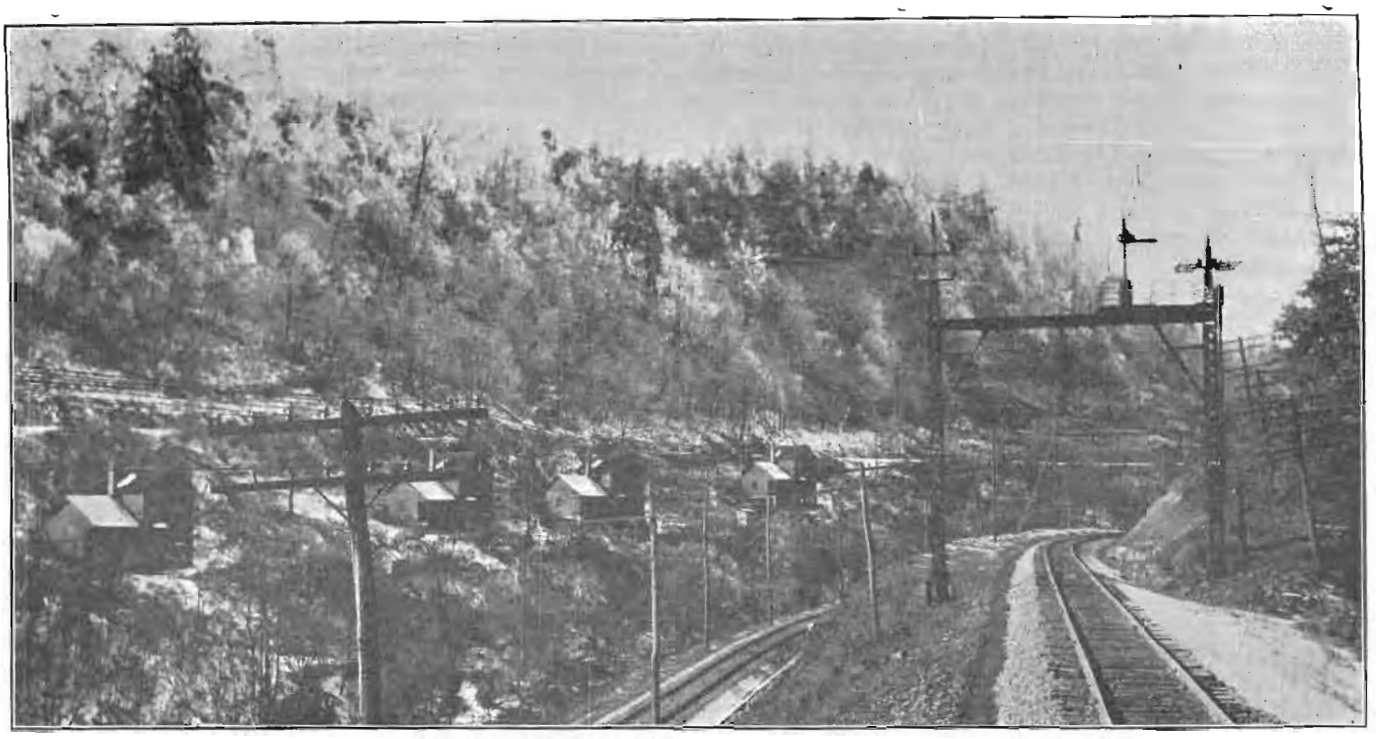


About a Mile East of the Elkhorn Tunnel on the Norfolk & Western

The Electrification of Steam Railroads

A Brief Survey of Operating Results on the Norfolk & Western and the C. M. & St. P.

THE PART that electrification will play in solving the traffic problem of the future is problematical. A large increase of traffic is inevitable and means must be provided for handling it. The extent to which electric operation will be adopted in the near future will be influenced materially by the success of the operation on those roads which are already electrified.

Comparatively little can be gained by a study of operating results of electrified roads in foreign countries because conditions are very different from those in the United States. In this country interest has been centered on the Norfolk & Western and the Chicago, Milwaukee & St. Paul. Tunnels on these two roads did restrict steam operation, but operation on neither road was circumscribed by tunnel and terminal requirements. Each new application of electric operation presents an individual problem, but many difficulties common to all roads have been and are being worked out on the two roads mentioned. The purpose of this article will be briefly to survey the operating results so far as data concerning them are available in a usable form.

OPERATING PROBLEMS common to a large number of railroads with heavy grades and tunnels have been worked out on the Norfolk & Western and the Chicago, Milwaukee & St. Paul with the aid of electric operation. The operating conditions on the two roads are very different, in that one may be likened to a big yard with very heavy switching operations, while the other is a long section of single track road on which the length of locomotive divisions has been doubled.

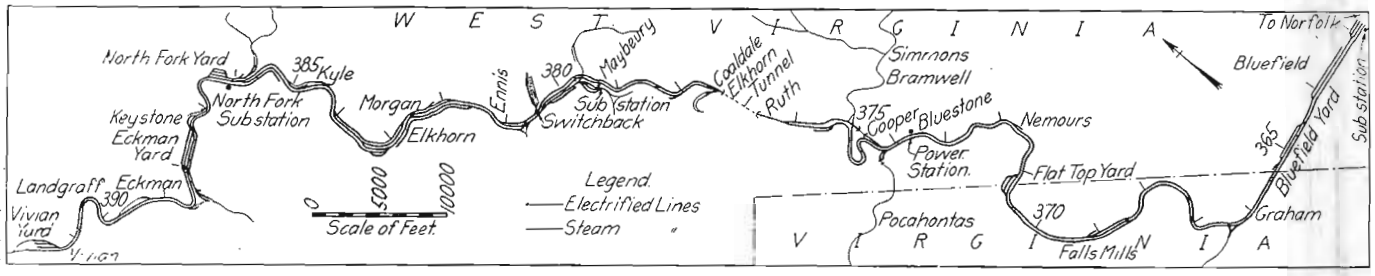
When electric operation on the Norfolk & Western is studied, the proper consideration should be given to a certain few fundamental facts. For example, locomotive maintenance costs have been high but it is logical that they should have been under the circumstances. The locomotives were put into a service heavier than anything which had been done before or has been done since; moreover, there was no precedent to follow in designing equipment for such service. Furthermore, the maintenance of any machine is to a large extent dependent upon the amount of work done by the machine, and the work done per mile and per day is greater for the Norfolk & Western locomotives than for any other locomotives, steam or electric. For example, about 60 per cent as much power is used by 12 locomotives operating over 28 miles of line on the Norfolk & Western as is used by 42 locomotives operating over 440 miles of line on the St. Paul. The power consumption on the Norfolk & Western during 1919 was 67,395,000 kw. hr., while that on the St. Paul was about 120,500,000 kw. hr. During 1918 the Norfolk & Western electric locomotives used 74,325,992 kw. hr., while the St. Paul used about 130,177,000.

In spite of many difficulties the electric system has been made to give excellent results and operating men agree that it has been the only practical solution for the division's problem.

The function of the electrified section is that of collecting

from mine sidings and yards in the coal fields the entire eastbound coal tonnage and transporting it up the grades and over the summit to the classification yard at Bluefield, which is a division point. The coal is partly classified at Bluefield and is then moved east by steam power to the various destination points, chiefly to the Norfolk & Western marine shipping pier at Lamberts Point near Norfolk, Va. All coal traffic originates west of the Flat Top yard, about 6 miles east of the summit of the heavy grade, and although a large amount of the coal which originates on the electrified division goes west, the shipments to the east constitute the bulk of the traffic handled electrically. Some coal originating east of the summit is shipped to the west, and this is also handled by electric service to yards near the western end of the electrified section. There is probably more Norfolk & Western coal shipped to the west than to the east, but over the electrified section the total eastbound tonnage is now about six times as great as the westbound. About 80 per cent of the eastbound traffic originates between Eckman and Coaldale.

Steam road locomotives are still used over the electrified section for through merchandise freight and for passenger trains, but electric locomotives are used regularly as helpers on three eastbound passenger trains and for most of the through freight trains. An electric helper is also occasionally used to help other delayed passenger trains to make up time. The principal duty of the electric locomotives, however, is to make-up and haul extra, eastbound coal trains over the electrified division into Bluefield.



Map of Electrified Section, Norfolk & Western. Fully 60 Per Cent. of the Line Is on Curves

Reason for Electrifying

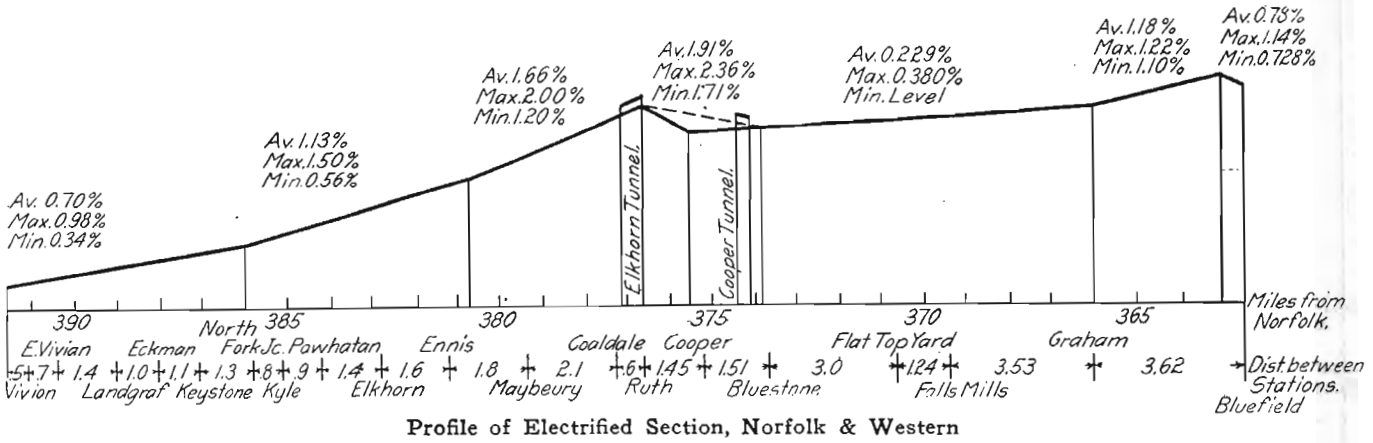
Decision to electrify the Elkhorn grade was made because this section of the road restricted the amount of main line traffic that could be handled. The increasing traffic, together with the heavy grades and added tunnel complications, had made it practically impossible to handle the traffic over this section with steam power. Because of the mountainous country through which the division runs it was not economically practicable to build more tracks and the only solution lay in handling heavier trains at higher speeds.

Two electric locomotives now haul a 3,250-ton train up the 2 per cent grade at 14 m. p. h. where originally three Mallet locomotives were used at a speed of about 7½ m. p. h. The effect of increased speed is especially marked at the single track Elkhorn tunnel, which is over 3,000 ft. long on a 1.5 per cent grade. Because of ventilation requirements, under steam operation, it was necessary to reduce the speed up the grade to about 6 m. p. h., requiring about seven minutes to clear the block. With electric operation this movement is made in about three minutes. Since electric operation was installed the Elkhorn grade has not caused restriction of main line traffic.

Train Operation

Several different methods of operation have been tried during the past five years. All trains do not do the same work, but following a locomotive and train crew through a typical day's work will give an idea of how the coal trains are handled.

A train of westbound empties, consisting of from 90 to 110 cars, is made up by a steam switcher in the Bluefield yards. The electric crew take the locomotive to the caboose track where they pick out their caboose and couple it on the rear of the train. The locomotive then goes to the head end of the train and proceeds out. The train is run at both the 14 and 28 m. p. h. speeds from Bluefield through the Elkhorn tunnel.



Profile of Electrified Section, Norfolk & Western

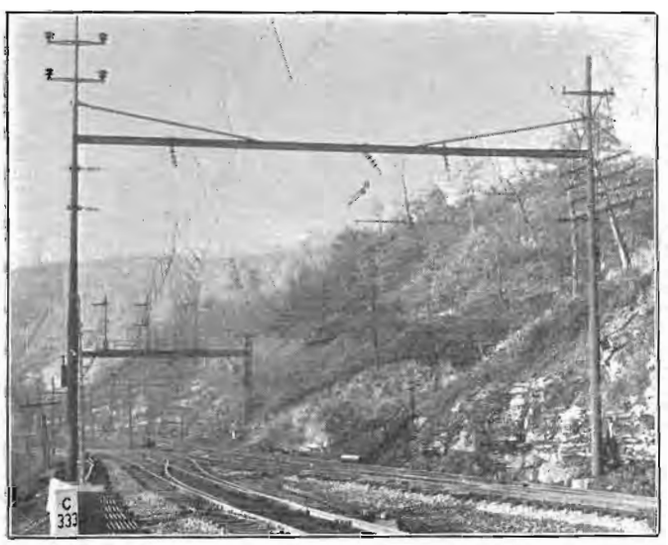
The train then drops down the heavier grade, regenerating power to the line. The empties are set off at various sidings on the way down the hill. When the last of the empties are to be set off, the caboose is uncoupled on the main line and is allowed to roll down the hill until it meets the locomotive as it comes out of the lower end of the siding. They then proceed to the Eckman yards. Had they taken westbound tonnage from Bluefield they would probably have proceeded to Vivian.

At Eckman all or a part of a 3,250-ton train is made up and taken up the grade to the Elkhorn tunnel with the aid of a pusher. If only a part of a full tonnage train is taken east from the Eckman yards the balance will be picked up at other points on the way to the summit.

The method of starting such a train is particularly interesting. When the engineer on the front end is ready to start he backs the train against the pusher. At this signal the engineer on the pusher applies power forward and holds with full load current on the motors until the front end locomotive has taken its share of the load. The pusher then starts forward automatically.

A special hook is used for uncoupling the pusher at the top of the grade, allowing it to go back for another train. The head-end locomotive then regenerates power down the steep grade east of Elkhorn tunnel. With a full tonnage train the one locomotive returns practically full load current to the line.

The train then proceeds to Flat Top yard where the pro-



Typical Overhead Construction on the Norfolk & Western

cedure depends on whether the crew is making its first or second trip for the day. In the former case, it is usual for the train to be left at Flat Top, the locomotive returning west, either light, with empties, or occasionally with westbound loads. In the latter case the train fills out to 4,700 tons at Flat Top yard and proceeds to Bluefield, a pusher being provided on Bluefield Hill. At Bluefield the time allowed for preparing the locomotive for its next trip is forty minutes.

Since the system was put in operation in 1915 more than 50,000 trains have been taken over the electrified section without a regeneration failure. Retaining valves are not used.

Power Despatching

All of the power for the electrified section is developed in one steam power house located at Bluestone. From the power house it is transmitted at 44,000 volts, 25-cycle single-phase to five substations, where it is stepped down to 11,000 volts and delivered to the trolley. The load sometimes changes from nothing to 25,000 kw. in a few minutes. One 3,250-ton train requires from 12,000 to 14,000 kw. for starting on a 2 per cent grade and about 8,000 kw. are required to move such a train up the grade at 14 m. p. h. Half of this power is used by each of the two locomotives and about one and one-half minutes are required to reach the speed of 14 miles. Naturally it is difficult under these circumstances to operate with a high load factor. A system of operation has been adopted, however, that has resulted in a 50 per cent load factor and a coal consumption of something less than 3 lb. of coal per kw. hr.

A record of all electric train movements is kept by the power despatcher at the power house. Telephones are placed along the right-of-way at all important signal towers or bridges. When a conductor has received his train he calls the power house and reports that he is about to start east or west from a certain place with a train of a certain tonnage and number of cars. This is recorded by the power despatcher on a log sheet and he also has the stokers and blowers speeded up to meet the coming increase of load. If it is not practicable to carry the increase of load with the number of boilers in service the power despatcher asks the conductor to delay starting for a few minutes.

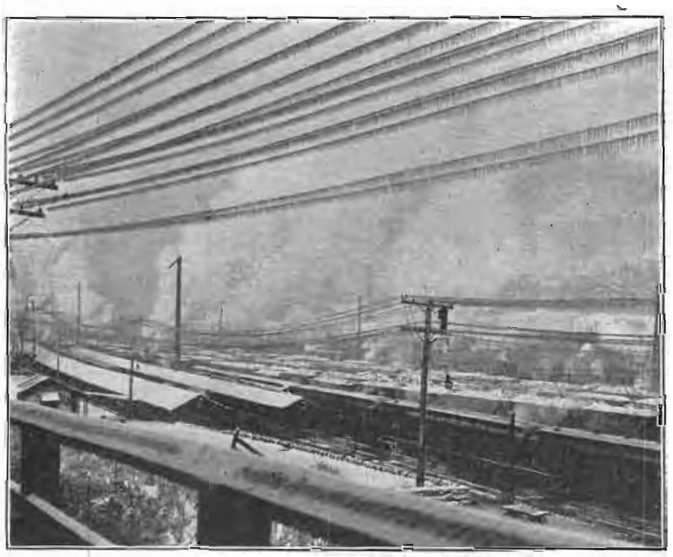
If for any reason a train is stopped at a signal for more than three or four minutes the power despatcher is again informed that it is about to proceed. This method permits the power house operator to anticipate the load, to forestall excessive peak loads and as a result operate with a minimum number of boilers and generators and obtain a high load factor and relatively high efficiency.

Overhead Maintenance

The 000 Phono-electric contact wire is supported by a 00 solid copper secondary messenger which in turn is supported by a ½ in. stranded steel primary messenger. The greater part of the main line overhead is supported by steel channels supported by tubular steel poles. In yards a built-up steel pole is used in connection with a cross catenary. The 44,000-volt transmission lines are carried on one of the steel poles.

A small car equipped with an elevating platform and also an insulated ladder, known as the "hot ladder," were provided for trolley maintenance. Now the platform car is seldom used and practically all overhead maintenance work is done with the ladder. As the name suggests the "hot ladder" is used for working on the catenary when the circuit is live.

As first installed a certain percentage of the auxiliary mes-



The Bluefield Yard. Sleet Like This Did Not Interrupt Traffic

senger was steel and the balance was copper. The action of the gases from the steam locomotives caused the steel wire to rust badly and it is gradually being replaced with 00 solid copper wire. This change will practically double the current carrying capacity of the overhead wires where iron was used as the secondary messenger.

A megger is used for testing insulators. If the test shows a resistance of less than 2,000 megohms the insulator is replaced. It is then taken back to the shop where cleaning may or may not bring the resistance, as measured by the megger, back to infinity. Wood pull-off insulators when taken down are dried out in the shop and revarnished.

In bonding the track originally, two 00 pin type, copper wire bonds were installed per joint, but in replacement only

one bond is put in. This maintains satisfactory continuity and the slight loss in conductivity is unimportant with 11,000-volt current distribution. The bond maintenance has been kept down by this practice.

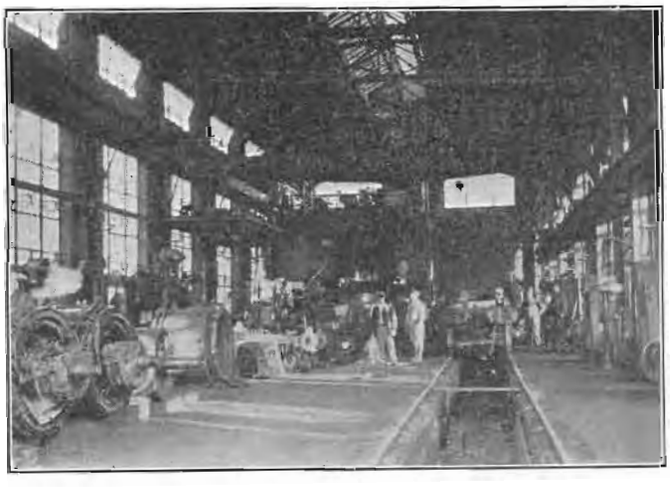
Sleet is not common in the southern part of West Virginia but has to be contended with occasionally. When there is sleet on the contact wire four pantagraphs are put up on the locomotives instead of the usual two. During sleet conditions, as shown in one of the illustrations, there was an insulator flash-over caused by a tree limb being blown over a trolley insulator. This slightly interfered with traffic, but aside from this, and occasional arcing at the pantagraph shoe, the sleet caused no trouble.

The wear on the contact wire has been measured and found to be between three and four thousandths of an inch per year on the main line. On branches and stub end yard tracks it has been somewhat higher.

Locomotive Maintenance

Maintaining the locomotives has at times taxed the ingenuity of all concerned. Frames have broken, been repaired and finally a new design of frame has supplanted the old. About half of the locomotives have been equipped with the new frames. The first new frame was installed early in 1920 and as yet none have failed. Crank pins and side rods suffered a similar fate, but the result of the repair and replacement has been highly satisfactory. Chattering wheel slip at first added much to the wear and tear on the locomotives, but it is now the exception rather than the rule.

Several other changes made in the locomotives are of general interest. For example, split babbitted bearings were used as main motor bearings, but were found unsatisfactory because of alinement difficulties and because of throwing oil, some of which would get into the motor windings. It was



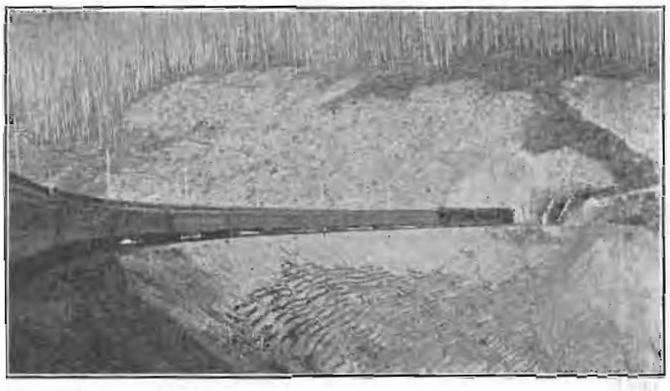
The Repair Shop at Bluestone

also necessary to provide drip pans under the gears to keep oil off the track. The split bearings are being replaced by the solid bearings with bronze inserts. These throw very little oil, do not show the tendency to run hot that the split bearings did and the bronze inserts are designed to prevent the motors from dropping down on the pole pieces in case the babbitt should flow.

There is a pinion on each end of each motor shaft. At first one of these pinions was shrunk on and keyed to the shaft, the other being shrunk on only. Now they are both shrunk on to the tapered ends of the shaft. The faces of the original pinions were flat and flush with the ends of the pinion teeth. The new pinions have an extended hub on the outer end, threaded so that a puller can be used and have an extended cup at the inner end grooved so that the oil which creeps along the shafts will be thrown back into the bearing well. A special transformer is used for heating the pinions before they are shrunk on.

Iron collector rings were at first provided for the main motors, but, seemingly due to vibration, they pitted and wore the brushes badly. Copper rings were substituted which have given satisfaction, many of them having the glossy chocolate brown finish considered ideal for commutators.

Several changes have been made on the water rheostats. Small particles of metal from the electrodes caused the outlet cylinders to stick in the gland. This was corrected by making a new gland with a collar which extended upward from the bottom of the rheostat tank for several inches into the liquid. The longest electrodes were also reinforced and the



A St. Paul Passenger Train as Seen from the Observation Car

level of the liquid is not allowed to get below the bottom of the plates. Originally the center electrodes could be lifted out of the rheostat tank while grounded electrode remained in the tank. This permitted a variation of distance between electrodes when assembled. The ground plates are now made integral with, and lift out with the others. Current limit relays have been applied to prevent the outlet cylinders rising too rapidly and thereby overloading the motors and slipping the wheels.

Headlights were removed from the top of the cab where they were close to the pantagraph and were placed on the forward and rear trucks.

A number of minor changes have been made to provide for better accessibility, better lubrication and for wear of certain parts.

The firemen or helpers, as they are called, say they consider the electrics simpler than steam locomotives. Inquiry into this statement brings out the explanation for this statement. Except in very few cases trouble or faulty operation of any part of the locomotive can be located and remedied by the helper. Even if a motor should burn out it can be cut out and the locomotive operated with three of the four trucks. Under these circumstances, of course, it may be necessary to reduce the tonnage.

The outstanding and pertinent facts are that a new type of locomotive was made to perform a service never before performed and was put into this service practically without experiment. Difficulties have been surmounted as they appeared and at no time have the electric locomotives been unable to handle the business that came over the division.

Electric operation has made it possible to handle the ever-increasing traffic that originates on this division. The far-sighted policy of adopting it has been profitable to the Norfolk & Western and the working out of the problems involved has been a service to all other roads confronted with similar problems.

Chicago, Milwaukee & St. Paul

Many factors were involved in reaching a decision to carry out the large electrification program of the C., M. & St.

P. and probably the most important of these was the desire to create a market for power. No complete figures have been published to show that the enterprise has been a success financially, but the data available indicate that such is the case. Some conception of the status of affairs may be obtained by a consideration of the following:

Operating and Capital Costs

The Pacific division has been operated electrically less than a year, so costs can now be considered only on the Missoula and Rocky Mountain divisions. A comparison of freight traffic operating costs from figures made available in 1918 shows that all costs affected by motive power on the Idaho division, which is steam-operated, were 90 per cent

The St. Paul Right of Way on the Western Slope of the Bitter Root Mountains

greater than those on the Missoula electrified division. On the Musselshell steam division they were 33 per cent greater and on the Rocky Mountain electric division these costs were 11 per cent greater than on the Missoula electric division.

The cost of maintaining and operating the transmission lines, substations, and trolley system, for the year 1919 is given in the table and a final figure showing the approximate total operating costs involved in the delivery of the electric energy to the locomotives.

OPERATING COSTS FOR 1919

Account		Total all services	Per unit
255.	Power substation buildings	$8,487	$606.00 per building
257.	Power transmission system	1,773	4.87 per mile
259.	Power distribution system	78,461	179.00 per route mile
261.	Power line poles and fixtures	24,299	55.50 per mile
306.	Power substation apparatus	40,224	2,870.00 per station
383. } 395. }	Train and yard power produced	102,152	7,300.00 per station
	Total	$255,396	

1.	Cost per thousand gross-ton miles trailing freight as actually distributed in accounts	28.8c
2.	Cost per thousands gross ton-miles train freight as actually distributed in accounts	24.9c
3.	Cost per thousands gross ton-miles trailing freight on basis distribution in proportion to freght kw.hr	30.2c
4.	Cost per thousands gross ton-miles train freight on basis distribution in proportion to freight kw.hr	26.2c
5.	Cost per actual kw.hr. delivered to locomotives	1.1c

The above unit figures include the cost of power.

Power is purchased from power companies and the cost of power at the high tension bus or point of delivery was 22.3 cents per thousand gross ton-miles trailing for freight service and 38.1 cents per thousand gross ton-miles trailing for passenger service. The freight traffic for the year was 2,476,085,000 ton-miles trailing and the passenger traffic 378,080,000 ton-miles trailing. The figures for the passenger service are approximate, as the ton-mile data are based on the assumption of an average weight per car, no record of particular cars handled in all the separate trains being available.

The above figures were taken from reports that have been issued from time to time and from them it appears that the savings in operating costs may vary from 20 to 90 per cent. This must be balanced against an additional capital charge, due to electrification, of about $23,000 per route mile. The construction cost, exclusive of locomotives, was $17,579 per route mile. In the first figure given, the value of the steam equipment displaced has been subtracted.

Power Supply

All power for the electric operation is purchased and is delivered to the railroad as 100,000-volt, 3-phase, 60-cycle current. Power for the section between Avery, Idaho, and Harlowton, Montana, is obtained from the Montana Power Company. To prevent the total power demand from exceeding a certain value, apparatus called a power indicating and limiting system is installed. When the power demand reaches a predetermined value, the trolley voltage is reduced automatically. The train speeds are, of course, also reduced accordingly and the reduction of voltage and train speeds continue until the total power demand falls off to something less than the predetermined value. Such a system was installed between Harlowton and Deer Lodge, Montana, in 1918 and on the sections between Deer Lodge and Avery, Idaho, early last year. Train speeds are reduced by this system from 2 to 13 per cent of the time, depending upon the amount of the traffic and the arbitrary value of the limit setting.

Power for the Pacific electric division which extends from Tacoma to Othello, Wash., is purchased from Inter-Mountain Power Company. This section was formally put under electric operation on March 5 last.

Motive Power

The first consignment of locomotives was purchased from the General Electric Company and consisted of 12 passenger, 30 freight and 2 switching locomotives. The freight and passenger locomotives were identical except for the gear ratio between the motor pinions and the gears on the main driving axles, as it was considered desirable at that time to have only one type of locomotive for both kinds of service. These locomotives are of the 4-4-4-4-4-4 type and the 12 passenger locomotives have now been regeared for freight service.

Two more switchers have been added and 15 new passenger locomotives were purchased and delivered during the latter part of 1919 and the early part of 1920. Ten of these were supplied by the Westinghouse Electric and Manufacturing Company and are of the 4-6-2-2-6-4 quill geared type and the other five were supplied by the General Electric Company and are bi-polar gearless locomotives with a 2-4-8-8-4-2 wheel arrangement. These locomotives were described in the following issues of the *Railway Age:* December 3, 1919, page 819; January 16, 1920, page 233 and March 26, 1920, page 1051.

Operating Results

The manner in which trains are handled with electric locomotives will be described in a series of three articles which will appear in early issues of the *Railway Age.*

The following are some particularly pertinent statements pertaining to the results of electric operation which have been made during the past year by different men familiar with conditions on the road:

"Nearly 30 per cent more tonnage can be handled by electric operation in about 80 per cent of the time it formerly took to handle the lesser tonnage by steam operation.

"The consensus of opinion of the roadmasters and superintendents of the electrified zone is that there is no more slipping of the locomotive wheels on the rail and consequently no more damage to the top of the rail under electric operation than there is with steam locomotives. It has not been found that there is any greater tendency for the rails to creep on account of regenerative braking on de-

scending grades than there was under the braking action of steam locomotives. No case has been found where electric locomotives moving at a high rate of speed have tended to displace the rail on the ties or the ties on the ballast. Roadmasters agree that the electric locomotive is easier on the track than steam locomotives because of less rigid construction. It is stated that the flange wear on curves under electric operation is actually less than under steam operation for the reason that the electric locomotives are less rigid in their wheel arrangement than the steam locomotives.

"One of the marked economies effected by electrification is the reduction of train and enginemen's expense, on account of the increased ton-miles per train mile and per engine-mile and the reduction of equipment repair and roundhouse expense.

"The spacing of trains to hold down the power demand has in combination with the action of the power indicating and limiting system worked out very well. When the load factor was running 60 per cent or higher, the automatic slowing up of trains involved an increased expenditure for freight train and enginemen's time of about 10 per cent. With a load factor of from 50 to 55 per cent, however, the limiting action takes place through only a small part of the day, and while there is a considerable reduction in the maximum demand, there is little effect on the operation.

"As to ease of starting trains, this feature of electric operation is noticeable, conducing to increased comfort of passengers.

"The technical result of the electrification has been quite a success. The financial result, due particularly to fuel and labor conditions, and the indirect value due to publicity of this operation, are equally satisfactory.

"Even allowing for the increased investment charges, the items of operating expense, depending directly upon motive power, are so reduced and additional benefits indirectly obtained are so great as to justify consideration of extending the electrification even on sections with easier grades."

The Pennsylvania's New Agreement With Trainmen

THE MANAGEMENT of the Pennsylvania Railroad System on December 29 concluded with the representatives of its engine and train service employees a mutual working agreement, regarding the settlement of future labor differences, which, it is expected, will eliminate any question of strikes on that road, as far as train operation is concerned; and a statement has been issued by the company, explaining what has been done, substantially as follows:

This agreement is the outcome of a series of meetings between representatives of the company and of the engine and train service employees, which began in Philadelphia on December 21 and terminated at Pittsburgh on the 29th. Both sides are ready to apply the new principles with the beginning of the new year.

The classes of employees who, through their accredited representatives, have joined with the management in this matter are the enginemen, conductors, firemen, hostlers, trainmen and switch-tenders. As a medium to carry out the purposes of peaceful settlement there has been established the "Joint Reviewing Committee of the Pennsylvania Railroad System" for the settlement of all controversial questions affecting the engine and train service men. Through this committee, the employees involved will, for the first time in the history of this railroad, have equal voice and vote with the management, as the committee will constitute a court of review involving grievances, rules and working conditions, including discipline.

The joint reviewing committee will be composed, on behalf of the management, of two representatives from each of the four "regions" of the system, and, on behalf of the employees, of the general chairmen of the men in the engine and train services. The vote of all members, whether representatives of the management or of the employees, will be of equal power and not less than a two-thirds vote will be necessary to reach a decision upon any question presented.

In all matters, except individual discipline cases, the full committee will vote, and its decisions will constitute precedents, which will be binding equally with respect to similar existing or future cases, upon the management and the employees in all four regions of the system uniformly.

Discipline cases will be handled somewhat differently, as they involve a personal element which must be accorded recognition. It has, therefore, been decided that when such a case comes before the joint reviewing committee, the two representatives of the management in the region in which the case arises, together with the representatives of the employee involved, shall not sit as members of the committee, during consideration of that particular case, but shall act as counsel for the presentation of their respective claims. The remaining members will hear the case and determine the matter at issue. This will insure expeditious handling and fair judgment upon all discipline cases.

The work of the joint reviewing committee will be supplemented by an extension of and improvement upon the methods of handling differences and grievances which were in effect prior to the war. Each division superintendent will have a meeting once a month with the local chairmen of the engine and train service employees under his jurisdiction, at which either side may present matters for consideration. Each general superintendent will have a monthly meeting with the general chairmen, and the general manager of each region will also hold monthly meetings with the general chairmen.

Appeals may be taken in the order named, and appeals from the decision of a general manager will be taken to the joint reviewing committee of the system. Thus, in the final determination of any matter, the employees, through their representation upon the joint reviewing committee, will have equal power with the officers in determining the issue. In this manner, the employees will participate in each step in decisions affecting their personal welfare and the conditions under which they work.

The joint reviewing committee will meet monthly in order that all pending matters may be promptly determined.

For the purpose of definitely establishing decisions and interpretations of committees upon the whole of the company's lines a provision has been adopted to the effect that whenever an agreement is reached regarding any particular controversy, between the representatives of the management and men—whether at a superintendent's meeting, a general superintendent's meeting, or a general manager's meeting—the settlement agreed upon will at once be placed in effect; but its terms will be immediately reported to the joint reviewing committee. The joint reviewing committee, in its turn, will at its earliest convenience, either ratify the ruling as adopted, or modify it as may be thought best: and the principles so established will then become binding upon the management and employees in all regions, and will govern all existing and future cases of a similar nature.

"The management feels justified in expressing the conclusion that the understanding reached should not only make future strikes wholly unnecessary, but should obviate even the necessity for ever taking a strike vote among the engine and train service employees of this railroad, if both sides live up to the friendly spirit in which the understanding has been established."