

Arbitration Between Western Railroads and
Brotherhood of Locomotive Engineers and
Brotherhood of Locomotive Firemen and Enginemen

~~Railroads~~ } Exhibit No. 54
Employees }

Date 1-18-15 Reporter Satterlee

Progress Made in Electrification of Railroads and Economies Effected Thereby

Quotations from Railway Technical Experts
and Publications.

Prepared Under Supervision of
W. S. CARTER

Exhibit Number

54

Presented by Witness
D. B. ROBERTSON

Presented by the Brotherhood of Locomotive En-
gineers and the Brotherhood of Locomotive
Firemen and Enginemen.

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and Publications.**

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Progress Made in Electrification of Railroads and Economies Effected Thereby

Atchison, Topeka & Santa Fe.

Operating Expenses About Half, With Engineers' Wages the Same.

That portion of the Atchison, Topeka and Santa Fe between Trinidad, Colorado, and Raton, N. M., is commonly known as the Raton mountain, and it is over this twenty-three mile section that the heaviest grades of the system are encountered and the maximum elevation above sea level is reached. Of all the lines owned by the Santa Fe this section would seem to be the most susceptible to electrification with resultant economy, . . .

. . . it was concluded that thirteen 115-ton electric locomotives would handle the traffic to best advantage with a minimum outlay of capital . . .

In arriving at the expense of enginemen's salaries it was assumed that two locomotives pulling a single train would be operated as a multiple unit with one crew, and that trains requiring three locomotives would require two locomotive crews. It was assumed that electric crews would be employed at the same wages as those of steam locomotives.

The cost of electric locomotive maintenance and repairs were figured at the rates of 4.06 cents, 4.85 cents and 5 cents per locomotive mile respectively for the direct current, single phase and three phase systems, these amounts representing averages of equipment maintenance records at hand . . .

. . . The following is a statement of the partially estimated costs of steam operation compared with the estimated costs of electrical operation by the use of the single phase system:

ANNUAL COSTS.		
Operating Expenses—	Electric	Steam
Locomotive maintenance and repairs.....	\$ 22,110	\$ 92,395
Other maintenance and repairs.....	18,000
Labor, locomotive operation	27,200	49,377
Other labor	22,000
Fuel	23,550	69,740
Water	2,175	1,765
Roundhouse expense	8,500	28,109
Locomotive lubricants and supplies.....	910	3,012
	\$124,445	\$244,398

. . . It is worthy of mention that the unit costs of electric operation decrease as the volume of traffic increases, whereas the unit costs in the case of steam operation remain comparatively constant . . .

The electric locomotive can indeed be said to have distinct physical advantages over steam motive power in the handling of trains on heavy mountain grades. . . . It

would seem quite reasonable to believe that, with further development in the art of manufacturing electrical equipment and reduction of its cost, increase in volumes of traffic over mountain grades, and the more extensive development of our water power resources, the electrification of trunk line mountain grades will be brought about to a considerable extent. . . . —Railway & Locomotive Engineering, April, 1914, p. 146.

Butte, Anaconda & Pacific.

Ninety-five Miles Already Electrified.

The Butte, Anaconda & Pacific is credited with being the first steam road operating both freight and passenger service to electrify its lines purely for reasons of economy. The special factors, such as terminal and tunnel operation or rapid suburban service, which have been the determining factors in a number of steam railway electrifications, were not present in this case. This is also the first line to use 2,400 volts direct current in the trolley. The first electric locomotives were put in service May 28, 1913, hauling ore cars between the East Anaconda yards and the smelter. During the first seven months, they made approximately 201,000 miles and hauled about 2,365,000 tons of ore. . . .

The Butte, Anaconda & Pacific is essentially an ore hauling road, the freight traffic from this source originating at the copper mines located near the top of Butte Hill. From the mines, the ore trains are lowered down the mountain a distance of 4½ miles to the Rocker yards located a few miles west of the city of Butte. At this point, new main line trains are made up for transportation to the smelters at Anaconda. The main line division extends through a rough mountainous country, a distance of about 20 miles.

At East Anaconda, the main line trains are broken up and hauled up Smelter Hill to the stock bins, where each car is run over the scales and weighed. The eastbound traffic consists in returning empty cars to the mines and the transportation of copper ingot to the Butte yards, where it is shipped over other roads to the refineries. The electrified lines extend from the Butte Hill yard to the smelter, a distance of 32 miles. There are numerous sidings, yards and smelter tracks that have been equipped with overhead trolley, making a total of about 95 miles of single track. . . .

The freight traffic consists largely of copper ore and amounts to more than 5,000,000 tons per year. This material is handled in steel ore cars weighing about 18 tons and having a capacity of 50 tons each. Trains of 30 loaded cars weighing 2,000 tons are made up at the Butte Hill yards and hauled by two-unit locomotives to the Rocker yards, where 4,000-ton trains are made up for the main line. At the East Anaconda yards, the trains are again broken up and 1,400-ton trains are sent up Smelter Hill to the ore bins. All of the shifting and spotting of cars, at the smelters and in the sorting yards, is done by single locomotive units. The customary train make-up for both east and west-bound traffic is shown in the accompanying table:

CONDENSED INFORMATION OF FREIGHT MOVEMENT.

	Westbound			Eastbound		
	Butte Hill Line	Main Line	Smelter Hill	Smelter Hill	Main Line	Butte Hill Line
Trailing load in tons.....	2,000	4,000	1,400	1,000	1,260	650
Number of cars.....	30	60	20	55	70	35
Number of 80-ton locomotives per train..	2	2	2	2	2	2
Approx. grade against load, per cent....	2.5	0.3	1.1	1.1	1	2.5
Approx. speed on level tangent track, m. p. h.	21	25	...
Approx. speed on max. grade.....	12	16	16	20	16	16
Average trolley voltage.....	2,200	2,200	2,200	2,200	2,200	2,200
Length of run in miles.....	4.6	20.1	7	7	20.1	4.6

Four passenger trains each way per day are operated between Butte and Anaconda. Single locomotives are used, hauling trains of from three to five passenger and baggage cars.

The energy for the operation of the electric trains is purchased from the Great Falls Power Company, Great Falls, Mont. The power is stepped up to 102,000 volts for transmission to the transformer substation at Butte, a distance of 130 miles, over two separate parallel lines constructed on the same right-of-way. An extension of the system transmits power at 60,000 volts to a second transformer station at Anaconda, 26 miles farther on. . . .

The locomotive equipment consists of 17 80-ton units, 15 for the freight and 2 for passenger service. The freight locomotives are geared for slow speed and are operated in pairs for the main line service. The maximum free-running speed is 35 m. p. h. The two passenger locomotives are of the same construction as the freight units, but are geared for a maximum free-running speed of 55 m. p. h. A speed of 45 m. p. h. is made with three passenger coaches on a straight level track. The continuous tractive effort of a single 80-ton freight locomotive is 25,000 lb. at 15 miles per hour. The maximum tractive effort for a period of five minutes is 48,000 lb., based on a tractive coefficient of 30 per cent. . . . —Railway Age Gazette, March 13, 1914, pp. 514-16.

"Safety First" With But One Engineman.

The Butte, Anaconda & Pacific Railway is, in many ways, the most remarkable example of steam road electrification in this country. Besides being the first 2,400-volt direct-current road, it is also credited with being the first steam road operating both freight and passenger schedules, to electrify its lines purely for reasons of economy. A number of steam railway electrifications have been made because of preemptory factors, such as terminal and tunnel operation or for rapid suburban service. This road, however, cannot be classed as an "enforced electrification," since no such special limitations have been the determining factors.

The first electric locomotives were put in service May 28, 1913, hauling ore cars between the East Anaconda yards and the smelter. During the first seven months of service, they made approximately 201,000 miles and hauled about 2,365,000 tons of ore.

The electrified lines of this system extend from the Butte Hill yard to the smelter, a distance of 32 miles. There are numerous sidings, yards and smelter tracks that have been equipped with overhead trolley making a total of about 95 miles on a single track basis.

The Butte, Anaconda & Pacific Railway is essentially an ore-hauling road, the freight traffic from this source originating at the copper mines located near the top of Butte Hill. From the mines, the ore trains are lowered down the mountain a distance of 4½ miles to the Rocker Yards, located a few miles west of the city of Butte. At this point, new main line trains of approximately 4,000 tons are made up for transportation to the smelters at Anaconda. The main line division extends through a rough, mountainous country, a distance of about 20 miles, with grades as high as 0.3 per cent.

At East Anaconda, the main line trains are broken up and hauled up Smelter Hill to the stock bins, where each car is run over the scales and weighed. The shifting of cars in connection with weighing and subsequent delivery to the concentrators is done by single locomotives.

The eastbound traffic consists of returning empty cars to the mines and the transportation of copper ingot to the Butte Yards, where it is shipped over other roads to refineries.

The usual train make-up on the Butte Hill Line consists of thirty cars with a load of 2,000 tons. With two 80-ton locomotives a speed of 12 miles per hour is made on an approximate grade of 2.5 per cent. The average trolley voltage is 2,200. On the main line sixty cars with a load of 4,000 tons is hauled by two 80-ton locomotives at a speed of 21 miles per hour, the grade being 3 per cent. The length of the run on the Butte Hill Line steep grade is 4.6 miles, that on the main line with the smaller grade being a little over 20 miles.

Energy for the operation of the electric trains is purchased from the Great Falls Power Company, which is 130 miles from Butte. The power is transmitted at 102,000 volts, and is stepped down at the substations where it is changed to 2,400 direct current by motor-generator sets. These motor-generators are three-machine sets consisting of one motor between two 1,200 volt generators, the latter being connected in series to give the 2,400 volts for the trolley. . . .

The locomotive equipment consists of seventeen 80-ton units, fifteen for the freight and two for passenger service. The freight locomotives are geared for slow speed and are operated in pairs for the main-line service. The maximum free-running speed is 35 m. p. h.

The two passenger locomotives are of the same construction as the freight units, but are geared for a maximum free-running speed of 55 m. p. h. A speed of 45 m. p. h. is made with three passenger coaches on straight level track.

The continuous tractive effort of a single 80-ton freight locomotive is 25,000 lbs. at 15 miles per hour. The maximum tractive effort for a period of five minutes is 48,000 lbs., based on a tractive co-efficient of 30 per cent.

These locomotives are of the articulated double-track type, with all the weight on drivers. . . .

. . . The engineer's compartment at either end of the cab contains the operators' seat, controller, air brake valves, bell and whistle ropes, ammeter, air gauges, sanders and other control apparatus within immediate reach of the engineer.

The contractors, reverser and rheostats, which are located in the central portion of the cab, are mounted in two banks running lengthwise of the compartment, and are conveniently arranged for cleaning, inspection and repair. . . . —Railway Age Gazette, February 13, 1914, pp. 313-16.

Twenty-five Per Cent More Ore Hauled.

For the past year there has been in operation on the above railway seventeen 80-ton electric locomotives. Recently four additional ones have been ordered. In order to make these locomotives suitable for very slow speed spotting service a tractor truck can be used in combination with the electric locomotives. These trucks are an ingenious adaptation of standard parts of the freight locomotives; by their use the tractive effort of the standard locomotive is increased 50 per cent at two-thirds speed without increase in power consumption. These units will be used especially for spotting cars at the smelter, and also for low speed switching in the Butte yards.

During the present year it is expected that approximately 25 per cent more ore will be transported from Butte to Anaconda than was hauled last year. This increase arises from the transfer of ore which was previously hauled to smelters at Great Falls. The additional haulage will bring the total annual traffic on the road up to about six and one-quarter million tons.

The tractor trucks, equipped with two motors of the same type as the locomotive, are each provided with cable and connecting plugs, so that the two motors can be operated with the other motors from the same controller.

The arrangement of the six motors are as follows: First, the six motors will be connected in series, and then with two sets in multiple, each set consisting of three motors.

Mechanically these trucks are similar in construction to the trucks on the 80-ton locomotives. Instead of a locomotive body, however, a platform is supplied, built up of channels, angles and plates which are supported on the truck transom. Struts are provided at the corners to secure the platform to the side frame. Ballast consisting of cement and iron punchings of sufficient quantity to bring up the weight of the truck to 40 tons is placed between the center channels of the platform in a box-like structure built for this purpose. A passageway protected by a hand rail extends along each side of the platform.

In the center of the platform is a crane extending at an angle, and which is provided as a support for the eight cables running between the truck and the locomotive. This

crane can be revolved 180 degs. so as to permit the coupling of the locomotive to either end of the truck.—*Railway & Locomotive Engineering*, July, 1914, pp. 267-68.

A Successful Year.

. . . A total of 27 steam locomotives was owned by the railway company, classified as follows: Switching, 7; Consolidation, 8; Mastodon, 10, and passenger, 2.

The coal used on the steam locomotives was obtained from the mines at Diamondville, Wyo., and had to be transported approximately 395 miles for delivery to the bins of the railway company, at which point its average cost was approximately \$4.25 per ton.

Most of the machinery at the mines and the smelter had been electrified, and the results had been so satisfactory that the railway company made a study of conditions for the purpose of investigating the advantage that might be expected from the electrification of its lines, the result of which was the placing of a contract in December, 1911, for the electrical equipment of the main line, with spurs and yards between Butte and Anaconda, the Missoula Gulch line between Rocker and Butte Hill yards, and the Smelter Hill lines. Owing to local conditions on the spur tracks leading to the various mines from Butte Hill yards, it was thought advisable not to electrify these until a later date. The tracks recommended to be electrified totaled approximately 90.5 miles.

Seventeen 80-ton electric locomotive units were purchased originally, 15 of which are being operated in freight service and two in the passenger service. These units are practically interchangeable with the exception of the gearing, the passenger locomotives being geared to operate normally at 40 or 50 miles per hour, while the freight locomotives are geared to operate at from 15 to 25 miles per hour, the maximum free running speed being approximately 35 miles per hour. The continuous tractive effort of the freight units is 25,000 lb., at 15 miles per hour, but they are capable of exerting a maximum tractive effort of 48,000 lb. for five-minute intervals, based on a coefficient of adhesion of 30 per cent.

Work on the electrification began in the spring of 1912, and the first electric locomotive was run in Anaconda on May 14, 1913, about one year later. On May 27, two ore trains were hauled up Smelter Hill on trial trips with electric locomotives and on the following day a double-unit electric locomotive took over the regular day service of hauling the ore from East Anaconda yards to the concentrator yards, a distance of approximately seven miles, with a ruling gradient of 1.1 per cent compensated, and the grade fairly uniform through the entire distance. The steam locomotives used in this service were of the Mastodon type, weighing 108 tons, 83 tons of which was on the drivers. The weight of the tender loaded was approximately 55 tons, making the total weight of locomotive and tender about 163 tons, which would average close to the weight of the double-unit electric locomotive superseding it. The steam locomotive ordinarily made six round trips per shift, hauling 16 loaded ore cars per trip, or 96 cars per shift.

The average time required by the steam locomotive for the trip from East Anaconda to the concentrator yards with 16 loaded cars was about 45 minutes. The double-unit electric locomotive began taking 16 cars per trip but made 8 trips per shift, delivering 128 cars per shift. The average time for the up-hill trip with the electric locomotive was about 22 minutes or approximately half the time required by the steam locomotive for the same number of cars. Empty cars were taken to East Anaconda on the return trip, which, being all down grade, gave the electric locomotive no decided advantage, as the speed in either case was limited to about 25 miles per hour for safety. The number of cars hauled per trip was kept the same with the electric locomotives in the beginning as it had been with steam, as it had been decided to make the change-over by gradually replacing one steam locomotive at a time with an electric, taking the engine crew off the one and placing it on the other, thus breaking them in on the electric locomotives in regular service.

The load per trip in this service was gradually increased from 16 cars to 25 cars, which is to be the standard for the present. The average time for the up-hill trip with 25 cars is about 26 minutes, so that eight trips per shift are made easily, making a delivery of 200 cars possible or an increase of slightly more than 108 per cent over what

had been possible for the same crew with steam locomotives. These loaded ore cars average from 70 to 72 tons each, making the trailing load for a 25-car train from 1,750 to 1,800 tons.

On arrival at the concentrator yards the ore trains are taken by a switching engine called the "spotter," which places one car at a time over the weighing scales, after which they are rearranged for placement over the concentrator bins. On June 20 this spotting service was taken over by a single-unit electric locomotive and on July 2 the night service up Smelter Hill was taken over by the double-unit electric locomotive. The steam locomotive used for the spotting service was of the Consolidation type and weighed 93 tons, 83 of which was on drivers, the tender weighing loaded 62 tons, making the total weight of engine and tender 155 tons. The steam locomotive used in the night service on Smelter Hill was similar to that used in the day service. When the electric engines were put on the night service all the handling of ore between East Anaconda and the concentrators was done electrically, and the hauling capacity per crew was so much greater that it was no longer necessary to have a "spotter" crew on the night shift so that this crew was eliminated, and the night crew hauling the ore up Smelter Hill did the spotting on arrival at the concentrator yards, it being no longer necessary to make the regular number of trips. Thus where formerly four engine and train crews had been required during steam operation, three similar crews were able to do the same work with electric locomotives in less time.

On October 1, regular passenger service between Butte and Anaconda was taken over for electrical operation. The steam locomotive used in the passenger service weighed approximately 80 tons, 60 tons of which was on the drivers, while the tender loaded weighed 52 tons, making the total weight of engine and tender 132 tons. The distance between Anaconda and Butte is 25.7 miles, and the schedule time for the trip, one hour. No change has been made in this time, though a reduction of 20 per cent would be possible with the electric locomotives were such desired. It may be of interest to note that on the day shift, averaging four trips per day, during the first five months the passenger train did not come in late a single time on account of engine trouble.

On October 10, a double-unit electric locomotive was put in the day freight service on the main line between East Anaconda and Rocker, a distance of 20.1 miles. The steam locomotive replaced in this instance was of the Mastodon type, weighing 103 tons, 77 of which was on the drivers, while the tender loaded weighed 55 tons, making the total weight of locomotive with tender 158 tons. The standard train, hauled on the trip west was 50 to 55 loaded ore cars weighing approximately 3,500 to 4,000 tons gross and the average running time of such trains where no stops were made was about 1½ hours, corresponding to an average speed of approximately 13.4 miles per hour. In the beginning the electric locomotive took only the standard train, but made the trip without stop in about one hour, corresponding to an average speed of 20 miles per hour. The ruling gradient on the westward trip is 0.3 per cent and about half the distance is down grade. On the 0.3 per cent grade with a 55-car train, the steam locomotive made about 7 miles per hour. The electric locomotives with similar train now make about 16 miles per hour on the same grade.

The weight of the trains hauled by the electric locomotives on this run has been gradually increased up to 65 loaded ore cars averaging about 71 tons each, making the gross weight trailing about 4,620 tons. Adding 160 tons for the weight of the double-unit electric locomotives and 20 tons for the caboose makes a gross train weight of approximately 4,800 tons.

The remainder of this main line freight service was gradually taken on during the months of October and November. As many as 76 ordinary freight cars loaded with coal, coke and general merchandise have been taken in a single train on the westbound trip and 85 empties are frequently taken from East Anaconda to Rocker eastbound, the ruling grade being 1 per cent.

Comparative results of the month of June, 1913, with steam operation and for the same month of 1914 with electrical operation of this main line service, show that with

a slight increase in the total tons of ore hauled the average tons per train was increased from 1,761 to 2,378, or 35 per cent, thus decreasing the average number of trains per day from 12.5 to 9.3, or 25.6 per cent. The average time per trip during steam operation was approximately 2 hrs. and 25 min., while with the electric locomotive it was approximately 1 hr. and 45 min., showing a decrease of 40 min., or 27.5 per cent. The overtime in this service has been decreased 73.5 per cent and the total time 42 per cent. . . .

The service on the Missoula Gulch line running between Rocker and Butte Hill yards was taken over for electrical operation on October 20. This line is 4.5 miles in length and the ruling gradient 2.5 per cent. The steam locomotives used on this line were of the Mastodon type, weighing 106 tons, 87 tons of which was on the drivers, the tender loaded weighing 56 tons, thus making the total weight of engine and tender 162 tons. Two complete crews had been required to handle this service during steam operation, averaging six trips per day each. A single crew with a double-unit electric locomotive has been doing this work successfully. . . .

On November 25, the last of the electric locomotive units went into service, thus completing the electrification originally intended. The full electrical service has, therefore, now been in operation more than nine months and that on Smelter Hill more than 15 months.

This was the first installation of 2,400-volt direct-current apparatus for the operation of a railway in this country, 1,500 volts being the highest heretofore installed for such a purpose.

The total saving from locomotive performance alone is at the rate of \$237,581 per year, to which should be added the credit of handling an increase of traffic at the rate of 13,938,136 ton-miles per year or 8.77 per cent more than was handled by the steam locomotives during the period compared. To this saving from locomotive performance should be added the saving from trainmen's wages, which is at the rate of \$31,146 per year, or a decrease of approximately 21 per cent, due largely to the elimination of overtime, making the total saving from these two items \$268,728 per year. From this should be deducted \$10,839 for maintenance of the distribution system, leaving \$257,889 as the net operating saving per year due to electrical operation.

The roadmaster states that it is quite evident that the electric locomotives are much easier on the track at curves, but that there is no noticeable difference on tangent track, and that while sufficient time has not yet elapsed to form definite conclusions, present indications lead him to expect that any difference relative to his work will be favorable to the electric locomotives.

Arranging the items of expense in the order of usual appearance in the summary of a standard locomotive performance sheet, and placing them on a yearly basis, results as follows:

Item of Operating Expenses	Steam, 1913	Electric, 1914	Decrease, 1914	Per Cent Decrease
Fuel and power.....	\$315,235.74	\$164,508.70	\$150,727.04	47.81
Repairs	124,787.90	92,278.08	32,509.82	26.05
Enginemen's wages	104,461.18	71,225.88	33,335.30	31.81
Enginehouse expenses	29,907.80	18,638.38	11,269.42	37.68
Water	4,953.66	1,193.70	3,759.96	75.90
Lubricants	9,751.44	4,942.32	4,809.12	49.30
Other supplies	5,823.52	4,552.36	1,271.16	21.83
Total locomotive performance..	\$594,921.24	\$357,339.42	\$237,581.82	39.93
Trainmen's wages	147,632.30	116,486.00	31,146.30	21.10
Grand total	\$742,553.54	\$473,825.42	\$268,728.12	36.19
Ton miles hauled	158,917,720	172,855,856	13,938,136[ⓐ]	8.77[ⓐ]

[ⓐ] Increase.

The total cost of the electrification, including a change of signal system on Smelter Hill, an extra motor-generator set recently installed at Anaconda, interest during construction and all incidentals due in way to the electrification, was in round numbers \$1,201,000. This does not include the step-down transformers, which are the property of the power company, but on the other hand no deduction has been made for the salvage due to the elimination of 20 steam locomotives.—J. B. Cox, *Railway Age Gazette*, December 25, 1914, pp. 1193-95.

Canadian Pacific.

To Electrify Tunnel.

The 5½-mile double-track Canadian-Pacific tunnel through the Selkirk Mountains, which will be the longest in the Western Hemisphere, is to be electrified. This tunnel will shorten the main line by 6 miles, will eliminate 5½ miles of snow-sheds, reduce the peak of grade 513 ft., and do away with all but 6 miles of 2.2 per cent grade. On its entire system of more than 12,000 miles in Canada it will have but a dozen miles of 2.2 gradient. The latest systems of electrification are to be used in operating the trains through this tunnel.—*Railway & Loco. Engineering*, Nov., 1914, p. 399.

Chicago, Milwaukee & St. Paul.

Government Grants Authority for Electric Transmission Line.

The Secretary of the Interior has this week granted the Great Falls Power Company, of Great Falls, Mont., authority to construct over government lands a transmission line for electric power which is intended to provide for the electrification of the road of the Chicago, Milwaukee & Puget Sound for a distance of 450 miles, from Harlowton, Mont., to Avery, Idaho. The grant is for fifty years and is subject to readjustment every ten years; and the government retains rights in relation to the regulation of rates and service. The permit cannot be transferred without the approval of the Secretary of the Interior.

The officers of the Chicago, Milwaukee & St. Paul say that preliminary plans for this electrification are now being made. The line in question includes the sections over the Bitter Root and Rocky and the Belt mountain ranges. The maximum grade on this part of the road is 1.7 per cent eastbound and 2 per cent westbound. Included in this section are the St. Paul Pass tunnel, nine thousand feet long, the Donald tunnel and several smaller tunnels. From Lombard east to Summit, 44 miles, there is a continuous ascending grade averaging 1 per cent.

Power will be delivered to the railway line at five points, Bowen, Harlowton, Deer Lodge, and at three points between Deer Lodge and Avery. It is expected that the overhead trolley will be used, with a working current of probably 2,400 volts and the alternating current on the transmission line will probably be 100,000 volts. It is expected that the work will be begun within two years. . . . —*Railway Age Gazette*, January 10, 1913, p. 70.

Fewer Locomotives, More Tonnage, Greater Speed.

. . . Experience with heavy railroad operation in and near New York City shows that electric locomotives can be run 2,000 miles without inspection under the conditions existing there. The locomotives which will be placed in service on the mountain divisions of the Chicago, Milwaukee and St. Paul can be relied upon to make from 250 to 300 miles at the outset. As there will be no delays for coaling, taking on water, clean-

ing fires or waiting for steam, it seems a fair conclusion that the tonnage will be handled with fewer locomotives, higher average speed and with a regularity which will result in better operating conditions. Passengers will be able to enjoy the mountain scenery without the annoyances incident to steam locomotion. Another point of interest is that while the steam locomotive is at its worst in freezing weather the electric locomotive is at its best at that time, since practically the only difficulty with the electric locomotive is to keep the motors from heating when doing maximum work.

One of the important benefits to result from electrical operation is the regenerative control of trains descending mountain grades by means of which energy will be returned to the line. . . . —Railway World, December, 1913, p. 1064.

Electrification of 440 Miles.

. . . The success attending the electrical operation of the Butte, Anaconda & Pacific has resulted in power contracts being placed for the electrification of 440 miles of the Chicago, Milwaukee & St. Paul and the selection of the same type of direct current locomotive upon the Butte, Anaconda & Pacific. Announcement has been made that the electrification of the first engine district through Butte will be pushed as rapidly as possible, and the other three districts will be electrically equipped in the near future. This electrification will be by far the most extensive as regards route mileage yet constructed in this country or abroad, and will afford every opportunity to secure all possible benefits resulting from electric locomotive operation.

The electrical installation in the tunnel of the Canadian Northern at Montreal may be looked upon as depending upon the same causes as governed the adoption of electric power for the New York terminal roads. The proposed installation on the Canadian Pacific at Rossland, however, must be considered as foreshadowing future activity on this road in the direction of main line electrification. Announcement is also made of contracts placed for electric locomotives to be used upon the 30-mile section over Elkhorn grade of the Norfolk & Western as well as possible action of the same nature by the Denver & Rio Grande.

All of these mountain grade electrifications are being made because the electric locomotive offers a means of improving the conditions that now exist with steam locomotive operation. The electric locomotive can be constructed of any capacity required by local conditions both as regards its hauling capacity in trailing tonnage and also in the speed at which this tonnage is hauled up the ruling gradients. There is little opportunity to increase the schedule speed of present steam locomotive drags except on the heavier grade divisions, as speed on level track in many instances is already carried as high as present freight car construction will permit. But the electric locomotive possesses the very qualification required for grade operation, as it can be constructed to give its maximum tractive effort at any speed found desirable, owing to the fact that it draws its power from a stationary power plant of relatively unlimited capacity and is therefore not subject to the boiler restrictions of the steam locomotive.

It is apparent that great benefits will result from the operation of the electric locomotive which can provide a drawbar pull as great as the draft gear of the trailing cars can withstand, at a speed limited only by the alignment and not the gradient of the roadbed, and with no enforced stops to take on coal and water. Furthermore, the electric locomotive provides a means of braking on down grades that can eliminate the dangers of overheated wheels and brake shoes attending braking with air. The energy of the descending train is converted into electricity and is pumped back into the distributing system to be used by other trains operating up grade or on level track. . . . —A. H. Armstrong, Assistant Engineer, Railway Department, General Electric Company, Railway Age Gazette, January 2, 1914, p. 12.

Requires Only 18 Electric Locomotives.

A decision has just been reached to begin actual construction on the electrification of one engine district of the Chicago, Milwaukee & St. Paul, between Three Forks.

Mont., and Deer Lodge, which is part of the project to electrify the line between Harlowton, Mont., and Avery, Idaho, 440 miles across the Belt, Rock and Bitter Root mountain ranges. This project was announced in the "Railway Age Gazette" of January 10, 1913, and additional details were published in the issue of May 2, 1913. The line between Harlowton and Avery includes four engine districts, with maximum grades of 2 per cent, 1.7 per cent, 1 per cent and .4 per cent, respectively.

The engine district between Three Forks and Deer Lodge, with the Butte terminals, will be undertaken first, as it includes the maximum grade of 2 per cent for 20.8 miles ascending the eastern slope of the Rockies. This district is 113 miles long and, with passing tracks, sidings and yard tracks, includes a total of approximately 168 miles of track. It is the present intention to undertake the electrification of an additional engine district each year until the entire line between Harlowton and Avery has been electrified.

It has been decided to adopt the 2,400-volt direct current system of propulsion, utilizing the regenerative electric braking feature, which will take the place of the air brakes on the mountain grades. This is the system which has been applied by the General Electric Company in the electrification of the Butte, Anaconda & Pacific, except that the regenerative electric braking feature is not used on that road, and it is expected that in large measure the details of that installation will be used on the Milwaukee with such modifications as are necessary to meet the conditions imposed by trunk line operation. It is expected to operate this district with twelve 200-ton freight locomotives, four 200-ton through passenger locomotives and two 100-ton local passenger locomotives. The switching will be done with electric locomotives. . . . The estimated cost of the complete installation between Three Forks and Deer Lodge is about \$1,500,000, exclusive of locomotives, but including all electrical apparatus, material, labor, sub-station buildings, overhead and track construction, and all incidental expense, except the changing of block signals from direct to alternating current. . . .

The sub-station capacities have been designed to allow locomotives to be started at their full tractive power on the heaviest grades, and to accelerate at the rate of .15 m. p. h. per second. . . . It is assumed that the consumption of current required to start a train will be practically the same on a 1 per cent grade and on a level track, so that two-unit sub-stations are proposed for all gradients below 1 per cent. In these sub-stations one unit will be operated normally, with the second held as reserve for emergency such as the disabling of the operating unit or a congestion of trains, which will require them to be operated at short intervals. Each unit in one of these sub-stations is capable of providing the energy required to start a 2,500-ton train on level track, and to operate a second train of equal weight at the full speed of 27 m. p. h., assuming that both trains are immediately adjacent to the sub-station and draw their entire energy from that station. . . .

The freight locomotives are designed to haul a trailing load of 2,500 tons on a 1 per cent grade at a speed of 15 miles per hour. It is proposed to operate through freight trains with a maximum tonnage of 2,500 tons, using one locomotive on grades up to 1 per cent and two locomotives between 1 per cent and 2 per cent. The speed with which two locomotives can pull the maximum tonnage trains on a 2 per cent grade will be approximately 15 miles per hour. These locomotives will weigh approximately 400,000 lb., with all of the weight on the drivers. Each locomotive will be handled by a single operator, but for convenience in shopping and making repairs, the locomotive can be divided into two 100-ton units which, if desirable, can be equipped with draft rigging and operated independently in switching service. The running gear is composed of four four-axle trucks articulated. Each axle is driven by a 2,400-volt direct current motor connected to it by twin gearing. Two superstructures rest upon the running gear and serve as housings for the air compressor and control apparatus. Each locomotive will be equipped with two air compressors of 150 cu. ft., piston displacement. The current will be collected from the overhead trolley by a roller pantograph collector.

The through passenger locomotives are to be designed to pull a 10-car passenger train weighing 1,000 tons with a speed of 24 miles per hour on a 2 per cent grade. The locomotives will weigh 200 tons, all of which is on the drivers.

A separate type of electric locomotive for local passenger trains will be designed which will haul a 300-ton train at a maximum speed of 42 miles an hour on level track. This locomotive will probably have double end control to eliminate the necessity for turning.

All the locomotives will be provided with controlling apparatus, permitting the motors to be reversed on down grades so as to operate as generators, thus providing for regenerative electric braking. This feature will relieve the brake shoes and wheels entirely, as the air brakes will only be needed in case of emergency. The regenerative action returns to the power line from 25 per cent to 50 per cent of the energy required in up-grade movement, resulting in a considerable reduction in the power bill. . . . —*Railway Age Gazette*, January 2, 1914, pp. 19-20.

Fewer Locomotives For 865 Miles of Road.

. . . Electrization work on even a larger scale than these just mentioned has been started by the Chicago, Milwaukee and St. Paul Railroad between Avery, Idaho, and Harlowton, Mont., a main-line distance of 440 miles. C. A. Goodnow, assistant to the president of this road, stated recently that the work undertaken by his company is the most general electrization yet undertaken by any steam road and undoubtedly foreshadows the electrification of the entire line from Harlowton to the Pacific Coast, a main-line distance of 865 miles, including the line to Tacoma. It is understood that the power for this long line is to be furnished under long-term contracts with the Montana Power Company and the Thompson Falls Power Company. It is planned that eventually a large power plant at Great Falls, Montana, is to be constructed, this to generate 100,000 horsepower. This, with the power from the other plants, will form one tremendous reservoir of electric energy from which to draw any amount of power necessary to operate the railroad. The intention is to do all work, including switching, inside the electrical zone, with electric locomotives. It has been determined that a single freight locomotive is capable of handling 2,000 tons trailing on a one per cent grade and two the same tonnage on a two per cent grade at a speed of from fifteen to eighteen miles an hour.

Mr. Goodnow also states that electric locomotives can make from 200 to 300 miles at the outset and there will be no delays on the road for coal, water or cleaning fires and it is a fair conclusion that the tonnage will be handled with fewer locomotives at higher average speed and with a regularity that will give greater satisfaction to shippers and passengers. . . . —*Railway World*, March, 1914, p. 219.

Electrification Now in Progress.

Construction work in connection with the electrification of the Chicago, Milwaukee & St. Paul between Harlowton, Mont., and Avery, Idaho, has been resumed. Thus far the poles have been placed for a distance of 30 miles on the 116-mile division between Three Forks and Deer Lodge, Mont., which is the first to be equipped. The company has ordered nine freight and three passenger electric locomotives from the General Electric Company. These locomotives will be of the same construction except that those to be used for passenger service will be geared for a higher speed. The total weight of these locomotives will be 519,000 lbs. each, and the weight on drivers 400,000 lbs. They are to be delivered in October, 1915, at which time, it is planned, the construction work over the entire line will have been completed.—*Railway Age Gazette*, Nov. 20, 1914, p. 980.

Late Comments.

. . . The Chicago, Milwaukee & Puget Sound, from Harlowton to the coast, crosses four mountain ranges, the Belt mountains at an elevation of 5,768 ft., the Rocky mountains at an elevation of 6,350 ft., the Bitter Root mountains at an elevation of 4,200 ft. and the Cascade mountains at an elevation of 3,010 ft. 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.

The eight motors for the complete locomotive will be type GE-253-A. This motor has a normal one-hour rating of 430 horsepower, with a continuous rating of 375 horsepower. The eight motors will thus give the locomotive a one-hour rating of 3,440 horsepower and a continuous rating of 3,000 horsepower. The drawbar pull available for starting trains will approximate 120,000 lbs. at 30 per cent coefficient of adhesion.

The freight locomotives are designed to haul a 2,500-ton train on all grades up to 1 per cent at a speed of approximately 16 m. p. h. and this same trainload unbroken will be carried over the 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 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 headend 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 the headend, 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 expected that electric braking will prove valuable, as in addition to providing the greatest safety in operation, it also returns a considerable amount of energy to the substations and transmission system.

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 to be used only in emergency and when stopping the train.

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. —Railway Age Gazette, December 18, 1914, p. 1126.

Complete Electrification by Jan. 1, 1918.

Plans for the electrification of the first engine division of the Puget Sound lines of the Chicago, Milwaukee & St. Paul have been completed and contracts let to the General Electric Company for the electric locomotives, substation apparatus and line material, and to the Montana Power Company for the construction of the transmission and trolley lines. The work is under the direction of C. A. Goodnow, assistant to the president, in charge of construction. This initial electrification of 113 miles of main line between Three Forks and Deer Lodge is the first step toward the electrification of four engine divisions extending from Harlowton, Mont., to Avery, Idaho, a total distance of approximately 440 miles, aggregating about 650 miles of track, including yards and sidings. While this comprises 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 for this work are of special interest, as this is the first attempt to install and operate electric locomotives on tracks extending over several engine divisions, under which conditions 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, this initial installation will constitute one of the most important milestones in electric railway progress.

Due to the 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 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 1, 1918. . . . —Railway Age Gazette, December 18, 1914, p. 1125.

Electric Locomotives Ordered.

. . . The Chicago, Milwaukee and St. Paul Railroad announced yesterday the signing of a preliminary contract with the General Electric Company for locomotives and apparatus, to cost more than \$2,000,000, required in the electrification of 450 miles of lines between Avery, Idaho, and Harlowton, Mont.

The entire project will cost about \$13,000,000. Electrification of other sections of the western lines of the St. Paul are under consideration, according to C. A. Goodnow, assistant to President A. J. Earling. . . . —Chicago Herald, November 18, 1914.

Denver & Rio Grande.

Over 200 Miles to Be Electrified.

One of the most important announcements which has been made by a railway management in the calendar year just closed was that of Vice-President Brown of the Denver and Rio Grande Railroad, that this system would immediately begin the electrification of its mountain lines. This is the first transcontinental line to utilize electricity on a large scale in train operation. The first unit to be electrified will be from Helper, Utah, to Salt Lake City, 114 miles. The second unit will be over Tennessee Pass, the great Continental Divide in Colorado, and will involve the electrification of the line from Salida to Minturn, Colorado, a distance of 87 miles.

The Utah work will be commenced early in 1913, and it is hoped that it will be completed by the time the new two per cent detour line over Soldier Summit is finished, in July of this year. The Utah Utilities Company is to furnish the power for the Utah lines, and the Central Colorado Power Company will probably furnish the electricity for the Colorado lines. The cost of the improvements to be undertaken by the Denver and Rio Grande, the Central Colorado Power Company, and the Utah Utilities Company will aggregate between twenty and twenty-five million dollars, most of which will be required in 1913 and 1914.

It is anticipated that other units, in addition to the two mentioned, will be added from time to time, and that perhaps, eventually, the entire system will be operated by electricity generated by the great power in the torrents now coursing down the mountain sides and which is only waiting to be harnessed.

This transition from steam to electric power is by far the most important plan yet announced by the new management of the Denver and Rio Grande.—Railway World, January, 1913, p. 57.

Electrification Was to Have Been Completed Before Now.

It is expected that the work of electrifying the western end of the Denver and Rio Grande's line between Helper and Salt Lake City in Utah, a distance of 15 miles, will be practically completed by July 1st, of this year. The electrification of the line from Minturn to Salida across the Tennessee Pass in Colorado, a distance of 87 miles, will be completed in 1913. The Utah Light and Power Company will furnish the power for the first line while it is expected that the Central Colorado Power Company will supply the power for the Colorado line, unless the railroad company decides to install a plant of its own near Tennessee Pass.—Railway World, March, 1913, p. 228.

New York Central & Hudson River.

Increased Size of Electric Locomotives.

The New York Central & Hudson River R. R. Company has recently ordered six additional powerful passenger electric locomotives from the General Electric Company for

terminal service out of New York City. Early in the year ten powerful electric locomotives were ordered from this company for the same service. These engines weigh 100 tons each. While the new machines are of the same type and construction, they are somewhat heavier, weighing 110 tons, and, due to the recent advancement in locomotive design, have materially increased capacity for continuous service.

There has been a notable growth in traffic, requiring larger and heavier train units, since electric locomotives have been in use in the New York Central Terminal. In 1906 thirty-five passenger electric locomotives were built for this electrification. These locomotives of the 4-8-4 type, each equipped with four motors, weigh 115 tons. Twelve more of the same type were placed in service in 1908. All have sufficient tractive effort to handle a 535 gross weight train at 60 miles per hour.

The ten 100-ton electric locomotives ordered the fore part of this year are designated type 4-4-4-4 and are each equipped with eight bipolar, gearless motors, all the weight of the machine being carried on motor-driven axles. These engines are designed for pulling the heavy limited trains. They are capable of operating a 1,000-ton train in emergency service.

But the weight of trains which are being hauled out of the Terminal is increasing steadily, and some of the more important trains now weigh over 1,000 tons.

The new locomotives will be of sufficient capacity to handle these heavier trains. The 10-ton increase in weight in these machines is due to the greater amount of material in the motors, which are of larger capacity.

The previous ten 100-ton locomotives have a capacity for developing 1,460 horsepower continuously, 2,000 horsepower for one hour and can develop as high as 5,000 horsepower for short periods. This corresponds to a tractive effort of 9,000 pounds, at 60 miles per hour continuously, or 13,500 pounds at 54 miles per hour at the one hour rating. The six new electric engines will develop 2,000 horsepower continuously, or 2,600 horsepower for one hour. The equivalent tractive effort is 14,000 pounds at 54 miles per hour continuously, or 20,000 pounds at 49 miles per hour at the one hour rating. They are able to haul 1,100-ton trains in continual service between the terminal and Harlem, are capable of operating 1,200-ton trains in emergency service, and 1,200-ton trains on level tangent track continuously at 60 miles per hour. . . . —Railway and Locomotive Engineering, December, 1913, p. 453.

New York, New Haven & Hartford.

Electric Switchers.

In March, 1911, the first electric switching locomotive on the New York, New Haven & Hartford was placed in operation at Stamford, Conn. In August, 1912, the first switcher started to work in the Westchester yards; in September, 1912, the first in the Oak Point yards in float service, and in August, 1913, the first began its operation in the Harlem River yards proper. The Oak Point yard is the terminal where all the cars on floats destined to the New England states are unloaded.

Ease of control, the elimination of stand-by losses and those that are necessary where coal and water are used, the elimination of freezing up in cold weather, are all features to be credited to the electric locomotive. Six single-phase electric locomotives do the work of approximately twice that number of steam locomotives formerly used. Eight electric locomotives are sufficient for practically all of the switching work between Stamford and the Harlem River. These are kept in service 24 hours a day. The electric locomotives handling the work between Westchester yard and Harlem River for a given month made 38,000 locomotive miles and consumed approximately 896,000 kilowatt-hours of electrical energy at the locomotive. During this same period, the six locomotives handled approximately 65,000 cars, which had a total weight of approximately one million tons. Practically all of these cars were transferred from floats. All of the heavy freight tonnage mentioned above is handled within the corporate limits of New York City, and the elimination of smoke by the use of the electric locomotive is another advantage.

The 16 switching locomotives in service are equipped with four Westinghouse 125 h. p., 25-cycle, single-phase motors and unit switch control. These locomotives each weigh 80 tons and exert a maximum tractive effort of 40,000 lbs. The rated hauling capacity is given in the accompanying table:

Rated Hauling Capacity, New Haven Switching Locomotives:

	Number of cars, each weighing 45 tons with load	Max. speed, m. p. h.
Straight level track.....	67	8.5
½ per cent grade.....	28	8.1
1 per cent grade.....	17	8.1
2 per cent grade.....	9	8.1

The locomotives are guaranteed to exert a maximum tractive effort of 36,000 lbs. for about three minutes at speeds up to 6 M. P. H. and a continuous tractive effort of 14,800 lbs. at a speed of 11½ m.p.h. It is not expected that the maximum voltage on the motors will be reached in ordinary switching service, but it is advisable when climbing grades or on longer runs in the yard. The average operating potential is estimated to be 190 volts. The hour rating corresponding to this voltage and current of 500 amperes is approximately 125 h.p. per motor. The locomotives are of the 0-4-4-0 articulated truck type with central cab.

. . . —Railway Age Gazette, June 19, 1914, p. 1515.

Norfolk and Western.

A Great Development Expected.

. . . The new rolling stock ordered in 1913, in addition to new improved engines of the same types, has a new type of locomotive, the so-called split-phase locomotive, designed specially for the Norfolk and Western Railway. These locomotives, 24 of which have been ordered of 135 tons weight and 11,000 voltage, will supersede some of the most powerful Mallet steam locomotives of the world and haul 3,250-ton trains at 14 miles per hour instead of seven, thus doubling the capacity of the mountain division of the road. . . .

The Chronicle believes that great development may be expected in the use of electric power in freight and assembly yards and for similar switching service in and around industrial plants. The switching service, owing to its inherent requirements, has always presented the most difficult problems for the operating electric engineer. But improvements in the control equipments and the slow-speed electric locomotive is producing an excellent type of engine which will doubtless prove beneficial to the various belt lines joining freight terminals in cities or in linking up water-front wharves with trunk line systems.—From Commercial and Financial Chronicle; Railway World, April, 1914, pp. 309-310.

Pennsylvania Railroad.

Electrifying Suburban Lines.

In order to relieve the congestion in the Broad Street Station, Philadelphia, Pa., and in the yards and running tracks approaching the station, the Pennsylvania announced more than a year ago, as mentioned in the Railway Age Gazette, of March 20, 1913, that it would undertake the electrification of certain lines on which a heavy suburban business is handled. Since that time a comprehensive study of the situation has been made by a committee of operating and engineering officials, and as a result of the reports of this committee and of the company's electrical engineers, it has been decided to begin work on the Philadelphia-Paoli suburban line with the probability of following this with a similar development on the

Chestnut Hill branch at an early date. The general details of this first step are practically settled and work is already under way on the necessary trolley and transmission lines. The initial electrified section will be 20 miles long, extending from Broad Street Station west on the main line to Paoli. Electric power will be used only for the operation of suburban trains whose runs terminate at that point. It should be made clear that the company does not expect to effect important economies by this installation, but it is hoped that some decrease in expenses will result from electric operation to apply as a partial offset, at least, to the interest charges on the investment. . . .

In the consideration of all the problems arising in connection with the present improvements, the company's engineers have taken into account the possibility of future extensions of the electrified system and every attempt has been made to adapt the system and details of construction to such future development. . . . —Railway Age Gazette, June 5, 1914, pp. 1243-45.

Southern Pacific.

A Network of Electric Roads.

The Portland, Eugene & Eastern was incorporated to electrify two branches of the Southern Pacific near Portland, Oregon, and two small steam roads which have been purchased, in addition to building a new electric interurban line from Portland to Salem, Corvallis and Eugene. When this construction work is finished the company will operate a network of electric roads which will cover practically the whole Willamette valley, and which it is expected will handle a large amount of freight from the ranches and orchards in the valley to the markets and shipping points in the larger cities, in addition to an important passenger traffic. The territory tributary to the line contains 190,000 people, exclusive of the city of Portland and the county in which it is located, the density of population being 19.5 per square mile. The Willamette valley contains the largest and most productive prune and cherry orchards in the northwest; one of the counties tributary to the new line raises almost half of the total crop of hops grown in the United States; and the products of truck gardens, dairy farms, agriculture and forests will also furnish some freight traffic. The decision to spend \$12,000,000 in building an electric system was reached in 1910 following a complete examination by Robert E. Strahorn, who is at present the president of the company.

The new main line from Portland to Eugene will be about 125 miles long and the total mileage, including all branches, will be about 340 miles. . . . The new main line south of Portland will use the existing Southern Pacific tracks to Oswego. From Oswego to Hubbard, 21 miles, a new double track line will be built, one track to be used by the interurban cars, and the other by the Southern Pacific main line steam trains. This location will reduce the distance on the Southern Pacific between Portland and Salem, and will also improve the line as to curvature and grade, reducing the maximum grade from 1.5 per cent to 0.5 per cent. . . .

The present branches of the Southern Pacific west of Portland, known as the West Side and Yamhill branches, reach Forest Grove, St. Joseph, McMinnville and Independence. The completion of the main line and the electrification of these two branches will provide three distinct routes into Portland for Willamette valley shipments.

The franchise for entering Portland over Fourth street has been granted and material for the construction has been received. The electrification of the two branches forming the McMinnville loop is practically completed, these lines having been practically rebuilt. . . .

The motors will be connected two in series when operating on the 1,500-volt circuit, and by means of a commutating switch, the connections can be so changed that each motor will be thrown directly across the trolley circuit when the car is operating on the 600-volt city lines. For freight service a number of 1,500-volt 60-ton electric locomotives equipped in somewhat the same manner as the passenger cars will be provided.

Plans have been made for general car shops near Portland, the buildings for which will be of reinforced concrete construction and will include all modern machine shop facilities. The main shop building will contain a floor area of 40,200 sq. ft. and will cost

approximately \$100,000. The yard layout around these shop buildings will include about three miles of track. . . . —Railway Age Gazette, Sept 12, 1913, pp 453-54.

Electrification Veiled by Organizing Subsidiary Companies.

Notwithstanding the fact that the Southern Pacific Company has been the pioneer in the work of changing from oil to electrical power, its activities in this line have been veiled by the organization of subsidiary companies to do the work. For instance, in the southern portion of California, the Pacific Electric, which is a Southern Pacific property, is now operating much mileage that was formerly under steam operation. In the San Francisco Bay District, the Oakland, Alameda and Berkeley, the Peninsular Railway Company and the San Jose Railway Company are doing a work similar to the Pacific Electric. In the San Joaquin Valley, the Visalia Electric is acquiring and electrizing some Southern Pacific mileage. While all of these roads are doing building on their own account, this work would doubtless have to have been done by the Southern Pacific if that company would keep its grip on the increasing traffic units of the State.

The Portland, Eugene and Eastern Company, as a subsidiary of the Southern Pacific, is probably doing the most characteristic piece of electrizing of that company's line in and about Portland. The lines to be electrized in that section will total 340 miles, and the cost of this work is estimated at \$12,000,000. Included in this work is the building of new lines through the Willamette valley, in addition to electrizing two Southern Pacific branch lines and two steam roads which were purchased. In main-line electrization the ever-progressive Southern Pacific is considering three outlets from the great central valleys of the State, south of the Tehachepi Pass, north over the Siskiyou Mountains and east of the Sierra Nevada, as strategic points from which to start. At a recent date Electrical Engineer Babcock, of those roads, made investigations as to the feasibility and possibility of doing this work. On account of the high market on bonds he is not optimistic so far as possibility is concerned, but he thinks the work is very feasible. . . . —Railway World, March, 1914, p. 219.

In spite of the rapid development of electric interurban lines throughout the country, the railroads, especially in the eastern and central states, have given relatively little attention to the possibilities of such lines as feeders for their main trunk lines. The roads on the Pacific coast have been the first to realize the opportunity for development in this direction on a large scale, and it is here that the greatest progress has been made. Over 1,500 miles of such lines are now in active operation under the control of the Southern Pacific and the Hill Lines, the former in the vicinity of Los Angeles, San Francisco and Portland, and the latter near Portland and Spokane. These lines are more than the ordinary interurbans in that they compete actively for all classes of freight as well as passenger traffic, and have the same standard of equipment and construction as steam roads.

The lines of this nature most nearly approaching steam road standards of construction, operation and traffic, are the Spokane & Inland Empire system, extending south and south and west of Portland, all of which are Hill properties. These systems compete actively with the steam roads for all classes of traffic in highly competitive territory and participate in through rates with the owning and other companies.

The Inland Empire is the older of the two lines, and extends from Spokane south to Colfax, Wash., and to Moscow, Idaho, and also east to Coeur d'Alene, Idaho, and Hayden Lake, with a total of 177 miles of main line. In addition, this company also operates 36 miles of street railway lines in Spokane, which, however, will be excluded from this study. The lines south, commonly termed the Inland division, are single track throughout, while 18 out of 41 miles of the Coeur d'Alene division is double track. **These two lines were built in 1906, and were consolidated under one management in 1908. They were acquired by the Great Northern and Northern Pacific in 1911. They are operated entirely separately from the parent companies, but are under the executive control of the Spokane, Portland & Seattle.** . . .

The territory south of Spokane is competitive with the Oregon-Washington Railroad & Navigation Company and the Northern Pacific, while the line east is paralleled by the Chicago, Milwaukee & St. Paul and the Northern Pacific.

At Spokane the passenger trains proceed over city streets for about a mile to a terminal in the center of the city. . . . Freight trains are assembled in a separate freight yard located between the yards of the St. Paul and the Great Northern, with transfer connection with all roads. Physical connection is also made with the Northern Pacific and the Oregon-Washington Railroad & Navigation Company at Moscow.

The terminals at Spokane are adapted for the handling of all classes of traffic ordinarily found on steam roads, while the station facilities at the smaller towns, including combination freight and passenger stations, house tracks and side tracks, are also similar. . . .

The motive power consists of six 47-ton and five 72-ton single phase, a. c., and two 37-ton d. c. 600-volt locomotives. On the Inland division, two locomotives are commonly operated in multiple on freight trains, two of the lighter ones hauling 450 tons and two of the larger ones 630 tons on the maximum grade. On the Coeur d'Alene division they are operated singly, a 37-ton locomotive hauling as high as 725 tons. Two of the a. c. locomotives make the trip from Spokane to Moscow and return, 180 miles, with a local freight carrying full tonnage daily, in 12 hours and 45 min. regularly.

An average of over 3,000 passengers are handled daily on the Spokane & Inland Empire, and the number exceeds 4,600 on Sundays during the summer. The passenger receipts last year were over \$565,000, forming practically half the total revenue. Three trains are operated each way daily from Spokane to Colfax and to Moscow and nine to Coeur d'Alene. The passenger business is especially heavy on this latter line with a considerable commuter traffic and two daily boat trains each way during the season of navigation which connect with steamers for Harrison and St. Maries. These latter trains run through without stops, making the 32 miles in 55 min., including crossing nine streets at grade entering Spokane. As indicating the heavy passenger traffic handled at certain times, 1,085 special trains were run on this line during the 55 day racing season at Coeur d'Alene in 1912. Parlor cars are operated on the four limited trains on this division. Great Northern express and United States mail are carried on several trains on each line.

However, it is the freight traffic which presents the greatest opportunity for development. About 75 carloads of freight are handled daily, two-thirds of which originates on the Inland division. This traffic consists principally of grain, lumber, fruit, stock, and merchandise. One regular freight train leaves Spokane about midnight daily for each branch of the Inland division, making the round trip in about 12 hours, while two freights are operated each way daily to Coeur d'Alene. Extra freights are run as required, an average of three being operated daily on the Inland division during the fall wheat rush. Previous to their acquisition by the Hill lines, through carload freight originating on these lines was turned over to different roads at Spokane indiscriminately. Now, however, as much of it as possible is routed over the Great Northern or the Northern Pacific, from 15 to 20 cars being given these two roads daily, aside from the heavy wheat business, most of which is also long haul traffic.

The heaviest carload traffic consists of wheat from the Palouse country, about 3,000 cars being brought into Spokane last year, most of which were billed to Tacoma, Seattle and Portland. Forty-two warehouses have been erected at various points along the line with a capacity of over 4,000,000 bu. Considerable lumber is also hauled out for eastern points, an average of about 10 cars being turned over to the Inland Empire by the Washington, Idaho & Montana & Palouse daily, in addition to some at other points.

The carload fruit business is growing rapidly, in addition to which much is handled by express and l. c. l. As indicating the possibilities along this line, 13 cars of berries and several cars of cherries were shipped in one week from one station, while a special train consisting of 12 cars of fruit was brought from Moscow to Spokane. To accommodate the heavy l. c. l. fruit business, a tri-weekly refrigerator service is operated on all lines, generally requiring two or more cars on each train.

About 18 cars of l. c. l. freight are loaded at Spokane daily. Freight received up to 5 p. m. is despatched on night trains for delivery at all stations along the line at 6 o'clock the following morning. In addition, local freight received up to 11 a. m. daily at Spokane is delivered at Coeur d'Alene at 1 o'clock the same afternoon. Solid cars are loaded for Colfax, Moscow, Palouse and Coeur d'Alene, while two solid cars are loaded for points on the Washington, Idaho & Montana via Palouse, and peddler cars serve other points. During the season of navigation at least three cars of l. c. l. traffic are also delivered daily to the boats at Coeur d'Alene for St. Joe, St. Maries and intermediate points. As indicating the extent to which this road is enabled to meet competition, it secures over 90 per cent of the l. c. l. business from Coeur d'Alene in competition with two other lines.

The Oregon Electric is a more recent development of the Hill lines, and is another example of the competition existing between the Hill and Harriman interests in the north-west, as it extends up the productive Willamette valley, long a stronghold of the Southern Pacific. The Oregon Electric operates from Portland south through Salem and Albany to Eugene, Ore., a distance of 122 miles, with a branch from Garden Home to Forest Grove, 19 miles long. It was originally built to Salem and to Forest Grove as an interurban road and was purchased by the Hill lines in 1910. Work was immediately begun on an extension to Eugene, which was completed in October, 1912. At the same time the Oregon Electric was purchased, the Hill lines also secured control of the United Railways operating from Portland west into the Tulatin valley, and have since extended it west 12 miles to Wilkesboro. The United Railways also possess valuable franchises for operation over city streets in Portland. While both lines are now owned by the same interests, they are still operated independently in all except executive matter.

Since taking control, the new owners have built these extensions and have revised the old line so that they now conform to steam road standards of construction. . . . South of Salem 2,000 ft. sidings are provided at intervals of four miles. Except in cities, the line is built throughout on private right of way of 100 ft. width. . . . This line was changed over from 600 volts d. c. in 1912, at which time the spacing of sub-stations was increased from 12 to 18 miles. The United Railways was changed over to the same system in July, 1913. . . .

Eight locomotives weighing 60 tons each with 19,000 lb. tractive effort when running, and 32,000 lb. when starting, are required on the Oregon Electric and one on the United Railways. These locomotives haul 500 tons on the ruling grades. . . . Among the numerous improvements which have been made on this line during the past few years is a five mile cut-off between Orenco on the Oregon Electric and Helvetia on the United Railways, which will eliminate the necessity of hauling freight through the streets of Portland, and gives direct access to the common yard of the Hill lines at that point. At Salem a detour line two miles long for freight traffic passes through the wholesale district and removes this traffic from the main residence streets, while a similar line has also been built at Albany. A second track was also built south to Garden Home last year. In connection with the construction of this second track, alternating current, automatic signals were installed.

Both passenger and freight traffic is actively solicited in competition with the Southern Pacific and its subsidiary, the Portland, Eugene & Eastern. Five passenger trains are operated each way daily between Portland and Eugene, two of which are limited trains making the run of 122 miles in four hours. Two additional trains are run from Portland as far as Albany, and three more to Salem. All these trains carry at least two cars and most of them three cars. Buffet parlor cars are carried on the limited trains, and one sleeping car is operated each way between Portland and Eugene nightly. All through trains carry express, the Great Northern having replaced Wells Fargo & Company on August 1, 1913. The express business has developed very rapidly, especially in milk and berry traffic, and six express cars have recently been purchased for this special use. Although most of this line has been in operation less than two years, a very satisfactory passenger business has already been developed.

Equally promising with the rapid development of the passenger traffic is the growth in both l. c. l. and carload freight traffic. One through freight train is operated each way nightly between Portland and Eugene, and another between Portland and Forest Grove, while a local freight is operated between Portland and Salem three times weekly. Merchandise is accepted at Portland up to 5:30 p. m. for these trains leaving at 8 o'clock, and is unloaded at all stations for delivery at 7 o'clock the following morning. Full cars of l. c. l. freight are loaded for Salem, Albany and Eugene with peddler cars for other points. In addition to Portland, freight houses have been built at Salem and Eugene with team tracks, eight such tracks with a capacity of 25 cars being provided at Eugene. The regular night freights place the cars on these tracks, and on the industry spurs, so as to require no further switching.

The principal commodities shipped in carload lots are: cord wood, hops, fruit and lumber. The hop movement is especially heavy, and is rapidly growing, over 200 cars being shipped during the fall of 1912, shortly after the line was opened and before complete facilities could be provided. Hop warehouses have since been built at several points along the line. Much cord wood is also shipped locally to Portland for fuel, while considerable quantities of fruit are handled for Portland and for eastern points. Practically all of the hops go to New York and other eastern points, the Hill lines securing the through routing to Chicago. This illustrates an important advantage resulting from the control of these lines as feeders, over 25 per cent of the carload freight handled on the Oregon Electric being billed through over the other Hill lines. In this connection it is instructive to note that, whereas the Hill lines secured only 40 per cent of the freight moving through Portland a few years ago, they now secure over 60 per cent of all this traffic. On the Oregon Electric proper about 50 cars of freight are being handled daily.

In addition to this road business, the United Railways does a switching business among industries along its tracks in Portland for all roads. Several tracks are laid in the city streets, through the wholesale district, and two electric locomotives are employed in switching here during the night. Cars are placed opposite the different warehouses during the evening, and are removed early in the morning. In this way these industries are given railway facilities without noticeable inconvenience to street traffic, and cars can be loaded or unloaded without the necessity of trucking through the street. From 15 to 20 cars are handled nightly in this way, this switching service being performed for all roads.

All trains on the Oregon Electric, the United Railways and the Spokane & Inland Empire are operated under standard steam road rules, modified where necessary to adapt them to electric operation. . . . —Railway Age Gazette, Sept. 4, 1914, pp. 423-27.

In General.

Past Experimental Stages.

The operation of steam railroads by electricity is no longer in the experimental stage. Electricity as a means of motive power has been tried out very extensively and has proved to the world that it is more reliable than steam and has many advantages over it. . . . —Railway and Locomotive Engineering, October, 1912, p. 372.

Ultimately Electric Service Will Be General.

. . . Mr. Judson: Have you any opinion, Mr. Worthington, about the future of the use of electricity in our railroad systems?

Mr. Worthington: I think the progress is going to somewhat slow. It probably will be used pretty generally around the large cities and places of that kind, but the first cost is extremely high, and it has been quite difficult to work out a satisfactory arrangement for switching yards. Ultimately it is quite likely that electric service will be general, but it is going to progress slowly; there is not much doubt of that. . . . —B. A. Worthington, Statement Before Arbitration Board in Eastern Engineers' Case, (1912), Pro., p. 172.

Two Electric Locomotives Handled by One Engineer.

"How does the electric locomotive compare with the steam locomotive as to its suitability for railroad operation?" The latter has two distinct parts, the boiler and the engine, each of which is designed for the service in which the locomotive is to be placed. The boiler has its limits in size, due to the railroad conditions, and it is necessary to work the same at its maximum capacity so as to get the most power possible out of the locomotive. . . . A steam locomotive, in general, is designed so that the maximum tractive effort corresponds to about 22 per cent adhesion between the drivers and the rails. The steam locomotive is not able therefore to start an increased load which requires more than the 22 per cent adhesion, even if the coefficient is increased by the application of sand to the rails. Moreover the tractive effort remains practically constant only up to 10 or 12 miles per hour for a passenger locomotive and 6 or 8 miles per hour for a freight locomotive, as it is necessary to use the steam expansively to obtain speed with a resulting decrease in the mean effective pressure.

The electric locomotive does not have the two distinct parts. The boiler is at the power house, which may be several miles away, and compared to the electric locomotive is unlimited in power. The torque of the motors is entirely different from the power obtained in the steam cylinder, in that the torque depends in the amount of current flowing through the motor. This value is at the control of the engineer, so that within safety limits as large a torque as desired can be obtained from the motors, and the maximum output is not fixed as in the steam locomotive supplied with constant steam pressure. This large variation of torque means large variation of tractive effort and draw-bar pull. It is therefore possible with the electric locomotive to take advantage of extra adhesion which may be natural, or caused by sand. A coefficient as high as 33 per cent has been obtained. It is then only a matter of having sufficient wheel load on drivers to take care of the maximum draw-bar pull required. Besides the motors can be so designed that the rated maximum draw-bar pull will remain constant to 20 or 30 miles per hour. . . .

Two electric locomotives can be connected together and controlled by one man.

. . . —Railway and Locomotive Engineering, October, 1912, p. 372.

Advantages of Electric Locomotives.

. . . The electric locomotive has many economical advantages, some of which are:

1. Due to the lack of smoke and gases maintenance charges on bridges, steel work, etc., are decreased.

2. There is a fuel saving on account of no standing charges against the electric locomotive; power is only used when hauling trains and no power is required when coasting and laying over; cheaper grade of fuel can be burned at the central power house and handled at less cost and at a higher efficiency.

3. Does away with turntables and decreasing shunting movements as an electric locomotive is operated equally well from either end. Much time is thus saved, resulting in increased capacity of the terminals.

4. Water stations, round houses, etc., eliminated.

5. The cleanliness is a comfort to the passengers, resulting in increased travel.

. . . —Railway and Locomotive Engineering, October, 1912, pp. 372-3.

Mallet Has Set Back Electrification Ten Years.

Mr. Babcock's discussion of the advantages of the electrification of steam railroads having heavy grades, with special reference to Tehachapi Pass on the Southern Pacific, which is abstracted on another page in this issue, is radically different in tone from many of the previous papers on electrification. Most of these have advocated the adoption of electric power on roads now operated by steam. Mr. Babcock is a practical steam railroad man who has been forced to go into the problems of electrification very thoroughly within recent years. The electrification of the mountain districts of the Southern Pacific must be justified, if at all, by increased economy in operation rather than by results such as increased safety, the elimination of smoke, the development of passenger traffic, etc., which have been the ends sought in practically all the electrification of steam roads, which has been

gone up to date. The problem on the Southern Pacific has been the subject of very animated discussions for several years. The contrast between this and previous papers brings out sharply the failure of many electrical engineers to understand steam road problems and to adjust their dissensions and plans to these conditions. The papers read before the American Institute of Electrical Engineers and other associations have been devoted more to technical details than to the larger problems of the practical application of electricity to steam road operation. Electrical engineers have complained that steam railway men refuse to adjust their methods of operation to secure the best results from electrification. Many of them have failed to realize that it will be necessary, at first at least, for them to adapt electrification to existing steam road practice. If the results then gained are measurably satisfactory, steam railroad men may become willing to revise their methods to secure yet greater advantages from electrification. Likewise, comparisons between steam and electric operation should be based upon the best types of steam locomotives, in which connection James J. Hill has said that the development of the Mallet locomotive has set back electrification at least 10 years. The paper by Mr. Babcock is timely in view of the widespread interest in the subject of electrification of trunk line railroads, and should stimulate the collection of data regarding the economies actually attained under such operation. Such material has not been available to any considerable extent up to the present time.—*Railway Age Gazette*, Sept. 12, 1913, p. 441.

Consols., Mallets and Electrics Compared.

Let us investigate how electrification compares in such instances with grade reduction or with the use of Mallet locomotives, or with both together. For this purpose we may take the case of a typical western road crossing the Rocky Mountains. The profile of the mountain division of this road is represented by Fig. 1. During the past two years this division has handled an average of about 5,400,000 ton-miles daily, of which about 4,300,000 is freight and about 1,100,000 passenger ton-mileage. Freight trains at present show a maximum weight of 950 tons, which is reduced at the bottom of the main grade to about 700 tons, and even with this reduction the speed over the grade is very low. Traffic conditions are becoming more and more congested. In order to increase the daily tonnage capacity of this road it is proposed to raise the present maximum tonnage per train from 950 to 1,100 tons, and to arrange so that this weight of train may be handled unbroken over the entire line at a reasonable speed. To make this possible it is proposed to reduce the ruling grade from 3 per cent to 2 per cent and to purchase Mallet compounds for operation on the heavy grade section.

The capital required for these improvements is estimated at \$2,100,000, from which may be deducted about \$240,000, this being the present value of the 24 consolidation locomotives now on the heavy grade section, which would be replaced by the Mallet compounds and could, therefore, be transferred to other divisions. The net cost of the improvement may thus be put down at \$1,860,000. By these means it is expected to raise the capacity of the road from 5,400,000 ton-miles to about 10,000,000 ton-miles per day, viz., 8,500,000 freight ton-miles and 1,500,000 passenger ton-miles.

The purpose of this inquiry is to see whether these proposed means offer as great a return on the new capital invested and the same operating advantages as electrification would do. Let us first look at the characteristics of the three types of locomotive involved. The table below gives the most important data with reference to the three engines:

	Consolidation	Mallet	Electric
Wheel arrangement.....	2-8-0	2-6-6-2	0-8-8-0
Total weight, lbs.....	380,000	500,000	360,000
Weight on drivers, lbs.....	194,000	307,000	360,000
Weight per driving axle, lbs.....	48,500	51,200	45,000
Total length, ft.....	70	84	74
Length of rigid wheel base.....	15 ft. 8 in.	10 ft.	8 ft. 8 in.
Total heating surface, sq. ft.....	3,480	5,770
Tractive effort, lbs.....	46,000	73,000	86,000
Coefficient of adhesion, per cent.....	23.8	23.8	23.8

. . . The principal advantage of the Mallet over the present consolidation lies in the increase of weight on drivers, which produces a corresponding increase in the tractive effort. . . . The maximum tractive effort of the Mallet is almost 60 per cent greater than the consolidation. At first glance this would seem to indicate a 60 per cent increase in traffic capacity, due to the 60 per cent heavier train which can be handled by the Mallet locomotive. On closer observation it is found, however, that this increased hauling capacity is only securable at low speeds and the ton-miles moved per hour at speeds between 10 and 14 miles per hour. . . . are seen to be not proportional to the increase in tractive effort, but only about 35 to 40 per cent greater for the Mallet than for the consolidation. Table II gives the hauling capacities of the three types of engines on the 3 per cent grade at speeds of 4, 10 and 20 miles per hour.

TABLE II.

	Consolidation	Mallet	Electric
Trailing tons at 4 miles per hour.....	510	880	1,160
Trailing tons at 10 miles per hour.....	430	590	1,140
Trailing tons at 20 miles per hour.....	150	240	1,100

If we take the most favorable points for each type of locomotive, with reference to actual service capacity, the consolidation is seen to be at its best at about 11 M. P. H. and can then move about 4,400 ton-miles per hour. The Mallet is at its best at about 13 M. P. H., and at that speed is capable of moving 6,100 ton-miles per hour. And the electric locomotive is at its best at about 20 M. P. H., when it can handle about 22,000 ton-miles per hour. At the maximum point the Mallet can therefore haul about 39 per cent more than the consolidation, and the maximum service capacity of the electric is five times as great as that of the consolidation and 3.6 times that of the Mallet.

The explanation of this tremendous increase lies of course in the fact that the electric locomotive cannot only haul a greater tonnage than the Mallet or the consolidation, but it can haul this greater tonnage at a much higher speed. When we consider that, in addition to its larger hauling capacity at high speeds, the electric locomotive is independent of the coal bunker, the water tower, and the roundhouse, and can operate for long periods of time without housing or attention, it will be realized that its actual relative daily service capacity is even larger than is indicated by the above figures for trailing ton-miles capacity.

To handle an 1,100-ton train at a speed of 20 M. P. H. on a 3 per cent ruling grade is quite feasible with an electric locomotive. . . . If the same thing were to be attempted with steam engines, it would take 8 consolidations or 5 Mallets; in other words, it appears almost, if not entirely impracticable. However, it was proposed to reduce the grade from 3 per cent to 2 per cent for Mallet operation. . . .

. . . An 1,100-ton train may be handled by a Mallet locomotive on the 2 per cent grade at any speed up to about $7\frac{1}{2}$ M. P. H., . . . at that speed the service capacity is about 8,700 ton-miles per hour, or rather more than twice the service capacity of the consolidation on the present 3 per cent grade. This confirms indirectly the estimate, referred to above, of the expected increase in the capacity of the road from 5,400,000 to about 10,000,000 ton-miles per day due to the grade reduction and use of Mallet locomotives.

The increase in capacity through electrification of the line, without grade reduction, is seen to be considerably greater. The maximum service capacity of the electric engine on the 3 per cent grade is 22,000 ton-miles per hour. Suppose, for the sake of argument, we take only 75 per cent of this, or 16,500 ton-miles. We still find the service capacity of the electric engine on the 3 per cent grade to be about twice as great as that of the Mallet compound on the 2 per cent grade. Or, putting it another way, if the use of the Mallet engine combined with a grade reduction from 3 per cent to 2 per cent will increase the capacity of the road from 5,400,000 to about 10,000,000 ton-miles per day, the use of the electric engine without grade reduction will increase it to about 20,000,000 ton-miles per day.

Now let us look into the financial aspect of the matter. The heavy grade section of the division in question is found to have 72 miles of main line, 26 miles of second track,

and 16 miles of sidings, or a total trackage of 114 miles. A distinctly conservative or ample figure to use is \$9,000 per mile of track for a suitable overhead contact line, including the necessary substations, feeders, etc., or \$1,026,000 for the 114 miles of track. Suitable electric locomotives of 180 tons each can be bought for about \$70,000 each. Eight of them are required, which makes the cost of the locomotives \$560,000. The total new investment for electrification may, therefore, be put down as \$1,830,000, which includes 15 per cent for engineering and contingencies. From this should be deducted the same \$240,000, corresponding to the present value of the 24 consolidations now on the line, as above in the estimate of the cost of grade reduction and Mallet compounds. The net cost of electrification is thus found to be about \$1,590,000, or \$270,000 less than the cost of grade reduction plus Mallet compounds. Add to this the fact that there will be a probable annual saving of not less than \$50,000 due to difference in maintenance of locomotives, saving in wages to engine men, saving in cost of electricity as compared with cost of coal, and saving in cost of water, oil and supplies, and the financial advantages are clearly seen to be with electricity as motive power.

Of course, these are figures applying to a specific case, but the case is rather representative of what is to be found on many of the heavy grade divisions all over the country. It may, therefore, well be said that, in all cases where a heavy grade has produced a traffic congestion, a careful investigation into the merits of electrification will be warranted and it will often be found that electrification will not only be less costly than grade reduction or the purchase of more powerful steam locomotives, or both combined, but electricity will often offer a very much greater increase in traffic capacity than either of those other means or the two means combined. . . . —C. L. DeMuralt, M. Am. Soc. C. E. (Prof. of Elec. Eng. University of Michigan), *Railway Age Gazette*, January 17, 1913, pp. 107-8.

Great Working Capacity of Electric Locomotive.

. . . One of the main advantages of the electric locomotive lies in its great working capacity. Due to this quality it can haul the heaviest trains over the most severe grades at the same speeds as on the level. The working capacity of any given locomotive is dependent on its tractive effort, its boiler power, and its engine power. The first is limited by the weight on drivers, the second by the size of the boiler, and the third by the size of the steam engine or electric motor as the case may be. . . .

The tractive effort and boiler power limitations may be entirely removed in the case of the electric locomotive, because the boiler is in the far-off power house where it can be built as large as necessary, and because, with the great flexibility of the electric drive, it is possible to turn any required number of axles into driving axles and thus make use of any desired weight for tractive purposes. The limitations to engine power are not serious, because, with careful design, it is always possible to make the engine or motor sufficiently strong to slip the wheels. Thus it is seen that sufficient power may be concentrated in an electric locomotive so that any train may be taken up any grade found in railway practice, in the composition in which it arrives at the bottom of the grade. Furthermore, with the proper type of electric motor, this can be done at the same speed at which the train runs on the level. This feature is likely to prove of great value in the case of roads where a severe grade has produced a congestion of traffic. . . . —C. L. DeMuralt, M. Am. Soc. C. E. (Professor of Electrical Engineering, University of Michigan), *Railway Age Gazette*, January 17, 1913, p. 107.

Superiority of Electric Over Steam Locomotives.

. . . Using the performance of the electric locomotive as a standard, he (A. H. Armstrong) finds that a simple locomotive on a two per cent grade will haul about 57 per cent of the total tonnage of the electric, while the Mallets will pull about 80 per cent. As against a speed of fourteen miles per hour for the electric locomotive, the simple engine will give a performance of 7.35 miles per hour and the Mallet will attain 6.38 miles per hour. The electric locomotive will show an elapsed time on a mountain division of 220 miles in 13.72 hours as contrasted with the steam engine's performance of 18.65 hours. In addition

to these advantages, Mr. Armstrong contends that the electric locomotive is more reliable, more rugged and is more uniform in operation than the steam locomotive; that it can be operated twenty-four hours in the day at a stretch, if necessary; that no time is necessary for coaling or watering, and that the fire risk with such engines is much lower. The aggregate of the savings from the use of electrical equipment will, under most conditions, more than offset the increased capital investment.—*Railway World*, February, 1913, pp. 140-141.

Electric Locomotives Save Dollars.

"There is no question that electrical apparatus has demonstrated its ability to handle large quantities of power reliably and economically, to meet successfully the increased traffic demand where steam locomotives fail in spite of their recent development, its superiority in handling double the trains in terminals with the same trackage as required for steam operations, no turning or shifting or necessity for frequent trips to round house for inspection and hostling, ready to go without advance preparations and for tunnel work has no competitors. There is no doubt that in this day of railroad regulations and difficult railway finance, no argument will appeal to a railway manager that does not show beyond doubt a saving in dollars and no small amount either." . . . —Address by H. Root Palmer, before Richmond R. R. Club. *Railway World*, June, 1914, p. 477.

Steam Locomotives Have Limitations.

. . . The limitations of the steam locomotive are, perhaps, more apparent on mountain divisions than elsewhere, and it is in this direction that the electric locomotive has made serious inroads during the past year. . . . The reason for considering electrification at all is on account of the greater advantages offered by the electric locomotive itself. It is in the electric locomotive, therefore, that the greatest interest centers as offering the possibility of introducing such radical improvements in present steam locomotive operation as to justify the large expense involved in electrification.

During the past year notable advance has been made in the application of the electric locomotive. Special interest centers in the electrical operation of the Butte, Anaconda & Pacific, which opened in part May 28, 1913, and which has been in complete electrical operation since October. While electric locomotives were installed on this road partly to demonstrate the feasibility of adopting electricity upon the Chicago, Milwaukee & St. Paul, there is operating evidence to justify the belief that the resulting economies effected in operation will pay an attractive return upon the cost of electrification. The service upon the Butte, Anaconda & Pacific is in every way comparable with that of the mountain divisions of our main lines. Trains of 4,000 tons are operated against a ruling gradient of 0.3 per cent at a speed of 16 miles per hour on the main line. The annual tonnage comprises the movement of approximately 5,000,000 tons of ore as well as mine supplies, in addition to the passenger service maintained between Butte and Anaconda. . . . —A. H. Armstrong, Asst. Engr. Ry. Dept., General Electric Co., *Railway Age Gazette*, January 2, 1914, pp. 11-12.

Adaptability of Electric Locomotives.

An example of the advantages to be obtained from the use of electric locomotives is that of the above. Two locomotives of the Baldwin-Westinghouse are used to haul freight about 1½ miles from the nearest railroad track up grade, with a maximum of 5 per cent to the plane of the Chase Rolling Mill Company, Waterbury, Conn. Heretofore all the hauling, raw material and finished product, to and from the station, has been handled by eight-horse teams, which proved to be expensive.

The locomotives make from 8 to 10 trips per day, and with a load of approximately from 100 to 125 tons each. This load is governed by the 5 per cent grade, which is 3,000 feet in length. These locomotives have been in operation from the beginning of last year and have had a perfect record. . . .

The electric locomotive is well adapted for this class of work, for it is easy to choose one of the proper weight to give the necessary tractive effort and adhesion for the class of work to be handled. Moreover, all of the weight is on drivers, each axle having an electric motor geared to it. The physical conditions in this application, i. e., the 5 per cent grade for 3,000 feet, would be a serious handicap for the steam locomotive, for it would be necessary to use one very much larger to handle the load over the grade than would ordinarily be required. It is possible with the electric locomotive to obtain for short periods tractive efforts much greater than the rating, which is not true with the steam locomotive, for the maximum depends on the boiler pressure. This inherent characteristic is of great value for a comparatively small locomotive, as above, of only 45 tons, can handle 125 tons up the 5 per cent grade. This advantage should be more generally known and realized, for there are hundreds of factory shops, etc., which could show a saving by doing the switching and freight work from the main line road by electric locomotives.—*Railway and Locomotive Engineering*, January, 1914, p. 30.

Electric Locomotives Eliminate Helpers.

The mountain grade division appears to be the present point of attack, and it is expected that economies effected over previous steam operation will give an adequate return upon the capital investment. The sources of these installations will undoubtedly lead to extensions of the initial electrified zone and to similar electrifications upon other roads.

Not least among the causes contributing to the marked activity in railway electrification during the year of 1913 is the preparedness of the electrical manufacturing companies to furnish the electric locomotives of large capacity and rugged construction required. While it is true that considerable diversity exists as to type of motor and mechanical drive used, the successful development of the electric locomotive is evidenced by the operation of such types, for example, as the New York Central gearless locomotives which operate at 90 per cent efficiency from third rail to driver rim and have been maintained in good operating condition at an expense of approximately $3\frac{1}{2}$ cents per mile run. The later locomotives of this type, constructed and put into operation during the past year, have capacity to handle a 1,000-ton train at speeds up to 60 miles per hour. High speed passenger locomotives of even greater capacity are in view which will permit of the elimination of helper locomotives for passenger service on ruling gradients up to 2 per cent. Here again is offered opportunity to effect improvements in service with the adoption of an electric locomotive having sufficient capacity to handle 1,000 tons on a 2 per cent grade at 25 miles per hour without helper locomotives and attain a speed of 60 miles with the same train on level track.—A. H. Armstrong, Assistant Engineer, Railway Department, General Electric Company, *Railway Age Gazette*, Jan. 2, 1914, p. 12.

An English View of Electric Locomotives.

The Institution of Electrical Engineers of England expects to hold six meetings in London during February, March and April, at which the various aspects of railroad electrification will be discussed. The series was opened on February 12 by a general paper entitled "Some Railway Conditions Governing Electrification," which was prepared by Roger T. Smith. His conclusions are as follows:

"To sum up the position as it appears to the author—the inherent advantages of the electric locomotive for goods (freight) and mineral haulage are, first, its ability to haul up to the maximum strength of the draw-gear at more than double the speed possible with the most powerful steam locomotive which can be built within British load gages; second, the ability, if necessary, to have all axles driven, so that the whole weight of the locomotive is available for adhesion while the weight per axle is sensibly reduced; third, the advantage that any driver (engineman) can work any locomotive; which is not the practice in this country with steam locomotives; fourth, the ability to run annually at least twice as many train-miles as the steam locomotive, partly due to increased speed and partly due to less time spent in the repair shops and for cleaning; fifth, the saving of all coal wasted by the steam locomotive when getting up steam, standing under steam, and left in the

firebox at the journey's end, with the result that with electrical energy at $\frac{1}{2}$ d (1 cent) per kilowatt-hour the bill for current per mile is about the same as the bill for coal and water per mile; sixth, the possibility, when the strength of the draw-gear permits, of loads being hauled quite beyond the capacity of any steam locomotive that can be built within our load gages. The electric locomotive takes its power from a generating station and not from a moving boiler; it can therefore be designed to give its maximum drawbar pull at any desired speed. It is for the electrical engineer to make the most of such advantages."—Roger T. Smith, (Paper read at meeting of Institution of Electrical Engineers of England), Ry. Age Gazette, March 6, 1914, p. 467.

Electrification of Swiss Railroads.

The Swiss Electrification Commission recently made its report to the Swiss Government, which is of great interest to our railroad systems, for it relates to the possible electrification of nearly 2,000 miles of track. This report has considered the system best adapted for railroad service and has come out strongly for the single-phase system.

The various systems were considered, namely, the high voltage direct current, the three-phase system and the single-phase system. The latter has a pronounced advantage over the others. This report is extremely gratifying to many of the prominent engineers in this country who have helped to bring the single-phase system to its present standard. There are many railroads electrified by this system, the most notable being the New York, New Haven & Hartford, which now has approximately 200 miles of track electrified, and in the near future, when present work is completed, will have nearly 400.—Railway & Locomotive Engineering, April, 1914, p. 147.

Pays a Reasonable Return.

Steam road electrification is, therefore, being considered from the standpoint both of improvement in the service rendered and also of effecting operating economies that will pay a reasonable return upon the capital investment required. Such operating facts as are thus far available substantiate both the claims advanced and indicate a wide field of usefulness for the electric locomotive as its qualifications become better appreciated.—A. H. Armstrong, Assistant Engineer, Railway Department, General Electric Company, Railway Age Gazette, January 2, 1914, p. 12.

A Profitable Revenue Producer.

The electric locomotive is becoming more and more each day a profitable revenue producer for electric railways. It is supplanting the steam switcher locomotive where freight is moved to and from the main line and a manufacturing plant, for this freight can be handled at a cheaper cost with the electric locomotive due to the much lower maintenance cost and the lower cost of electric power over coal. . . . —Railway & Locomotive Engineering, February, 1914, p. 68.

Electrification of Chicago Terminals.

The Chicago Association of Commerce Committee on Smoke Abatement and Electrification of Railway Terminals has submitted a report to the association stating it has practically completed its investigation of the situation with respect to smoke in Chicago, but it has not completed its studies as to the remedy. The report says in part: "Meanwhile the committee is actively at work upon a program of study and design touching the important problems affecting the technical practicability and the cost of complete electrification. This is a problem presenting many details, each one of which is receiving careful and systematic attention.

"Studies are being made also concerning the financial practicability of carrying out the necessarily extensive program for electrification of the railway terminals of Chicago, in the event that such electrification shall be recommended in the committee's report.

"In conclusion, it may not be amiss to say that most of the materials necessary to solve the question of the necessity for the electrification of Chicago's railway terminals

and the mechanical feasibility of such electrification are in hand, but that the information so far gathered as to the financial practicability of such an undertaking is not sufficient at the present time to enable the committee to determine this phase of the problem."—Report Chicago Association of Commerce Committee on Smoke Abatement and Electrification of Railway Terminals, *Railway Age Gazette*, January 16, 1914, p. 134.

Ten Years Into the Future.

It is the belief of many of the electrical men in the Western part of this country that the next decade will see half of the railroad mileage west of and through the Rocky Mountains, that are now propelled by steam, under electrical operation. This decision has been reached after a careful examination and study of the present railroad situation. At the present time the Southern Pacific is steadily electrifying lines entering and contiguous to important terminals, the Santa Fe has broached a plan for the electric operation of trains on a portion of its system in the inter-mountain country, the Chicago, Milwaukee and St. Paul is engaged in the application for hydro-electric power to 440 miles of main line track in the Northwest, and the Hill lines are now starting the development of 40,000 horsepower in the Cascade mountains. Coupled with these facts are the plain truths that coal and oil are increasing in price, while electric power, especially of the hydro-electric variety, is getting cheaper. This statement is proven by the report of Electrical Engineer Babcock, of the Southern Pacific, to the effect that the electrizing of the line over Tehachapi Pass would effect a saving in fuel amounting to \$140,322 a year for that line. Since the vast California and Texas oil fields were opened oil has been generally used for fuel in that Western country. It is claimed, however, that cheap oil is a thing of the past. An evidence of this action of the Kansas City Southern, when placing an order for locomotives, in contracting for coal burners rather than oil consumers. This action is generally considered as premonitory to the change in power of all oil-burning roads. It is very probable, however, that the change in power, especially where hydro-electrical energy is available, will be from oil to electricity rather than from oil to coal. . . . —*Railway World*, March, 1914, pp. 218-219.

Electricity to Reduce Operating Expenses.

The subject of the electrification of railroads is of particular interest in Montana, where the most important work in the world has been done and is projected in this direction. But the subject is of growing interest in all parts of the United States. A great deal of work in electrification would doubtless now be under way but for the fact that during the past year or two the railroad business has been in a state of depression, profits having been small and many important railroad systems having actually been unable to meet operating expenses.

If the Interstate Commerce Commission grants permission to the railroads to increase freight rates, another boom may be expected in railroad construction and development and this will in many cases be in the direction of electrification. Even if the request for higher rates is denied, the result may prove beneficial to electrification, for railroads may have to hasten the change from steam power to electrical power in order to reduce operating expenses.

An eastern authority has summarized the most important recent developments in the electrification of steam railroads—work which has either been completed or is in progress or about to be started. The Butte, Anaconda & Pacific is mentioned first of all. Other railroads which are doing work in the same direction are noted as follows:

Boston and Maine, Hoosac tunnel; Northern Pacific, tunnel under Coast range; Pennsylvania, Newark to New York, the Hudson river tunnel; New York Central and New Haven, Yonkers to New York, and Stamford, Conn., to New York; Michigan Central, Detroit to Windsor, tunnel under White river; West Jersey & Seashore, Camden to Atlantic City; Southern Pacific, about 10 miles entering Oakland, Cal., and 150 miles of interurban roads in Southern California; Chicago, Milwaukee & St. Paul, about 128

miles of single track through its Rocky Mountain division.—Anaconda Standard, February 17, 1914.

Mr. Mellen's Belief.

. . . "I was trying to secure control of the trolleys contiguous to the lines of the New Haven," he said, "because I had the theory and belief that, first, all railroads were going, sooner or later, especially in congested communities, to be operated by electricity. . . ."—Chas. S. Mellen, ex-Pres., N. Y., N. H. & H. R. R., Everybody's Magazine, July, 1914, p. 102.

