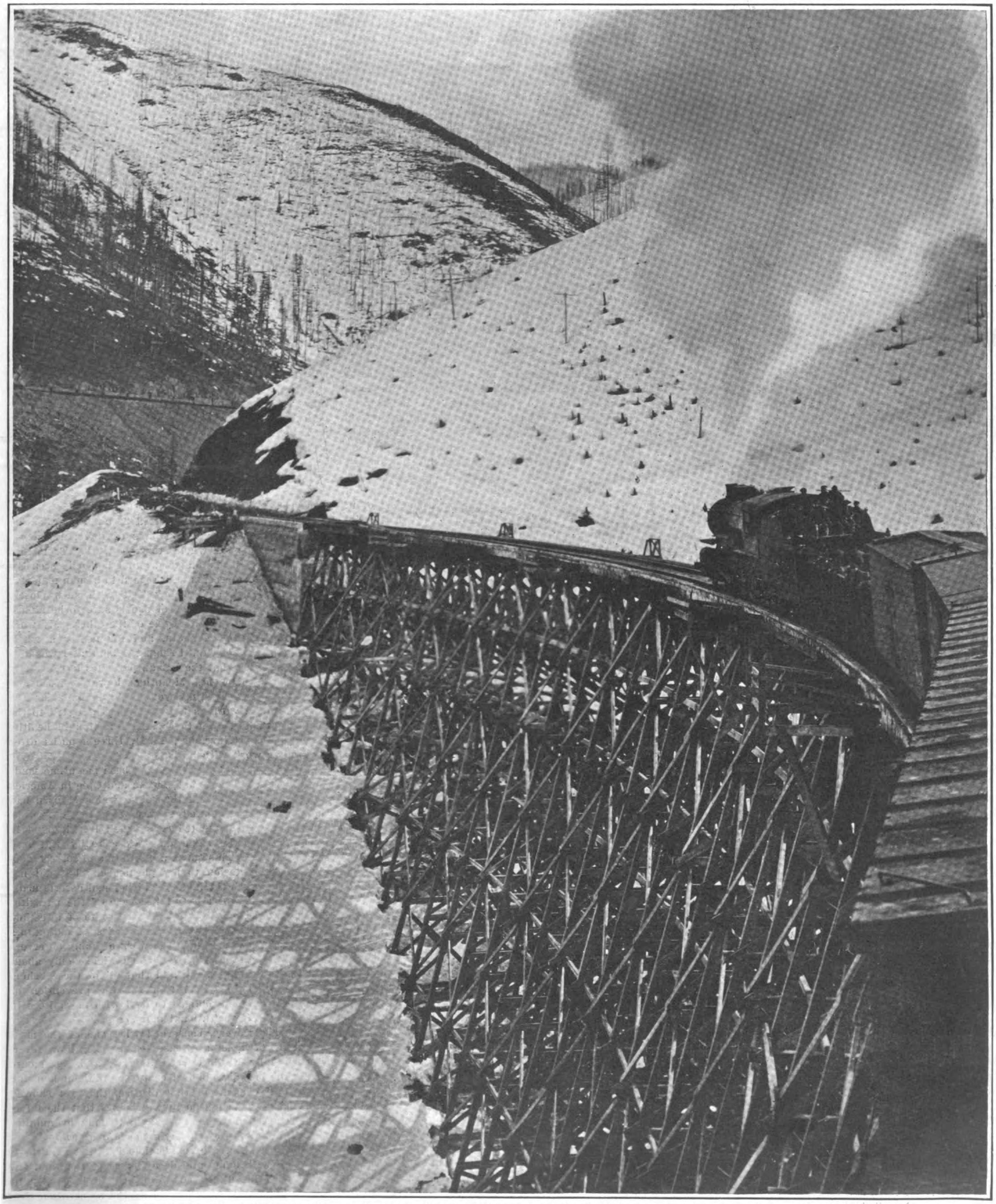


Scene in the Bitter Root Mountains, where the Chicago, Milwaukee & St. Paul Railway is to supplant steam with electricity.

RAILROAD ELECTRIFICATION IN THE FAR WEST.—[See page 56.]

A Great Railway Electrification Project

440 Miles of the Chicago, Milwaukee & St. Paul Mountain Lines to be Operated by Electric Power

THE Chicago, Milwaukee & St. Paul Railroad has decided to electrify four engine divisions of its Puget Sound lines, extending from Harlowton, Montana, to Avery, Idaho, a total distance of about 440 miles, aggregating approximately 650 miles of track, including yards and sidings.

Work has already been started on the first engine division, consisting of 113 miles of main line track between Three Forks and Deer Lodge, Montana, and contracts have been let to the General Electric Company for the electric locomotives, substation apparatus and line material. Power will be secured from the Montana Power Company, which will also construct the transmission and trolley lines.

While the four engine divisions of 440 miles comprise the extent of track to be equipped in the near future, it is understood that plans are being made to extend the electrification from Harlowton to the coast, a distance of 850 miles, should the operating results of the initial installation prove as satisfactory as anticipated.

The plans of the Chicago, Milwaukee & St. Paul Railway are of especial interest, as this is the first attempt to install and operate electric locomotives on tracks extending over several engine divisions, under which condition it is claimed the full advantage of electrification can be secured. The various terminal and tunnel installations have been made necessary, more or less, by reason of local conditions; but the electrification of this road is undertaken purely on economic grounds with the expectation that superior operating results with electric locomotives will effect a sufficient reduction in the present cost of steam operation to return an attractive percentage on the large investment required. If the anticipated savings are realized in the electric operation of the road this initial installation will constitute one of the most important milestones in electric railway progress, and it should foreshadow large future developments in heavy steam road electrification. The success of electric operation on such a large scale will, at least, settle the engineering and economic questions that enter into the advisability of making such an installation, and will limit similar future problems to the means of raising the money expenditure required.

The first step taken toward electrification by the Chicago, Milwaukee & St. Paul Railway was to enter into a contract with the Montana Power Company for an adequate supply of power over the 440 miles of main line considered for immediate electrification. The precautions taken, both by the railway company and power company, to safeguard the continuity of power supply should guarantee a reliable source of power subject to few interruptions of a momentary nature only.

The Montana Power Company covers a great part of Montana and part of Idaho with its network of transmission lines, which are fed from a number of sources of which the principal ones are tabulated below:

Madison River	11,000 kilowatts
Canyon Ferry	7,500 kilowatts
Hauser Lake	14,000 kilowatts
Big Hole	3,000 kilowatts
Butte, steam turbine	5,000 kilowatts
Rainbow Falls	21,000 kilowatts
Small powers aggregating	7,390 kilowatts
Total power developed	68,890 kilowatts

Further developments, part of which are under construction, are as follows:

Great Falls	85,000 kilowatts
Holter	30,000 kilowatts
Thompson Falls	30,000 kilowatts
Snake River	20,000 kilowatts
Missoula River	10,000 kilowatts
Total	175,000 kilowatts
Total power capacity, developed and undeveloped	244,000 kilowatts

The several power sites are interconnected by transmission lines, supported on wooden poles and operating at 50,000 volts for the earlier installations, and on steel towers and operating at 100,000 volts for later installations. Ample water storage capacity is provided in the Hobgen reservoir of 300,000 acre-feet, supplemented by an auxiliary reservoir capacity at the several power sites, which brings the total up to 418,000 acre-feet. The Hobgen reservoir is so located at the head waters of the Madison River that water drawn from it can supply in turn the several installations on the Madison and Missouri rivers, so that the same storage capacity is used a number of times, affording an available storage capacity considerably greater than is indicated by the figures given. It would seem, therefore, in changing from coal to electricity as a source of motive power, that the railroad is amply protected in respect to the reliability and continuity of the power supply.

Due to the great facilities available and the low cost of construction under the favorable conditions existing, the railway company will purchase power at a contract rate of 0.00536 cent per kilowatt-hour, based on a 60 per cent load factor. It is expected, under these conditions, that the cost of power for locomotives will be considerably less than is now expended for coal. The contract between the railway and power companies provides that the total electrification between Harlowton and Avery, comprising four engine divisions, will be in operation January 1st, 1918.

In order to connect the substations with the several feeding-in points of the Montana power transmission lines, a tie-in transmission line is being built by the railway company that will permit feeding each substation from two directions and from two or more sources of power. This transmission line will be constructed with wooden poles, suspension type insulators, will operate at 100,000 volts, and will follow, in general, the right of way of the railway company except where advantage can be taken of a shorter route over public domain to avoid the necessarily circuitous line of the railway in the mountain districts.

The immediate electrification of 113 miles will include four substations containing step-down transformers and motor-generator sets with necessary controlling switchboard apparatus to convert 100,000-volt, 60-cycle, three-phase power to 3,000 volts direct current. This is the first direct current installation using such a high potential as 3,000 volts, and this system was adopted in preference to all others after a careful investigation extending over two years. The 2,400-volt direct current installation of the Butte, Anaconda & Pacific Railway in the immediate territory of the proposed Chicago, Milwaukee & St. Paul electrification has furnished an excellent demonstration of high-voltage, direct-current locomotive operation during the past year and a half, and the selection of 3,000 volts direct current for the Chicago, Milwaukee & St. Paul was due, in a large measure, to the entirely satisfactory performance of the Butte, Anaconda & Pacific installation.

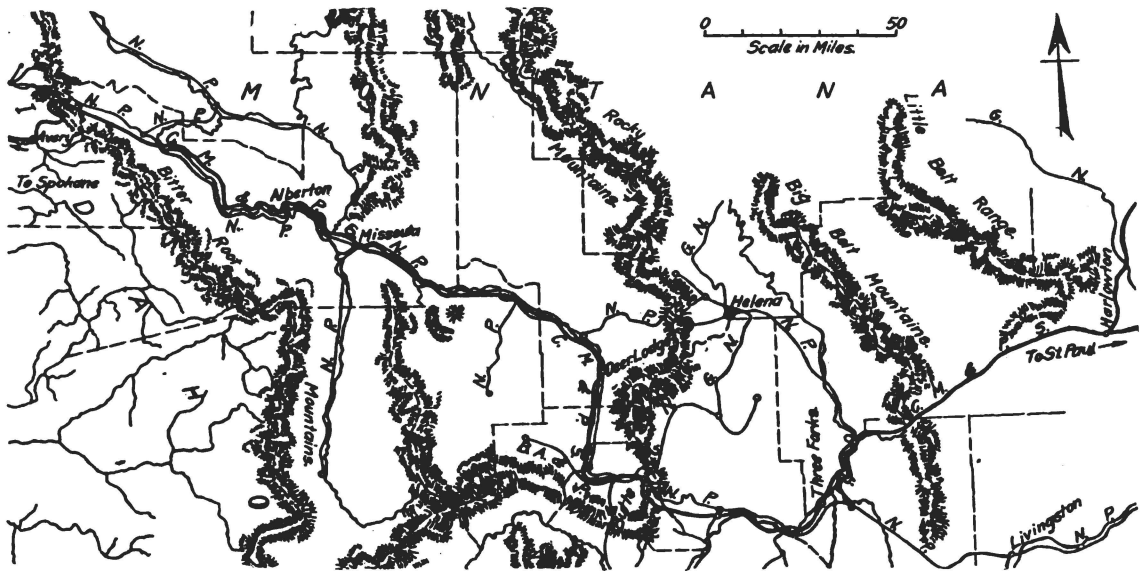
The equipment for this road was also furnished by the General Electric Company, and a comparison based on six months' steam and electric operation shows a total net saving of more than 20 per cent on the investment or total cost of the electrification. These figures, of course, do not take into account the increased capacity of the lines, improvement to the service, and the more regular working hours for the crews. The comparison also shows that the tonnage per train has been increased by 35 per cent, while the number of trains has been decreased by 25 per cent, with a saving of 27 per cent in the time required per trip.

SUBSTATIONS.

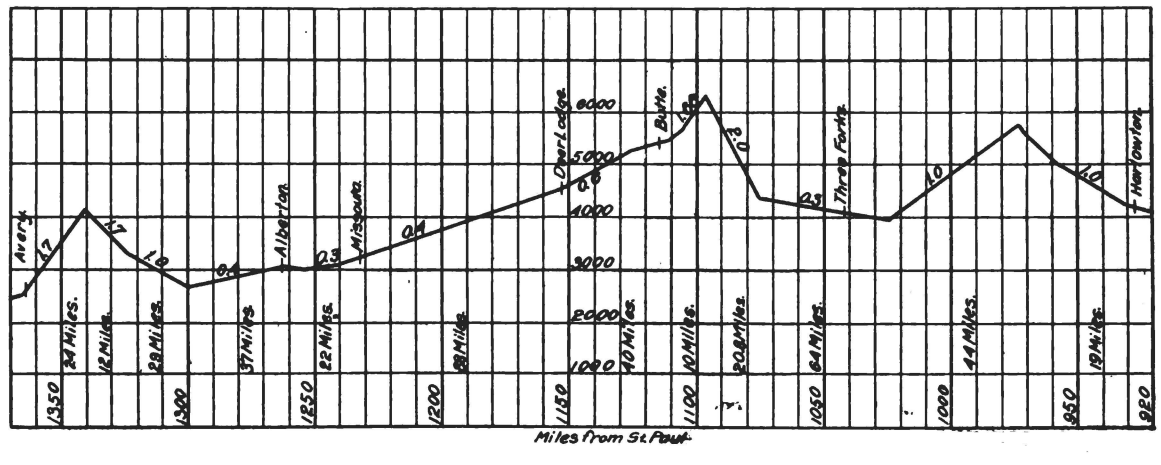
The substation sites of the Chicago, Milwaukee & St. Paul electrified zone provide for an average intervening distance of approximately 35 miles, notwithstanding that the first installation embraces 20.8 miles of 2 per cent grade westbound and 10.4 miles of 1.66 per cent grade eastbound over the main range of the Rocky Mountains. With this extreme distance between substations and considering the heavy traffic and small amount of feeder copper to be installed, it becomes apparent that such a high potential as 3,000 volts direct current permits of a minimum investment in substation apparatus and considerable latitude as to location sites.

The substations will be of the indoor type, transformers being three-phase, oil-cooled, and reducing from 100,000 volts primary to 2,300 volts secondary, at which potential the synchronous motors will operate. The transformers will be rated 1,800 and 2,500 kilovolts-amperes and will be provided with four 2½ per cent taps in the primary and 50 per cent starting taps in the secondary.

The motor generator sets will comprise a 60-cycle synchronous motor driving two 1,500-volt, direct-current generators connected permanently in series for 3,000 volts. The fields of both the synchronous motor and direct-current generators will be separately excited by small generators direct connected to each end of the motor-generator shaft. The direct-current generators will be compound wound, will maintain constant potential up to 150 per cent load, and will have a capacity

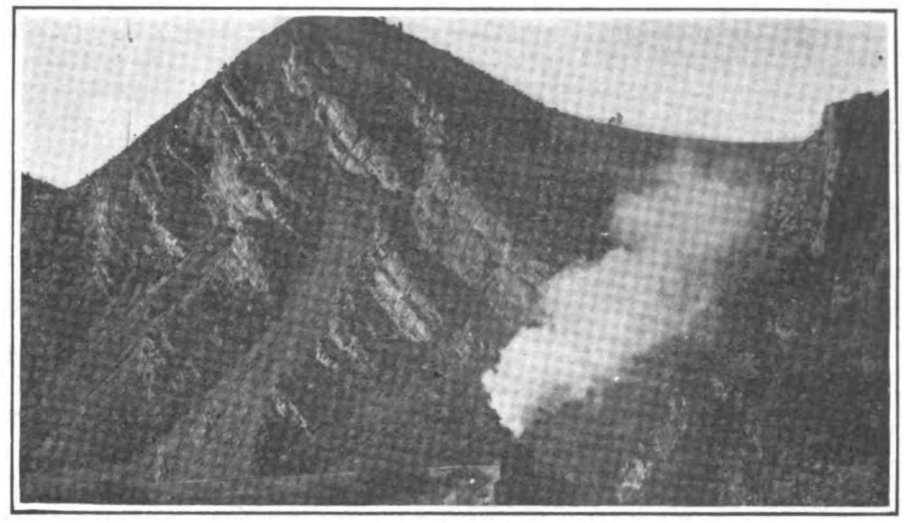


Map of the mountain country of Montana where the Chicago, Milwaukee and St. Paul Railroad proposes to use electric power to haul its trains.



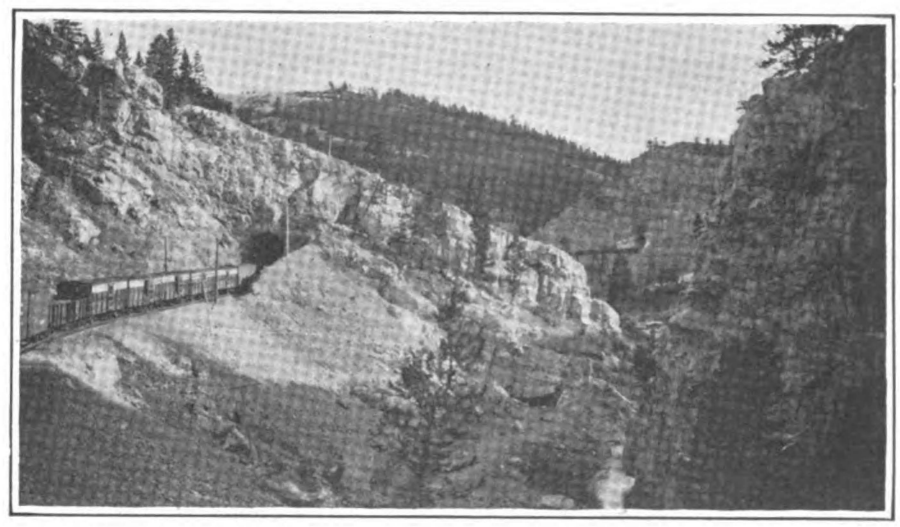
Profile of the route in above map, showing grades and distances.

Through Jefferson Valley, Montana.

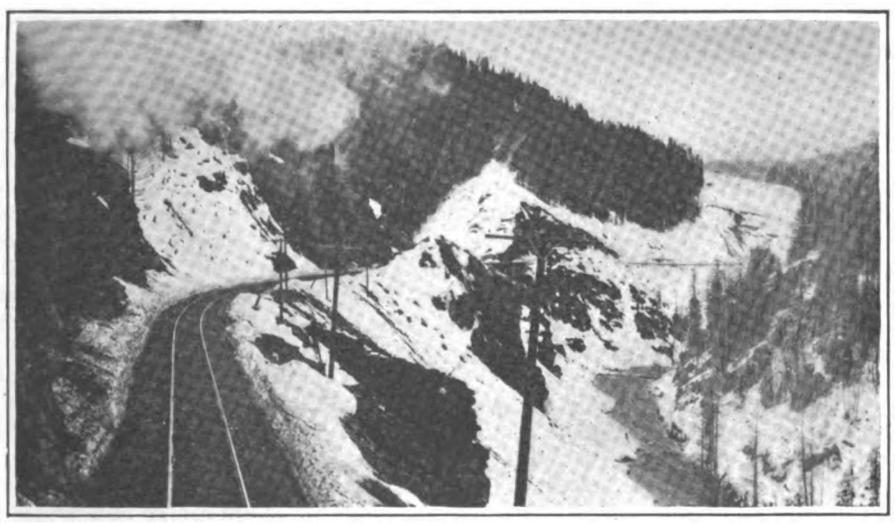


Skirting the mountain tops, near Jefferson Valley.

Pulling over a heavy grade in the Rocky Mountains.



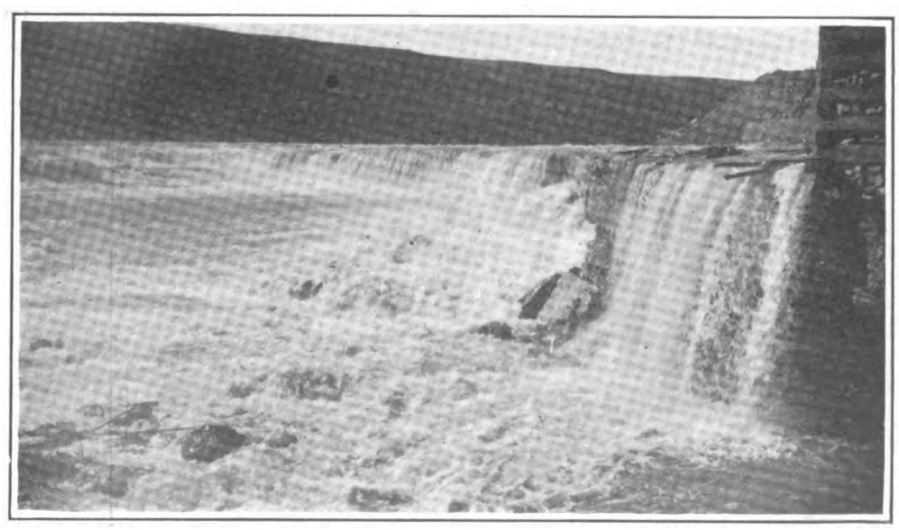
Tunnels and bridges in Sixteen Mile Canyon, Belt Mountains.



The east slope of the Bitter Root Mountains.

The devious trail through the Bitter Root Mountains.

On a two per cent grade in the mountains of Montana.



Raton Falls, which will supply part of the electric power.

SCENES IN THE REGION IN WHICH THE CHICAGO, MILWAUKEE AND ST. PAUL RAILROAD WILL USE ELECTRIC POWER.

for momentary overloads up to three times their normal rating. To insure good commutation on these overloads, the generators are equipped with commutating poles and compensating pole-face windings. The synchronous motors will also be utilized as synchronous condensers, and it is expected that the transmission line voltage can be so regulated thereby as to eliminate any effect of the fluctuating railway load.

The location and equipment of the several substations is as follows:

Station.	Miles from Deer Lodge.	No. of units.	Kw. per unit.	Total.
Morel	17.1	2	2,000	4,000
Jancy	50.5	3	1,500	4,500
Piedmont ..	77.9	3	1,500	4,500
Rustis	120.6	2	2,000	4,000

OVERHEAD CONSTRUCTION.

The trolley construction will be of the catenary type, in which a 4/0 trolley wire is flexibly suspended from a steel catenary supported on wooden poles, the construction being bracket wherever track alignment will permit and cross-span on the sharper curves and in yards. Steel supports instead of wooden poles will be used in yards where the number of tracks to be spanned exceeds the possibilities of wooden pole construction. Poles for the first installation are already on the ground and thirty miles of poles are set. Work in this direction will be pushed with all speed and will be completed in the summer of 1915, ready for operation in the fall on the delivery of the first locomotives.

As the result of careful investigation and experiments, a novel construction of trolley will be installed, composed of the so-called twin-conductor trolley. This comprises two 4/0 wires suspended side by side from the same catenary by independent hangers alternately connected to each trolley wire. This form of construction permits the collection of very heavy current by reason of the twin contact of the pantograph with the two trolley wires, and also insures sparkless collection under the extremes of either heavy current at low speed or more moderate current at very high speeds. It seems that the twin-conductor type of construction is equally adapted to the heavy grades calling for the collection of very heavy currents, and on the more level portions of the profile where maximum speeds of 60 miles per hour will be reached with the passenger trains having a total weight of over 1,000 tons. The advantage of this type of construction is due partly to the greater surface for the collection of current, but largely to the very great flexibility of the alternately suspended trolley wires, a form of construction which eliminates any tendency to flash at the hangers either at low or high speed. Including sidings, passing and yard tracks, the 113 miles of route mileage is increased to approximately 168 miles of single track to be equipped between Deer Lodge and Three Forks in the initial installation.

LOCOMOTIVES.

The locomotives to be manufactured by the General Electric Company are of especial interest for many reasons. They are the first locomotives to be constructed for railroad service with direct-current motors designed for so high a potential as 3,000 volts. They will weigh approximately 260 tons, and will have a continuous capacity greater than any steam or electric locomotive yet constructed. Perhaps the most interesting part of the equipment is the control, which is arranged to effect regenerative electric braking on down grades. This feature as yet has never been accomplished with direct-current motors on so large a scale. The general characteristics as proposed are tabulated below:

Total weight	260 tons
Weight on drivers	200 tons
Weight on each guiding truck	30 tons
Number of driving axles	8
Number of motors	8
Number of guiding trucks	2
Number of axles per guiding truck	2
Total length of locomotive	112 feet
Rigid wheel base	10 feet
Voltage of locomotive	3,000
Voltage per motor	1,500
Horse-power rating 1 hour-each motor	430
Horse-power rating continuous, each motor.	375
Horse-power rating 1 hour, complete locomotive	3,440
Horse-power rating continuous, complete locomotive	3,000
Trailing load capacity, 2 per cent grade	1,250 tons
Trailing load capacity, 1 per cent grade	2,500 tons
Approximate speed at these loads and grades	16 m.p.h.

The Chicago, Milwaukee & St. Paul Railway, from Harlowton to the coast, crosses four mountain ranges. The Belt Mountains at an elevation of 5,768 feet, the Rocky Mountains at an elevation of 6,350 feet, the Bitter Root Mountains at an elevation of 4,200 feet, and the Cascade Mountains at an elevation of 3,010 feet. The first electrification between Three Forks and Deer Lodge calls for locomotive operation over 20.8 miles of 2 per cent grade between Piedmont and Donald at the crest of the main Rocky Mountain Divide, so that the locomotives will be fully tested out as to their capacity and general service performance in overcoming the natural obstacles of the first engine division.

The initial contract calls for nine freight and three passenger locomotives having the above characteristics and similar in all respects, except that the passenger locomotives will be provided with a gear ratio permitting the operation of 800-ton trailing passenger trains at approximately 60 miles per hour, and will, furthermore, be equipped with an oil-fired steam heating outfit for the trailing cars. The interchangeability of all electrical and mechanical parts of the freight and passenger electric locomotives is considered to be of very great importance from the standpoint of operation and maintenance.

The cab consists of two similar sections extending practically the full length of the locomotive. Each section is approximately 52 feet long and the cab roof is about 14 feet above the rail exclusive of the housings for ventilation. The trolley bases are about 5 feet above the roof, owing to the unusual height of the trolley wire, which will be located at a maximum elevation of 25 feet above the rail. The outer end of each cab will contain a compartment for the engineer, while the remainder is occupied by the electric control equipment, train heater, air-brake apparatus, etc.

MOTORS.

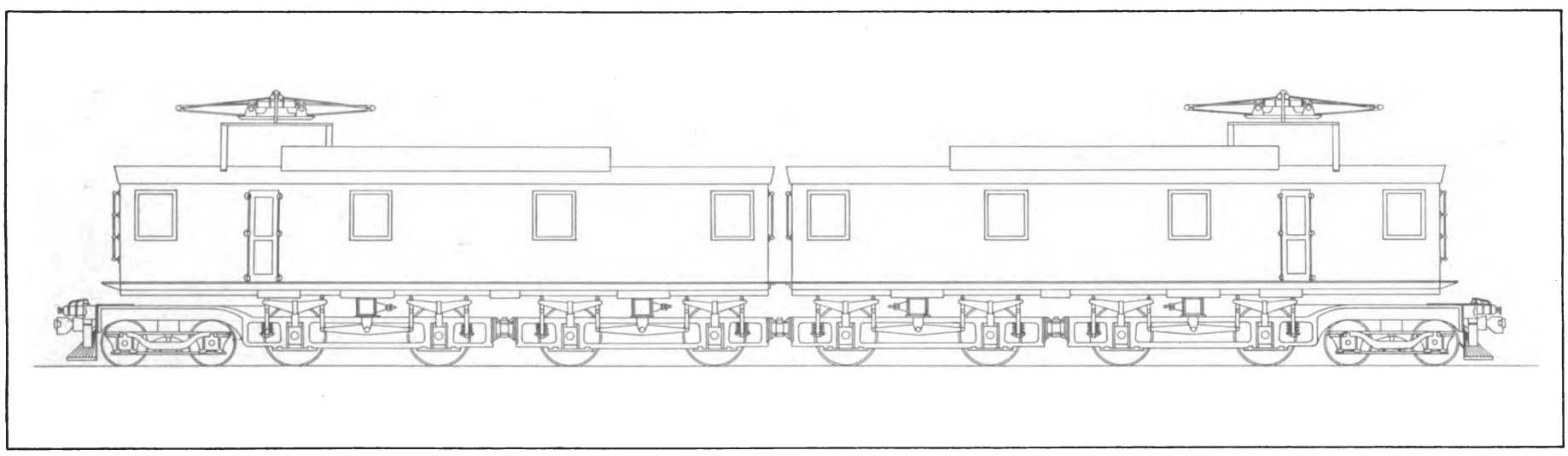
The eight motors for the complete locomotive will be type G.E.-253-A. This motor has a normal one-hour rating of 430 horse-power with a continuous rating of 375 horse-power. The eight motors will thus give the locomotive a one-hour rating of 3,440 horse-power and a continuous rating of 3,000 horse-power, which makes it more powerful than any steam or electric locomotive ever built. The drawbar pull available for starting trains will approximate 120,000 pounds at 30 per cent coefficient of adhesion.

Each motor will be twin-geared to its driving axle in the same manner as on the Butte, Anaconda & Pacific, the Detroit River Tunnel, and the Baltimore & Ohio locomotives, a pinion being mounted on each end of the armature shaft. The motor is of the commutating pole type and has openings for forced ventilation from a motor-driven blower located in the cab.

The freight locomotives are designed to haul a 2,500-ton trailing load on all gradients up to 1 per cent at a speed of approximately 16 miles per hour, and this same trainload unbroken will be carried over 1.66 and 2 per cent ruling grades on the west and east slopes of the Rocky Mountain Divide with the help of a second similar freight locomotive acting as a pusher. Track provision is being made at Donald, the summit of the grade, to enable the pusher locomotive to run around the train and be coupled to the head end to permit electric braking on the down grade. In this case, the entire train will be under compression and held back by the two locomotives at this head end, the entire electric braking of the two locomotives being under the control of the motorman in the operating cab of the leading locomotive. It is considered that electric braking will prove very valuable in this mountain railroading; for, in addition to providing the greatest safety in operation, it also returns a considerable amount of energy to the substations and transmission system. which can be utilized by other trains demanding power. In this connection, the electric locomotives will have electric braking capacity sufficient to hold back the entire train on down grade, leaving the air-brake equipment with which they are also equipped to be used only in emergency and when stopping the train. There is, therefore, provided a duplicate braking system on down grades, which should be reflected in the greatest safety of operation afforded and the elimination of a considerable part of break-downs, wheel and track wear and overheating, with consequent reduction in maintenance and improvement in track conditions.

With the completion of the remaining engine divisions, it is proposed to take advantage of the possibilities afforded by the introduction of the electric locomotive by combining the present four steam engine divisions into two locomotive divisions of approximately 220 miles length, changing crews, however, at the present division points. As the electric locomotive needs inspection only after a run of approximately 2,000 miles, requires no stops for taking on coal or water, or layover due to dumping ashes, cleaning boilers or petty roundhouse repairs, it is expected that the greater flexibility of the locomotive so provided will result in considerable change in the method of handling trains now limited by the restrictions of the steam engine.

The electrification of the Chicago, Milwaukee & St. Paul is under the direction of Mr. C. A. Goodnow, assistant to the president and in charge of construction. The field work is under the charge of Mr. R. Beeuwkes, electrical engineer for the railway company.



3,000-volt, direct-current electric locomotive. Most powerful yet built.

Handling Freight by Motor Trucks

A FEW years ago an innovation appeared in the way of a motor-driven truck for handling baggage in a few large railway passenger stations, and since that time great progress has been made in adapting the system to the handling of freight, with the result that the cost has been very considerably reduced. An instance illustrating the advantage gained is the report of the experience of the Central Georgia Railroad in handling cotton between the piers and storehouses at Savannah, where by the old methods of hand labor the cost was a little over six cents per bale, which the electric trucks driven by storage batteries reduced to about two and one third cents. Portable motor-driven jib crane loaders were then added, and these brought the cost, including fixed charges, maintenance and cost of power, to about 2.2 cents per bale. This is a remarkable showing in view of the fact that the electric outfit is in use only about four months each year. By the use of the loader the trucks can be loaded at the rate of a 500-pound bale every twelve seconds, which is much quicker than hand loading, and can be kept up all day, which is not the case with hand labor. Besides the money saving effected by the use of electric power there is an additional saving in time.