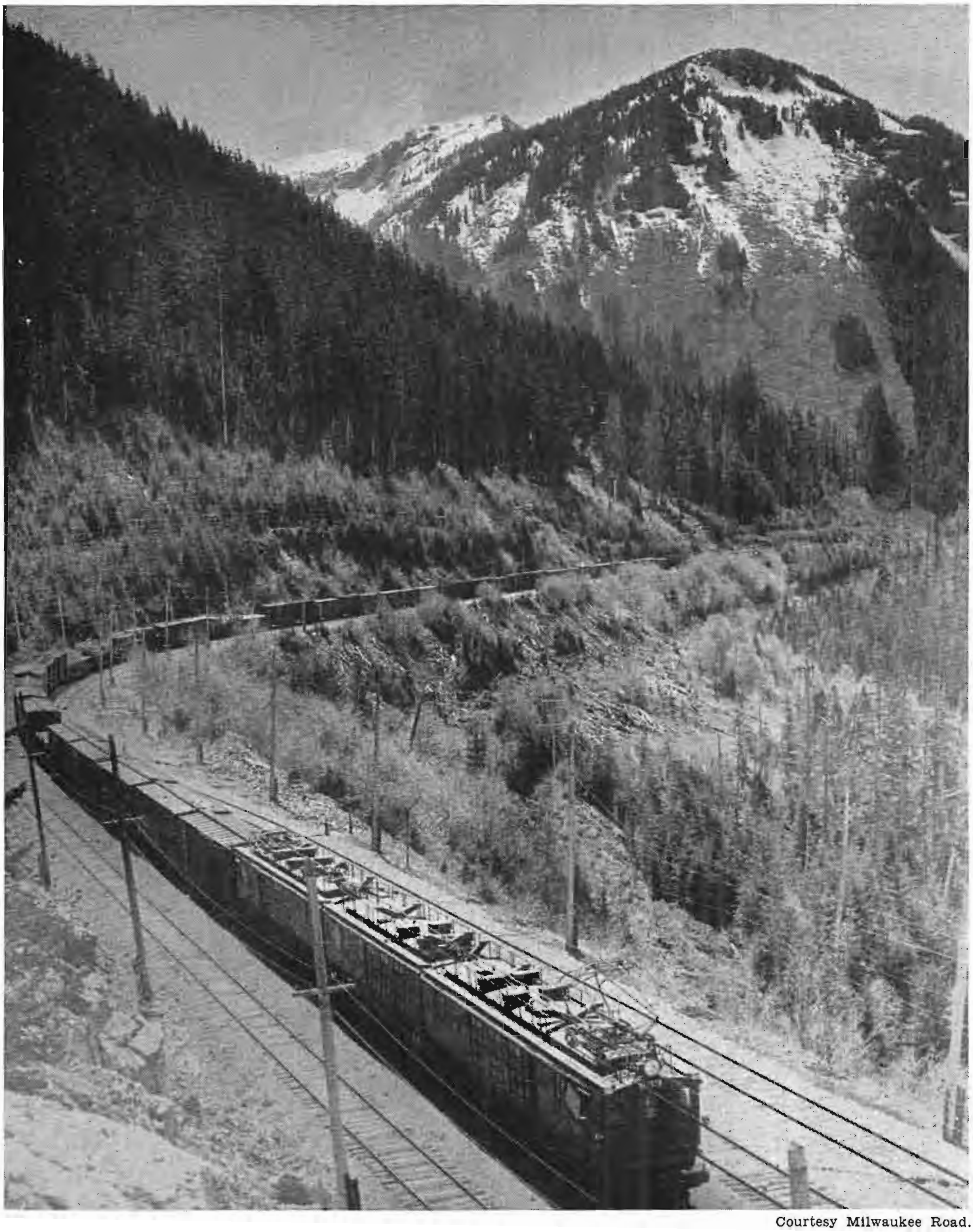


Courtesy Milwaukee Road.

Northwest passage from the Orient.

The romance of world trade rides with these freight cars, loaded with goods from ships at Seattle and Tacoma and with products of our Pacific Northwest. The Chicago, Milwaukee, St. Paul & Pacific is one of three great railroad routes across the northern states to the Pacific. It is electrically operated for 656 miles across four mountain ranges. A three-unit freight locomotive, as above, with a similar helper at the middle of the train, can lift a 5000-ton trainload over the passes and then ease it gently down grade with regenerative braking—not a hot brake shoe on the train!

Milwaukee Electrification

★ CMStP&P electric locomotives help each other climb the Rockies and the Cascades.

By Edwin H. Bowers.

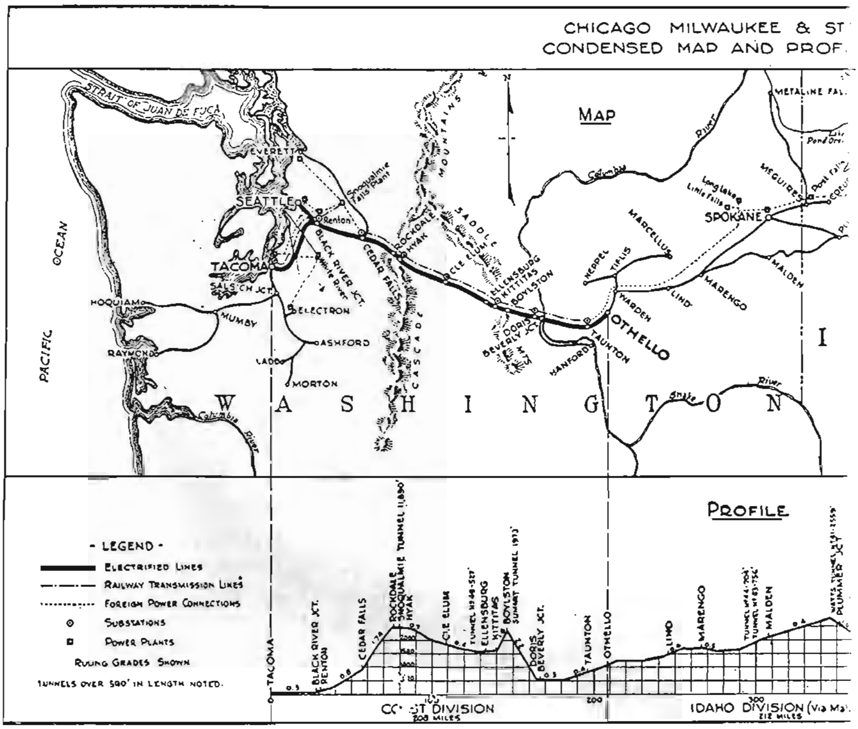
THE sun had just popped up from behind the Cascades when she left Seattle, and now it's nearly 8:30 a. m. as Milwaukee Road time freight No. 264 pauses in Cedar Falls, Wash., during switching and addition of a helper for the big climb to Snoqualmie Pass Tunnel. One big three-unit General Electric freight motor is at the head end, another coupled in the middle of the train where it can pull its half of the tonnage. Business is good! The Eastern lumber market improved measurably last year, and the diversion of ships to the more lucrative wartime trade has loaded thousands of tons additional onto the transcontinental railroads. Yet time freight 264 will be through to Chicago on schedule.

The train engineer on the front locomotive pulls out his throttle, watches the ammeter. Nothing happens for noticeable seconds as the motors soak up the current, and then the huge machine starts to move, very slowly, evenly, and gradually. Slack clanks out. The helper engineer watches the slack in the train immediately ahead of him and when the pull gets back to a few cars from his locomotive he inches out his throttle. Thus his engine merely takes up the second half of the load at just the right time, instead of giving a push to the front portion of the load. The train must be worked up to full speed control position within half an hour or so not only to avoid damage to the equipment, especially the control resistance grids, but also to avoid the waste of power by heat dissipated from the resistances. Ahead lies the 20-mile 1.74 per cent climb up Snoqualmie River Valley to the crest of the Cascades, beautifully green in their late Spring finery.

Talk about the Northwest passage—this is it! In normal peacetime the Milwaukee hauls out of Seattle raw silk, wood, oil, and tea from China and Japan; cotton from China, porcelain from Japan, wool from Manchuria, raw skins from Siberia, and hemp and cocoanut oil from the Philippine Islands. Foreign trade or no foreign trade, from our own Northwest states various forms of finished lumber, posts, poles and piling, wood pulp and paper, fish and agricultural products, livestock, wool, grain, crude oil, manganese, zinc, copper and copper products all go East over the steel-paved trade route. The lumber business is a big factor in traffic volume, and, according to the Northwest Lumberman's Association, the increase in railroad-shipped lumber in the last year has amounted to about 12 per cent of all the lumber produced in the area.

To the Milwaukee Road this sudden increase in business afforded another opportunity to test the efficiency of its electrical operation under emergency conditions. The load on train No. 264 was increased on the big hill over the Cascades between Cedar Falls and Hyak from 3500 to 5000 tons. At the same time both east and westbound schedules were speeded, cutting a full day off the running time between Chicago and the Pacific Coast. But, because an electric locomotive will assume an overload when its speed is reduced due to adverse gradients, and will develop over twice its normal power output during acceleration, a given tonnage can be moved over the rails at much better schedule speed than can be achieved by steam or other constant horsepower locomotives. To handle the tremendously increased tonnage over the Cascade mountains, it was necessary only to change from a two- to a three-unit motor for the helper on the hill between Cedar Falls and Hyak, and to make a similar increase on the hill between Avery, Ida., and East Portal in the Bitter Roots.

In many ways the electrification on the Milwaukee Road is unique in the history of the application of electricity to the hauling of main line trains. The Milwaukee Road was the first heavy traffic road to turn to electricity solely for the purpose of reducing



The line.

Two stretches of tough trackage are electrified with the comparatively level Idaho division steam operated between. The magnitude of this electrification is only realized when one looks at the mileage figures. The map covers a territory equal to that from Chicago to New York!

operating costs and for expediting traffic over its lines (on other projects, electrification was undertaken as a necessity because of tunnel and terminal operations), and the first steam road to operate electric locomotives over more than one division.

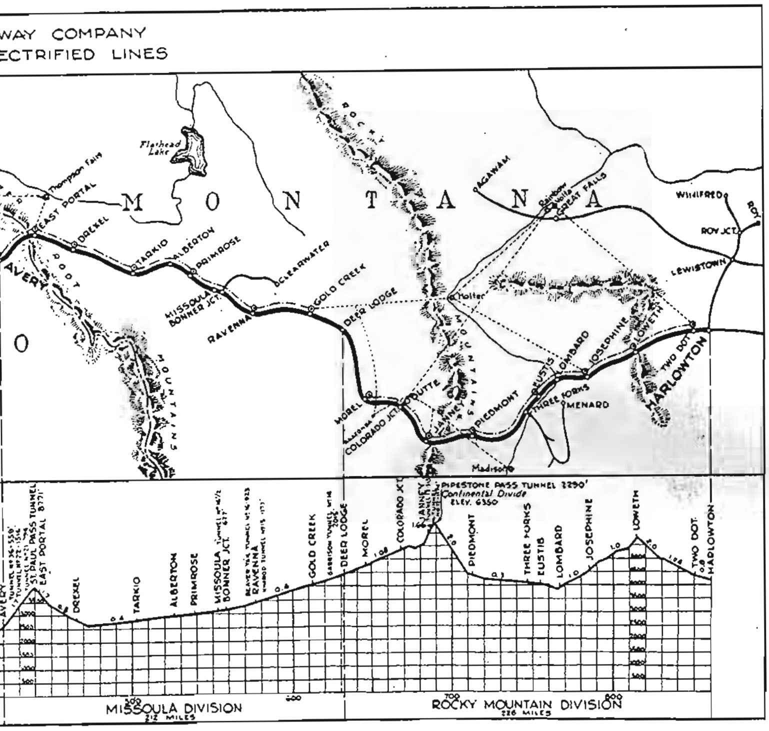
It was A. J. Earling, who was president of the Milwaukee Road at the time that it was being extended to the Pacific Coast in 1906-09, who first saw the wonderful possibilities in the abundance of cheap water power in the mountains of the West, and long before electrification was begun he had made provisions for power sites. However, when electrification was finally decided upon, it was determined through negotiations with the Montana Power Company and the Washington Power Company that it would be more feasible to utilize the existing facilities of their systems, and power contracts were signed with those companies.

With Reinier Beeuwkes, electrical engineer, in charge, preliminary surveys were made, and specifications drawn up that were so accurate in every detail that the changeover was made with little or no interruption of regular schedules. The same engineers who had handled the steam locomotives were instructed by the manufacturer's experts in handling the new

Coutesy E. H. Bowers, 623 White Bldg., Seattle, Wash.

Freight engine.

General Electric built 42 locomotives like this for the original Milwaukee electrification, 30 geared for freight and 12 for passenger. All are now used in freight service, and most of them have been doubled up into three-unit locomotives with maximum tractive effort of 172,750 pounds.

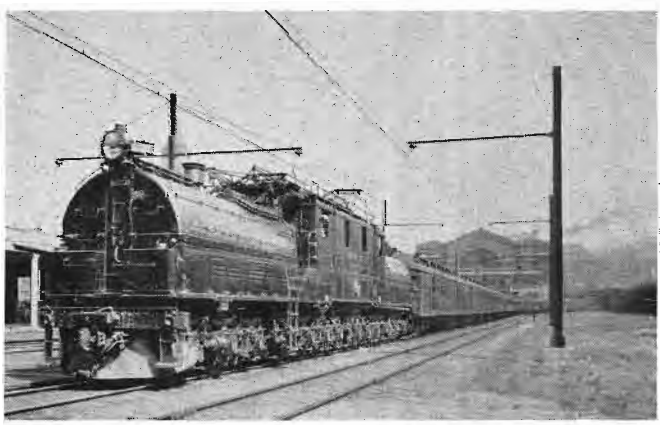


electrical equipment on trains in regular service.

The initial electrification of the Milwaukee Road included four steam engine divisions extending from Harlowton, Mont., to Avery, Ida., a distance of 438 miles. This distance is approximately equal to that between New York and Buffalo, and is more than the electrified route mileage of any trunk line now operating electric locomotives. Electric service was started during December, 1915, and was gradually extended over the entire Rocky Mountain and Missoula divisions, steam engines being entirely superseded about a year later. At this time there were 42 main line freight and passenger locomotives in operation and two switching locomotives, these machines replacing 112 steam locomotives of various types used just prior to the beginning of electrification.

In traversing the mountain districts, the tracks of the Milwaukee Road include many long grades and short radius curves. In crossing the four mountain ranges, Belts, Rockies, Bitter Roots, and Cascades (to list them from East to West), there are several grades of 1 per cent and more, the most difficult of which is the 19-mile 2.2 per cent westbound grade between Beverly, Wash., and Boylston, Wash., and the longest of which is the 49-mile 1 per cent grade ascending the west slope of the Belt Mountains. The maximum curvature is 10 degrees, and there are many sections where this curvature is reached. There are also numerous tunnels in the electrified zone, the longest being Snoqualmie Tunnel, over 2¼ miles in length, piercing the ridge of the Cascade Mountains. In Winter the heavy snows in the mountains make the problem of train movements most difficult, and Winter temperatures as low as 40 degrees below zero in the Bitter Roots caused serious delays under steam operation through engine failure or inability to make steam.

Outstanding feature of the power system is the unusually high D. C. voltage used. The



Courtesy General Electric Co.

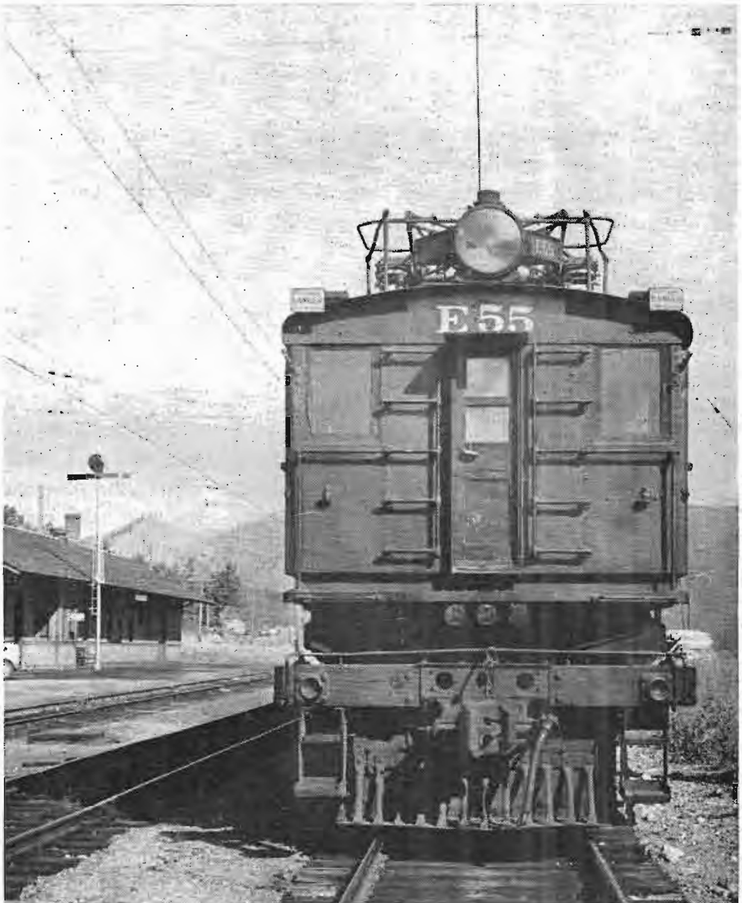
Passenger engine.

The bi-polar gearless (motor armatures mounted right on drive axles) passenger locomotives used on the Coast Division can take 13 heavy Pullmans up the Cascades at 30 miles per hour. Train is the *Olympian* in Seattle's Union Station, which is also used by the Union Pacific Railroad.

Milwaukee Road; Linn H. Westcott; E. A. Bowers collection.

Climbing the Bitter Roots.

Thrill of the eastbound ride on the *Olympian* is the daylight ascent of the Bitter Root Mountains in eastern Idaho. Before the summit is reached the train, behind a powerful Westinghouse locomotive, negotiates a 10-mile detour into a side canyon in order to gain altitude. Passengers looking from the upper line (background of top photo) can often see a following freight train on the lower line across the canyon. Half-mile Pipestone Pass Tunnel (middle photo) is at the Continental Divide, its western approach looking down upon the railroad winding up from Butte. Substation with operator's homes, at Kittitas, Wash., is typical of the Milwaukee Road's power supply facilities (lowest photo). Alternating current is purchased, then converted to 3000 volts D. C. by the road.



Moving freight with juice.

All Milwaukee Road electric locomotives formerly bore cumbersome five-digit numbers, but when all steam locomotives were renumbered a few years ago electrics were moved down into a two-digit series with the prefix E. The front end portrait is of a two-unit freighter with a westbound scheduled train, waiting for a meet. The lower picture was taken from the open observation car of the *Olympian* near Cobden, Mont., as the eastbound passenger train ran around a freight. Fifty miles back both trains crossed the summit of the Bitter Root Mountains through 8771-foot St. Paul Pass Tunnel. For 200 miles they will climb to the Continental Divide, first along the smoothly undulating valleys of Clark Fork, Columbia River, through Missoula and Deer Lodge and then up, up into Butte, and finally over.

Linn H. Westcott; John J. Bowman Jr.

power is delivered from the power company's line to the Milwaukee Road substations, where it is converted from 100,000 volts, three-phase, 60-cycle A. C., to 3000 volts D. C., and delivered to the specially designed twin trolley catenary overhead. There are 14 substations on the Missoula and Rocky Mountain divisions (now consolidated), and eight on the Coast Division.

Current is taken from the trolley wires by a pantograph collector, two of which are mounted on each locomotive (except the switchers, which have one). This collector is the double pan type, with a working range of from 17 to 26 feet above the rail. The contact elements are of the same material as the trolley wire so that the current passes from copper to copper. There are control cabs at both ends of the locomotives, and the pantographs at either end are raised or lowered by air pressure as the engineer changes ends. The rear pantograph is normally used so that an accident to it is less likely to also damage the other pantograph.

The main line locomotives furnished for the initial 440 miles of electrification in Montana were of uniform design, except that 12 were equipped with passenger gears and with boilers and oil and water storage tanks for providing steam heat for use in passenger train service, and 30 were fitted with freight gears. To replace the original passenger engines, and to handle passenger trains on the Cascade electrification, 15 new passenger locomotives were purchased.

The main line freight locomotives are constructed in three units, permanently coupled together, the two end units being duplicates, each capable of independent operation. It is possible to separate the units and use them singly for light freight service, construction trains, and snow plows, or to add units and increase power indefinitely, or up to the point of maximum draw bar strain.

The specifications of the various types of power are as follows:

Class of Locomotive	EF-1	EF-3	EP-2	EP-3
Service	Frt.	Frt.	Pass.	Pass.
Make	G. E. Co.	G. E. Co.	G. E. Co.	W. E. & M. Co.
Wheel arrangement	444444	44444444	248842	462264
Drivers	16-52″	24-52″	24-44″	12-68″
Total weight	576,000	816,000	521,200	620,000
Weight on drivers	451,000	691,000	457,800	420,000
Rating—Hourly:				
Tractive effort	84,500	126,750	48,500	66,000
Horse power	3,440	5,760	3,517	4,200
Max. tractive effort	112,750	172,750	114,450	105,000
Miles per hour	40	40	65	65

Perhaps the most outstanding single feature of the electric locomotives is the solution by the use of regenerative braking of the difficult braking problem on the long sustained grades encountered in crossing the mountain ranges. To handle either the heavy and varied freight or high speed passenger trains on the mountain grades with the usual air brakes requires great skill. The entire energy of the descending train must be dissipated by the friction of the brake shoe on the wheels. This energy approximates 3500 kilowatts, or 4700 horsepower for a 2500-ton train running 17 miles per hour down a 2 per cent grade. This explains why brake shoes frequently become red hot, and serious damage is done. The use of retainers causes further delay, and it is necessary for the trainmen to "decorate," by no means a pleasant job, particularly during cold and stormy weather. All these difficulties are eliminated by regeneration.

With regenerative braking, the motors become generators which convert the energy of the descending train into electricity, thereby restricting the train to a safe speed and at the same time returning electric power to the trolley for the use of other trains. The strain on draw bars and couplings is minimized, since the entire train is bunched behind the locomotive. The electric braking mechanism automatically controls the speed by regulating the amount of energy fed back to the line. This smooth descent is in marked contrast to the periodical slowing down and speeding up of a train controlled by air brakes.

The usual speed of the electrically handled freight train is 15 miles per hour ascending, and 17 miles per hour descending the maximum grade, but half that speed can easily be maintained with series connections of the motors should conditions require it.

In case there are no other trains between the substations to absorb the power generated by a descending train, this power passes through the substation machinery, is converted from D. C. to A. C. current, and fed into the distribution system connecting all substations. The power company's line is extensive and the load is of such a diversified character that any surplus power returned can readily be absorbed by the system.

The advantages of regenerative braking are: elimination of difficulties incident to the use of air brakes in heavy freight trains when descending mountain grades; elimination of stops to cool wheels; elimination of shoe and wheel wear with resultant reduction in maintenance; maximum safety in operation assured by a duplicate braking system relieving the air brakes; the entire absence of grinding of the brakes, which is especially disagreeable on a heavy passenger train; increased comfort to passengers; and reduced wear and tear on freight equipment, owing to uniform speed on grades. Helper engines work clear over each summit, being used to help hold the train on the descending grade. They are then in position for service in the opposite direction.

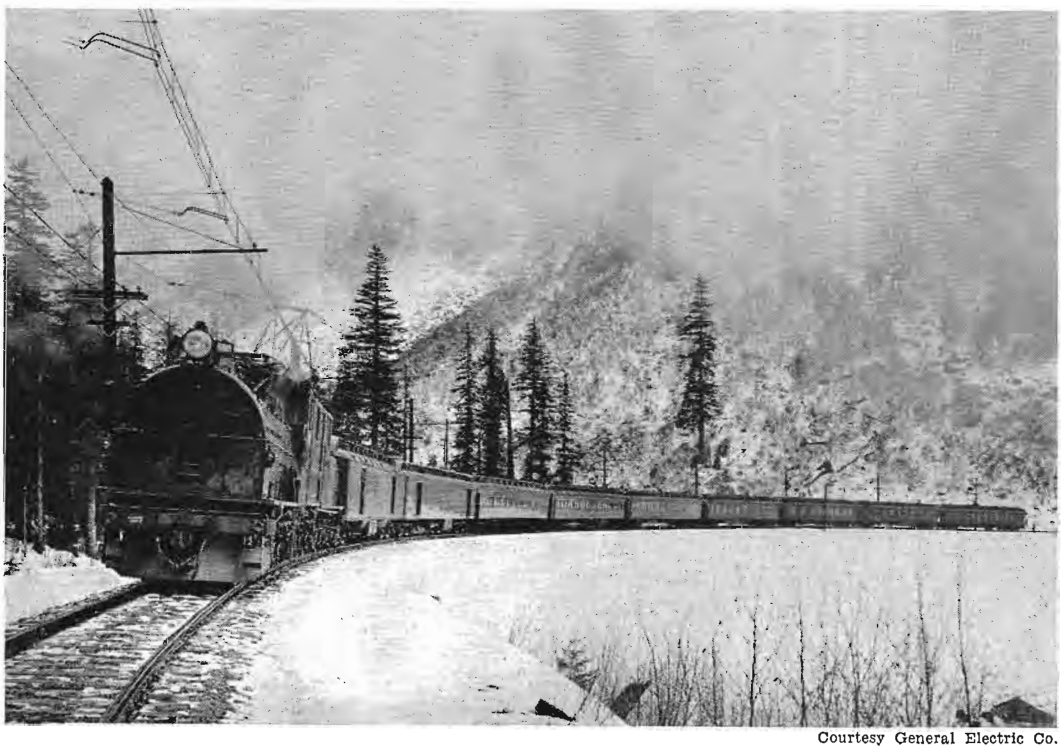
Air brakes are used for ordinary braking purposes, and to bring the train to a complete stop. The air brake equipment is practically the same as that on steam locomotives, except that motor-driven air compressors are used to furnish compressed air. One of these air compressor systems is located on each end unit, and has a capacity of 150 cubic feet of free air per minute. Besides the air brakes, compressed air is used for signals, whistles, bell ringers, sanders, pantographs, part of the control equipment, and, in the passenger locomotives, for the oil-fired steam boilers.

With an eye to the future, the Milwaukee Road is continuing to improve its electrical equipment now in service, and new types are tested as they are developed by the manufacturers. Diesel-electric power has been given a trial on the mountain divisions, but, without regenerative braking power, it was found to be not as satisfactory as the present equipment. The only Diesel-electrics now in service on the Milwaukee Road are 600- and 1000-horsepower switchers.

The success of the electrification on the Milwaukee Road was forecast by the late C. A. Goodnow while vice-president in charge of electrification for the railroad when, after the first Winter of electrical operation, he said, "Our electrification has been tested by the worst Winter in the memory of modern railroaders. There were times when every steam locomotive on the Rocky Mountain District was frozen, but the electric locomotives went right on rolling along."

Winter time in the Cascades.

The big climb in Washington is on the eastbound ascent of the Cascades. The railroad rises from sea level to nearly 2500 feet in 45 miles (from Black River Junction) before threading Snoqualmie Tunnel. Here is the *Olympian* in Winter hauled by a gearless bi-polar locomotive built by General Electric.



Courtesy General Electric Co.