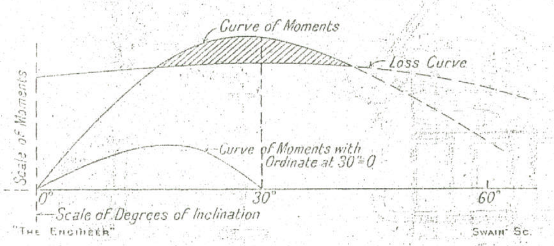
ordinate of the curve of moments for the inclination of 30 deg., the decimal value from the table is to be multiplied by the breadth of the ship, and the result must then be added to twice the length of the lever corresponding with the ordinate of the moment curve at 30 deg. This rule assumes that, if half the G M height be set off from the 30 deg. point on the base line, the straight line drawn from the offset point to the origin of the lever curve is a tangent to the latter. For the approximation here in question the assumption is sufficiently correct.

The accompanying figure will sufficiently illustrate the question:—



The hatched part of the curve of moments projecting above the loss curve represents the spare stability. The point of intersection of the curves at about 15 deg. shows the steady inclination from the upright which, under static treatment, the ship might be supposed to assume under the action of the careening forces in question. If the loss curve could be assumed to be raised bodily till it touched the curve of moments at a single point, this latter would give the angle of inclination at which the ship would capsize, provided the conditions were not further modified by rolling. The effect of rolling would be alternately to raise and lower the loss curve. Under the conditions assumed for the sketch, the gunwale of the vessel would enter the water at a moderate angle of heel with the result that rolling would be damped and the rise and fall of the loss curve would then not be very great. For the sake of clearness, the curves the combination of which makes up the loss curve are left out of the figure. These, as well as combination loss curves for different assumptions, the angles at which the deck edge might become immersed, angles of assumed list, &c., might in an actual stability estimate diagram be given. Something like a comprehensive picture of the probable effects of different occurrences at sea could then take the place of the mound of statical stability hitherto presented.

ELECTRIFICATION ON THE CHICAGO, MILWAUKEE, AND ST. PAUL RAILWAY.

The work in connection with the electrification of the western lines of the Chicago, Milwaukee, and St. Paul Railway is progressing rapidly. More than 200 miles of the overhead construction, and the 100,000 transmission line have been completed, and extensive yards and sidings at Three Forks, Deer Lodge, and Piedmont, and various tracks at other points are ready for electrical operation. When it is remembered that the order for the electrification of the 650 miles of single track was only placed with the American General Electric Company in September of last year it will be seen that the progress to date is highly satisfactory.

Wooden poles—see Fig. 1—are used for carrying the twin 4/0 trolley wires, which are suspended separately from the same steel catenary, and the hangers of one trolley wire are placed at points midway between the spans of the other trolley wire. In the shunting yards, however, there is only one contact wire.

Seven sub-station buildings have been completed, and the electrical machinery is now being installed. Motor generator sets, transformers, switchboards, &c., have been dispatched from the General Electric Company's works for these sub-stations, four of which are now practically ready for operation. As shown on the profile, Fig. 2, there will be fourteen sub-stations in all, and the table below gives their equipments.

Sub-station name.	Miles from Avery.	No. of units.	Size of sets K.W.	Total K.W.	Size of transformers. K.V.A.	Total K.V.A.
Two Dot	425	2	2000	4000	2500	5000
Summit	392	2	2000	4000	2500	5000
Josephine	361.8	2	2000	4000	2500	5000
Eustis	331	2	2000	4000	2500	5000
Piedmont ..	289.1	3	1500	4500	1900	5700
Janney	261.7	3	1500	4500	1900	5700
Morel	228.3	2	2000	4000	2500	5000
Gold Creek ..	192.7	2	2000	4000	2500	5000
Ravens	160	2	2000	4000	2500	5000
Primrose	122.2	2	2000	4000	2500	5000
Tarkio	85.6	2	2000	4000	2500	5000
Drexel	47.5	2	2000	4000	2500	5000
East Portal ..	23.7	3	2000	6000	2500	7500
Stetson	3.6	3	1500	4500	1900	5700
Total		32				74,600

One of the motor generator sets is shown in Fig. 4. Each set consists of a 60-cycle three-phase 2300-volt synchronous motor directly connected to two 1500-volt direct-current generators, which are permanently connected in series to supply current at 3000 volts. At the outside end of each dynamo is an exciter, one supplying current for exciting the field magnets of the synchronous motor, and the other exciting current for the dynamo. In general these converters are similar to the five 1000-kilowatt 2400-volt machines in operation on the Butte, Anaconda and Pacific Railway. One new feature, however, is the ventilating arrangement, which is similar to that adopted in the General Electrical Company's railway motors; that is to say, the air is drawn through the armature and field coils in a longitudinal direction. One of the locomotive motors is shown in Fig. 7.

To ensure sparkless working the generators of the motor generator sets are fitted with commutating

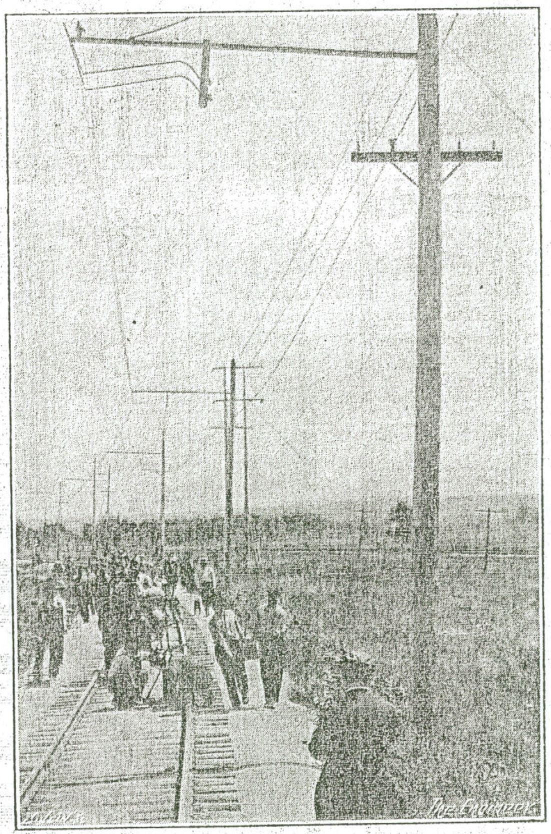


Fig. 1—WOODEN POLES FOR TROLLEY WIRES

poles and compensating windings on the pole faces, and it has been possible in this way to obtain without sparking overloads of 150 per cent. for two hours and 300 per cent. for five minutes. These overloads give ample margin for starting a train of maximum weight on the most severe gradients. The motor generators are designed for receiving current from the lines, so that when the trains are descending gradients current is sent back into the 100,000-volt system.

The switchgear in the sub-stations—see Fig. 5—is of special interest, representing as it does the latest high-tension direct-current practice. There is, of course, a separate panel for each converter, and two feeder panels are provided for the feeders running in each direction. The circuit breakers and switches are mounted on separate panels above the operating panels, and a short distance behind them. The control handles for operating the circuit breakers and switches are placed upon the main panels, and are connected to the circuit breaker panels by insulated rods. Besides these special high voltage direct-current panels there are also alternating-current switch panels for controlling the synchronous motors and auxiliary circuits. Similarly, for controlling the 100,000-volt circuits other switch gear is being installed.

The transformers—see Fig. 6—are being made in the Pittsburg works of the General Electric Company. There are to be thirty of these transformers, and they will be used for reducing the transmission line pressure of 100,000 volts to 2300 volts, at which pressure the current is supplied to the stator windings of the motors belonging to the converter sets. These transformers are to be installed in the fourteen sub-stations which will provide current for the lines from Harlowton (Montana) to Avery. There will also be twenty-three 2500 kilovolt-ampère and nine 1900 kilovolt-ampère transformers. All the transformers are of the three-phase core type, with a pressure ratio of 102,000 to 2300. For regulating purposes tappings are provided for 97,200 volts and 94,200 volts. There are also tappings on the secondary side to give 1150 volts for starting purposes. The transformers are air-cooled, and the tanks are of the tubular type, the main body consisting of steel plate with tubes welded to the side of the tank at the top and bottom. An air drier is attached to the tank, which has chambers containing a moisture extracting medium, which prevents the entrance of moisture into the tank. The bushings are water-tight, and suitable for outdoor as well as indoor operation.

As the top of the high-tension lead is a glass, which shows the height of the oil in the leads. The usual accessories, such as thermometers, oil gauges, &c., are also provided. Each transformer is mounted on wheels to facilitate repairs. A lifting device is also provided for lifting the core. For lighting and auxiliary power, each sub-station will be furnished with a standard three-phase transformer, the primary of which will be fed from the 2300 volt supply.

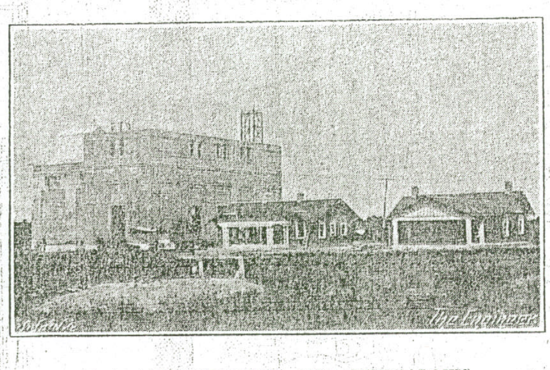


Fig. 3—SUB-STATION AND BUNGALOWS

The secondary voltage will be 110. Each sub-station is also to be equipped with a 25-kilowatt single-phase transformer for supplying the railway signal circuits. These transformers will also be connected to the 2300 supply, and will give on the secondary side a pressure of 4400 volts. A portable oil-drying outfit will be used for removing moisture from the transformer oil. This outfit consists of a motor-driven pump, which forces the oil through a filter, and an electric drying oven. A portable transformer drier and an oil-testing set will also be supplied.

For housing the families of the sub-station operators two bungalows are being erected at the side of each sub-station—see Fig. 3. One bungalow has four rooms and the other five rooms. Current for lighting these buildings will be taken from the low voltage auxiliary circuits.

With the locomotives we dealt pretty fully in a previous article—see The Engineer, January 29th, 1915. We are now able to illustrate the first goods engine—Fig. 8—which was tested at Erie in September of this year. This locomotive is now being exhibited at various points on the Chicago, Milwaukee and St. Paul system. Tests on the engine have indicated that in practice its performance will easily exceed the expectations of its designers. The actual weights of the goods engine are as follows:—

Total	564,000 lb.
Weight on drivers	448,000 ,,
Weight per driving axle	56,000 ,,
Weight per guiding axle	29,000 ,,

In all forty-two of these locomotives are on order. Twelve are to be geared for passenger service, and the remaining thirty for goods service. All the engines, as we said in our previous article, are designed for regenerative brakeing, and all the passenger locomotives and several of the goods locomotives are to be equipped with oil-fired steam boilers for heating the trains.

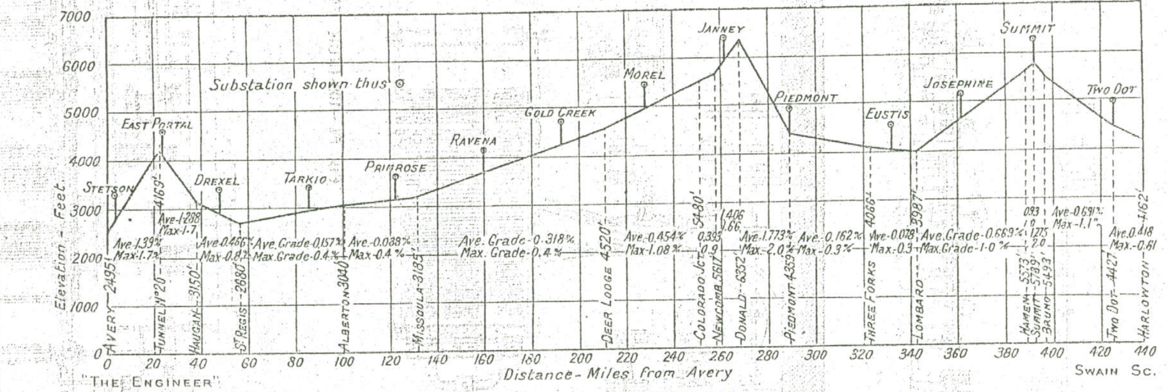


Fig. 2—PROFILE OF ELECTRIFIED LINE

It was eighty years on the 7th instant since the first sod of what is now the Erie Railroad was cut. The actual spot is now covered by a monument erected after the seventieth anniversary, and the original shovel is preserved by the Erie Railroad Company.