Great Northern Electrification

Motor-Generator locomotives will be used on 24-mile heavy grade section including the Cascade tunnel

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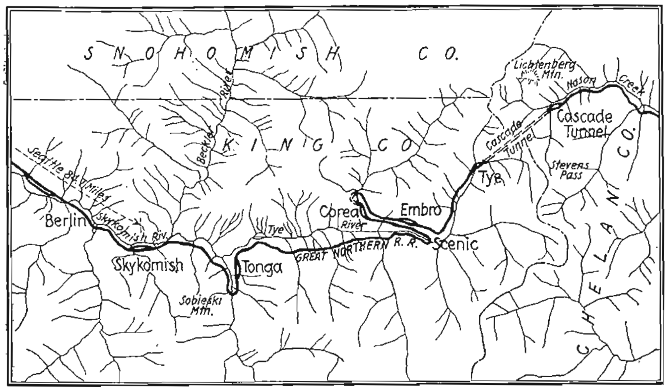
THE recent announcement by the Great Northern of its intention to electrify 24 miles of main line on the west slope of the Cascade mountains, extending from Skykomish to Cascade tunnel, Washington, again turns the attention of the railway field to activities in the Northwest. Interest in the undertaking is much increased by the decision of the management to adopt as the motive power unit the motor-generator type of locomotive and the fact that one of the original electri-



Map Showing Location of Section to Be Electrified

fication projects in this country, the three-phase system through the Cascade tunnel, is to be retired to give place to the new work.

By eliminating the duplication of helper service, the delays caused thereby, and other losses of time incident to the operation of steam locomotives, such as watering, refueling, etc., the electrification will effect a substantial reduction in operating expenses, permit of faster train movement over this section, and fulfill, in every way, the requirements of present operating conditions. Consideration has also been given to future requirements by an ample allowance for expansion; and by its willingness and desire to materially assist in the development of a new type of locomotive, the Great Northern gives evidence of a keen interest in the future of electrification, as a means of solving transportation problems of the country in general, as well as its own.

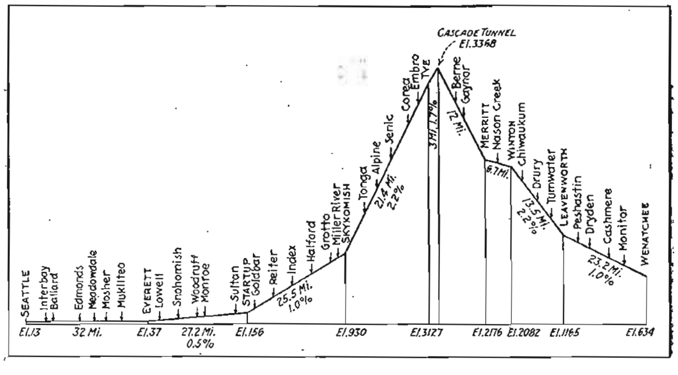
The main line of the Great Northern extends from St. Paul to Seattle. Of the freight traffic, a large portion is a through traffic, originating at one of the mentioned cities and, as such, requires a fast and reliable train service, which the company is well fitted to provide, having the least ruling grade to the coast of any of the western railroads, and an enviable roadbed, laid with heavy steel and double tracked at most of the critical points. The heaviest curves and grades against load movement are encountered in crossing the Cascade mountains in Washington, over what is yet a single track line. Here the rise to the summit is, on both sides, very precipitous and on the west slope a very circuitous route is required in making the ascent. Many snow-sheds protect the track from winter slides, and, in several places, the mountain has been pierced with tunnels, the longest of these being the Cascade tunnel at the summit of the range. This tunnel, constructed on a 1.7 per cent grade, is approximately 2¾ miles long and the present electrification was installed through the tunnel in 1909 for the purpose of eliminating gas and smoke.

Present Electric Equipment

Extending between Tye, the west portal, and Cascade tunnel station, the east portal, the existing electrification comprises four miles of main line track and an equal amount of yard trackage, equipped with a double overhead three-phase trolley of 6,600 volts. The present locomotive equipment consists of four, three-phase, 25-cycle General Electric units, as follows:

Total weight of unit	227,000 lb.
Classification of wheels	0-4-4-0
Weight on drivers	227,000 lb.
Number of driving axles	4
Capacity at one hour rating	1,300 hp.
Capacity continuous rating	1,300 hp.
Max. starting tractive effort	37,500 lb.
Tractive effort, continuous	25,000 lb.
Speed	15 m.p.h.
Total length wheelbase	31 ft. 9 in.
Rigid wheelbase	11 ft.
Length over-all	44 ft. 2 in.
Width over-all	10 ft. 2 in.
Maximum height (trolley down)	15 ft. 6⅝ in.
Diameter driving wheels	60 in.
Gear ratio	4.26
Method of drive	Gear and pinion
Number and type of motor	4 G. E. I—506
Voltage of motor	500

At the time this installation was made, there were no electric power lines within an available distance and to



Condensed Profile of Western End of Great Northern Lines, Including Section to Be Electrified

meet the situation the railway company was obliged to build a hydroplant at Tumwater on the Wenatchee river, thirty miles east of the tunnel. In this plant are three 2,000-kw. three-phase 25-cycle, 6,600-volt hydro-generators, operating under a head of 176 ft. and obtaining the water through an 8½-ft. flume, 2½ miles in length. The power thus furnished is transmitted to the sub-station at Cascade tunnel over a 33,000-volt transmission line.

Though serving the purpose for which it was installed, and relieving an almost impossible condition under steam operation, the necessity of maintaining a special tunnel organization has resulted in extremely high operating cost, and thus this electrification has long been tolerated as a necessary evil.

Between Seattle and Skykomish the condensed profile shows that the grades are not unduly heavy, nor are the curvatures excessive, the heavy grades and curves being confined to that section on the west slope of the Cascade mountains, between Skykomish and Cascade tunnel and, on the east slope, between Cascade tunnel and Leavenworth. With conditions on the east slope the railway is not especially concerned at this time, as certain contemplated changes in line with other reasons, have for the present delayed the electrification of that side. On the west slope, however, a consistent grade of 2.2 per cent is encountered from Skykomish to Tye, a distance of 21.4 miles, with curvatures up to 10 degrees and from Tye to the summit of the range, through the Cascade tunnel, the grade is 1.695 per cent.

East and west bound traffic, over this section each day is very similar, consisting each way of two passenger trains of about 1,000 and 850 tons, one express and mail train of 600 tons and a minimum of two time freights of 2,500 tons, none of these weights including locomotives.

Steam Operation

A 2,500-ton time freight, out of Seattle, or rather Interbay, the terminal yard, consisting of about 60 cars, covers the 80 miles to Skykomish in approximately 5½ hours when hauled by a 250-ton Mikado type 2-8-2 oil burning locomotive having a normal tractive power of 64,300 lb. At Skykomish, two 2-6 + 8-0 mallet type locomotives of 260 tons and developing a tractive effort of 78,300 lb., are cut into the train at about uniform distance apart, to assist on the 2.2 per cent grade to Tye. Including a delay at Skykomish for this operation of one hour and for water at Scenic of 20 minutes, the 21.4 miles to Tye is covered in 4½ hours. On arrival at Tye, the steam helpers are replaced in 30 minutes by the electric locomotives, located two ahead and two in the center of the train, and from Tye, the run to Cascade tunnel station is made in 22 minutes. Allowing 15 minutes at Cascade tunnel for cutting out the electrics and inspecting air brakes, the train when reassembled completes the remaining 53 miles to Wenatchee in four hours.

Reasons for Adopting New Type of Electric Equipment

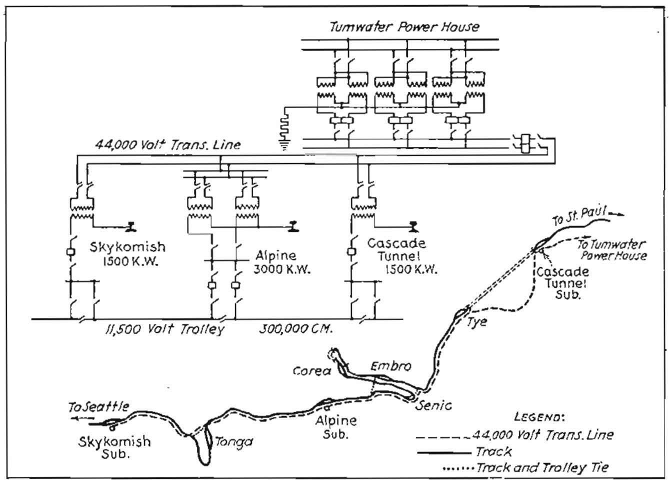
Realizing, as shown in the foregoing review of the operation, that a considerable improvement could be made in the schedule and a substantial reduction in the operating expenses, the management authorized the necessary appropriation for an electrification to accomplish the desired results. The authorization provided for a new system of electrification, as all concerned were acquainted with the fact that it would not be advisable to extend the present system.

The straight three-phase system, though used extensively in Italy and Switzerland, is not a highly desirable type of electrification, chiefly from an operating standpoint, but, as the general reasons for this are well known, reference will be made here to those only which are more distinctive to the operation on the Great Northern. First of these is the relatively low power factor of the system, and, second, the excessive power required during periods of train acceleration.

In the case of the former, without power factor correction on the line, the useful power at the locomotive is but little more than half of the kw. output of the station and, therefore, has been insufficient to pull the present large trains, requiring the four locomotives, at the rated speed of 15 m.p.h. To somewhat relieve this condition, the motor connections were arranged, a short time ago, to permit of operation at 7½ m.p.h. with the motors connected in "cascade," or at 15 m.p.h. connected in multiple. But, even with this change, the enormous starting current required by a three-phase motor makes the assistance of the steam locomotive necessary in accelerating the train, as the flow of the water in the 2½-mile flume is not sensitive enough to load variation to meet the excessive demand placed upon the station when starting without the steam helper.

The experience, both favorable and unfavorable, gained from the present electrification, proved invaluable to the company in selecting the system to be used on the new work with the result that the one adopted, comprised of a motor-generator type of locomotive, taking power from an 11,000-volt trolley, will unquestionably be more flexible than any system in operation at this time.

The inherent economy in transmission and operation of the high voltage trolley system, with its static non-attended transformer sub-station, minimum amount of copper, general lightness of supporting construction, and



Wiring Diagram Showing Power Connections and Location of Transmission and Trolley Lines

ready adaptation to increase in loading conditions with increase in traffic is today generally recognized; and in this case the lightness of the overhead construction is of special value. In the snowshed and tunnel district, this will appreciably lessen the difficulties and cost of construction and during the period of annual snowshed repairs, will aid greatly in maintaining uninterrupted service, when at times the trolley must be removed and replaced between trains.

With limitations existing, for the present, in the power supply, it will always be possible, with the flexibility of control of the motor-generator locomotive, to operate at a practically unlimited number of speeds, up to that of the continuous rating of the locomotive. Furthermore, the method of accelerating a train by means of voltage control of the motor is ideal from the standpoint of economy, both in starting losses and in power demand from the source of supply and by using a synchronous motor to drive the main motor-generator set power factor correction is obtained, thereby making practically the entire output of the station useful power.

In regeneration, the same flexibility of control is obtained as in motoring, it being possible to regenerate at all speeds within the range of the locomotive to practically standstill. The varying train weights over this section, and the conformation of the country, makes this large range a very desirable feature, as the speed, while regenerating, can always be adjusted to conform to the traffic requirements on the particular section of track.

The new locomotive will consist of four identical cabs as to size, weight and traction equipment, though for the present two only will be furnished with motor-generator sets; the other cabs will be connected to and obtain their power from them. It is interesting to note that because of the large range of speed obtainable by varying the voltage of the traction motors through the main field of the main generator, there will be no need of a variety of motor connections and therefore the motors of each cab are to be connected permanently in parallel with the exception that the motor cutout switches through the two cabs, when operating together, will be connected in series.

Electric Locomotives

The tentative characteristics of each cab are as follows:

Total weight (approx.)	340,000 lb.
Weight on drivers	260,000 lb.
Classification of wheels	2-8-2
Length rigid wheelbase	16 ft. 9 in.
Length total wheelbase	30 ft. 3 in.
Length over couple knuckles (approx.)	48 ft. 8 in.
Length of cab (approx.)	42 ft. 0 in.
Number motors	4
hp. motor (continuous)	500
Voltage of motor	600
Diameter driving wheels	56 in.
Tractive effort (continuous)	44,000 lb.
Max. speed at about tractive effort	15.2 m.p.h.
Max. allowable speed	35 m.p.h.
Continuous capacity, m. g. set	1,500 kw.

To obtain the benefit and use of the present three-phase locomotives, a synchronous phase converter, similar to those being furnished on the Virginian Railway, will be mounted with the necessary auxiliary apparatus, transformers, etc., on a car between two of these locomotives but as the car will not be equipped with traction motors, will serve as a trailer or tender car. Connection to the trolley will be made from the pantagraph mounted on this car and with practically no change in the present control the locomotives will be capable of duplicating their present performance.

Power Supply

The Tumwater plant, operating single phase, is, for a short period, to furnish all the power for the electrification and it is interesting to note that practically the full capacity of the generators can be obtained under this operation, without imposing any undue stresses on them, while present day machinery designed on a much closer margin can only be worked single phase to about 70 per cent of its three-phase capacity. In general, very little change in the plant will be necessary, excepting a rearrangement of the transformer banks.

To furnish three-phase power at 33,000 volts, each transformer bank, at present, is composed of three 6,600 to 19,000-volt single-phase transformers with secondary windings connected in star. The change will consist of using six of these transformers, connected in pairs, to the single-phase transmission line and, as shown in the wiring diagram, the transformers in each pair will have their primary windings connected in parallel and their secondaries in series.

The power thus obtained at 38,000 volts will be transmitted to the substations at Cascade tunnel, Alpine and Skykomish, where the stepdown transformation will be made to 11,000 volts for the trolley. Cascade tunnel substation is an indoor station and is to be changed only as regards the switching arrangement and the replacement of the present transformers with a new one of 1,500 kva. capacity. The two new stations at Alpine and Skykomish will be of the outdoor type and will have for the present a capacity of 3,000 and 1,500 kva. respectively though each of the three stations will be so arranged that their capacity may be increased at any time.

Contact System

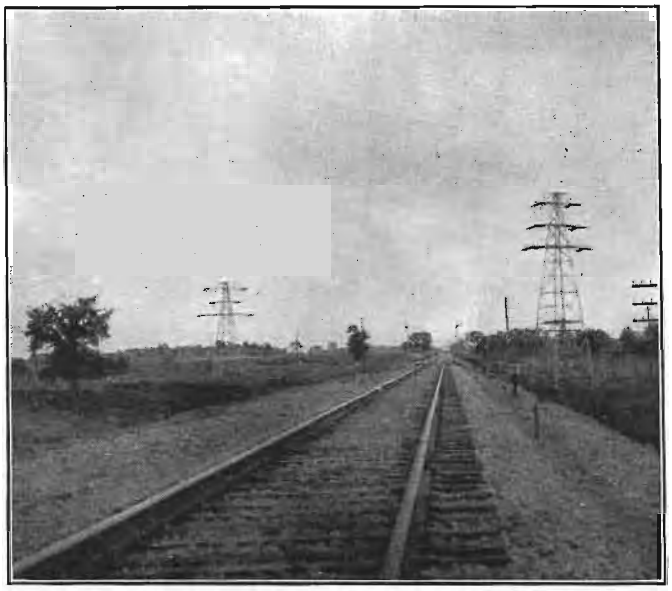
The trolley system will consist of a simple catenary with inclined catenary on the curves, all of which is to be constructed with non-ferrous materials and to obtain the necessary strength and conductivity of 300,000 c.m. equivalent copper, a 19-strand composite messenger and a 4/0 high strength cadmium bronze contact wire will be used.

Around the Tonga and Corea loops this heavy construction is not required as it is possible to tie the tracks and trolleys together at various places as shown in the diagram. In these sections the messenger will consist of a 4/0-19 strand high strength cadmium bronze messenger and a 4/0 contact wire of like characteristics.

Wood pole structures will be used for supporting the trolley, excepting through the snowsheds and tunnels, where the suspension will be made direct from the roof. The power transmission and signal transmission lines will also be carried on the trolley poles.

Operation over the electrified section is to commence June 1, 1926, and to that end the installation is being pushed as much as possible. The program of construction consists of placing all the pole structures this year and the wire and apparatus as soon as the snow conditions will permit next year.

As a whole, the electrification constitutes an important engineering development, but to the Great Northern the chief significance is of an economic nature. Much is expected of the change and the rigorous conditions under which operation is to commence will test the merits of the system, as perhaps none have been tried before. Freight train time over the division will be shortened an hour and a half, the wear on the rolling stock, especially in descending grades, will be reduced to a minimum, track capacity will be considerably increased, and the operation of smokeless passenger trains will permit the passengers to enjoy to the fullest one of the most scenic spots in America.



Near St. Anns, Ontario, on the T. H. & B.