THE OPERATION OF LOCOMOTIVES IN SERVICE ON THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

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The author writes an interesting account of the manner of operating the electric locomotives on the C., M. & St. P. Ry., going into considerable detail concerning the actual handling of the trains. The article is written in such a manner that it will be especially interesting to the operating man. The results of regeneration are stated briefly; and in a subsequent issue we hope to deal at greater length with this phase of the installation.—Editor.

Electrical operation between Deer Lodge and Three Forks on the Chicago, Milwaukee & St. Paul Railway was commenced early in December 1915 and the last steam engine was removed from regular service in July 1916. In the 9 months ending Sept. 1, 1916 there has been a gradual change from steam to electric power and a period of about a month and a half of complete electric operation of the entire Rocky Mountain Division.

The Rocky Mountain Division extends from Deer Lodge, Mont., to Harlowton, Mont., a distance of 226 miles. It is divided into two subdivisions, familiarly known as the West End and the East End. The West End extends from Deer Lodge to Three Forks and the East End from Three Forks to Harlowton. The shops are located at Deer Lodge and the division headquarters at Three Forks. From the latter point the dispatching of the trains is handled. Engine crews on both freight and passenger trains change there and train crews on freight trains only.

The profile and location of substations is shown in Fig. 1. The line is single track throughout, passing tracks being located at each station, the distance between them varying from 1.3 to 9.7 miles, the average being 5 miles. In addition to the heavy grades there are many sharp curves, particularily in the mountains, 10 degrees being the maximum. Automatic block signals are in use through the mountain sections now and are being installed over the entire division. There are several tunnels, of which Pipestone Pass Tunnel, 2580 ft, is the longest one. This is near Donald, the summit of the Rocky Mountains and the Continental Divide. As will be noted from the profile there are all kinds of grades both as to length and magnitude, so that the locomotives have been tried out under almost all conditions of service to be met with anywhere on main trunk lines.

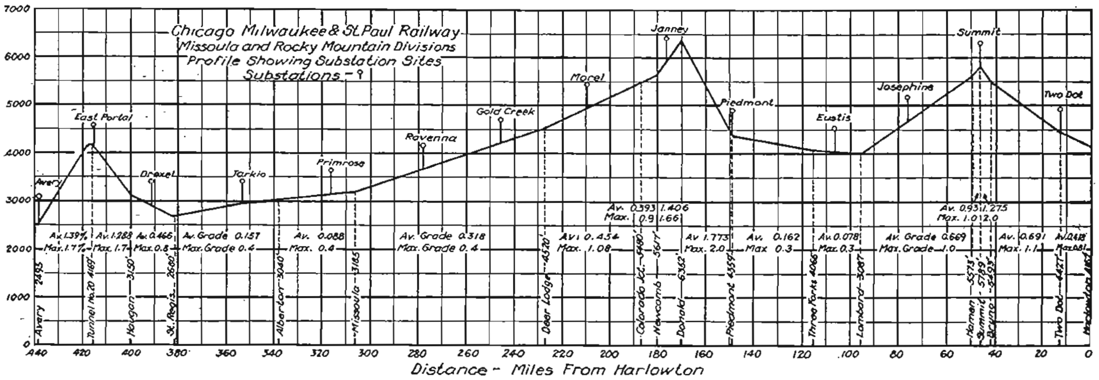

Fig. 1. Profile of Electric Zone

The climatic conditions that have been met are also severe. Last winter there were several weeks of weather when the thermometer was 20 deg. F. to 30 deg. F. below zero continuously, the coldest on the section then operating electrically being about 45 deg. F. below. There was also considerable wind but only about 2 feet of snow at any time, which however was of the extremely fine dry variety. This summer the weather has been very hot and dusty so that really

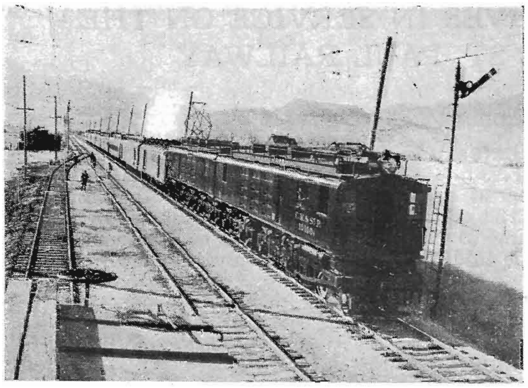

Fig. 2. Passenger Locomotive and Standard Through Passenger Train

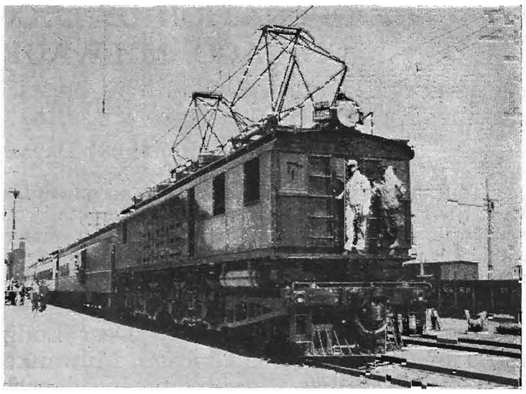

Fig. 3. Passenger Locomotive and Local Passenger Train

the only condition these locomotives have not faced has been a heavy fall of wet snow. From their performance in other respects there is every reason to expect that they will prove entirely successful in heavy snow.

The pictures, Figs. 2 to 7 inclusive, show some of the types of locomotives used on this division, both steam and electric. The steam locomotives used were practically all coal burning, coal being obtainable at several places near the division. The type of locomotive used for passenger service is shown in Figs. 5 and 6. Fig. 5 is an oil burner, these being occasionally used on passenger runs and identical in all other respects with the coal burners. The locomotives used for freight service were mostly heavy engines of the Mikado Type of Mallets (Fig. 7).

It is the intention of the writer to describe in detail how the electric locomotives are used to handle the trains and point out from this their superiority over the steam locomotives they have superseded, and, also, in a general way some of the results that have been attained in traffic handling. Inasmuch as freight traffic forms the greater percentage of the business and as in many respects more care is required in handling heavy freight than passenger trains this subject will be taken up first.

Freight Service

The freight traffic on this division consists mostly of loaded cars eastbound and about equal numbers of loads and empties west bound. The cars employed are of all kinds from different roads, of different capacities and with different air brake equipments so that the problem of handling the trains smoothly and quickly is exceedingly difficult, much greater care being required than on roads handling ore and coal trains of greater

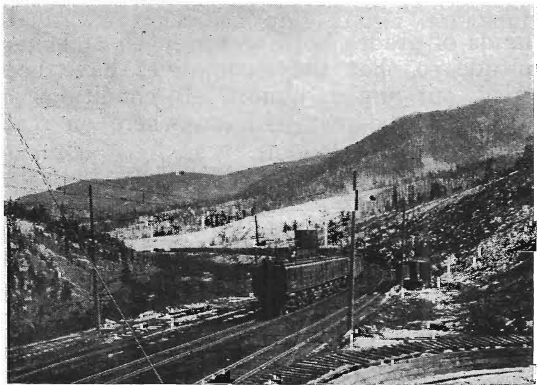

Fig. 4. Freight Locomotive and Westbound Train at Donald

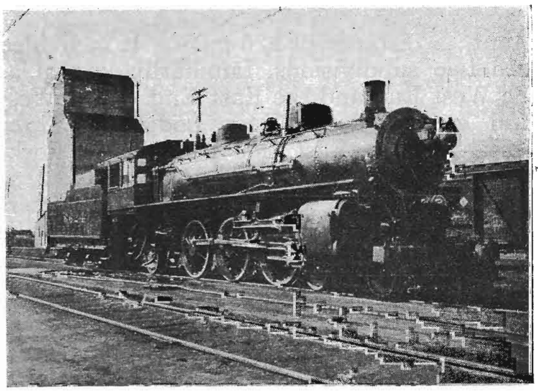

Fig. 5. Type of Passenger Locomotive Used During Steam Operation

total weight, but with cars almost entirely all steel and of nearly uniform size. The fundamental requirement which applies first, last and all the time is to properly control the slack action. Everybody is probably aware that the couplers in a freight car are not rigidly fastened to it but are connected through a friction or spring arrangement or both, which means that there is considerable stretch in them when transmitting a large drawbar pull. For practical purposes this may be taken as about 1 foot per car so that with a train of 80 cars, the locomotive would move about 80 feet before the caboose started. Little imagination is required to picture the shock to the rear cars if the locomotive is started suddenly, or especially if stopped suddenly after having the drawbar springs compressed (drawbars fully extended) while exerting the tractive effort necessary to pull the train. This condition requires that torque be developed by the locomotive very gradually while the train is first starting, which requires a large number of steps on the controller. These locomotives are excellent in that respect, the first step giving only about 17500 lb. tractive effort (61 lb. per ton of locomotive weight) and successive ones about the same increment.

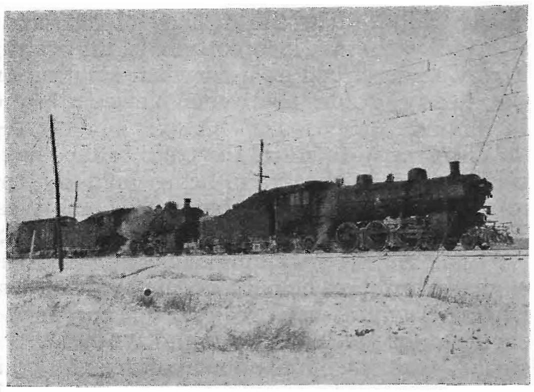

Fig. 6. Double Heading Passenger Train out of Three Forks During 20 deg. F. Weather

Inasmuch as the air brakes play an important part in the handling of the trains, a very brief description of the locomotive equipment may be of value in helping to make clear what follows. This equipment is the Westinghouse No. 14 EL, being similar to the No. 6 ET equipments used extensively on steam locomotives. It has two interconnected operating valves, one controlling the brakes both on the train and the locomotive and the other controlling the locomotive brakes only. This latter is known as the independent brake valve and permits applying or releasing the locomotive brakes regardless of the train brakes.

The operation of these locomotives can best be appreciated by following in detail the movement of a freight train from Deer Lodge to Harlowton.

Trains of about 3000 to 3500 tons trailing are taken out of Deer Lodge eastbound by one locomotive. The trains are made up in the yard, and brakes, etc., inspected before the locomotive is coupled on. As soon as the locomotive has been coupled on, the brake pipe is charged from the locomotive and then the brakes are applied and released once, an inspection being made by the train crew to see that they apply and release properly on all cars. As soon as this has been done the locomotive is started. As shown above the starting must be very gradual at first and the controller is usually brought on and off the first notch two or three times until the slack has been taken out of the forward end of the train. It is then brought on notch by notch gradually so that the locomotive is kept moving very slowly until the distance covered equals the amount of slack in the train, after which the rate of acceleration may be increased as desired consistent with the wheel slipping point of the locomotive. The above should not be interpreted to mean that the first notch gives too much tractive effort, for it gives only enough to just start the locomotive itself; but if the controller should be left on the first notch from the beginning the

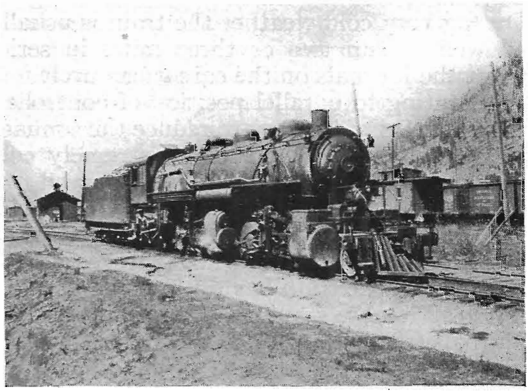

Fig. 7. Type of Mallet Locomotive Used for Freight Service

locomotive would accelerate enough so that the cars a short distance back in the train would be started with a bad shock. This may seem to be a fairly simple operation and so it is in ordinary weather, but the first starting of a train in −10 deg. F. weather and colder is not accomplished easily and usually requires two or three attempts and a thorough sanding of the tract, particularly if the train has been standing some time. The train friction under these conditions is exceedingly high due to the congealed oil on the journals and the locomotive must sometimes be moved back and forth in order to start the train. When finally started it requires a long time to accelerate to the series position of the controller, which demands ample rheostat capacity as well as carefully distributed steps, both of which these locomotives possess to a remarkable degree. During very cold weather the train is usually allowed to run two or three miles in series to let the journals on the cars warm up before accelerating to parallel position of controller. Of course it is necessary to reduce the tonnage of the trains handled in this extremely cold weather (−10 deg. F. and below) and the reduction varies from 10 to 25 per cent or even more under the most severe conditions. The friction drops off to a fairly reasonable value when the train has run a few miles, but if it is allowed to stand any length of time, the journals freeze up again and starting becomes just as difficult as at first. This difficulty is also increased due to the rail being frosty or covered with snow, thus making the locomotive slip its wheels easily.

After the locomotive has been accelerated to full parallel position it is allowed to run there until the current drops to about 150 amperes per motor when the controller can be brought to the last notch, which shunts the motor fields about 50 per cent and gives about 5 m.p.h. increase in speed. This can be done with train weights as high as 2800 tons by taking advantage of one or two nearly level stretches of track.

The first place which might be called a regular stop for freight trains is the Butte Freight Yard. This place is not shown on the profile but is between Colorado Junction and Newcomb and is near the beginning of the mountain grade. There are usually enough cars to be set out here so that the train is reduced to about 3000 tons or less. A second or helper locomotive is cut into the train at this point. The general practise under steam operation was to put the helper engine at the rear of the train and electric operation was started the same way, but after considerable experimenting it was found that the best place to locate the helper locomotive was at about the middle of the train so that each locomotive would handle approximately its own trailing tonnage. It was originally the intention to put the helper at the head end of the train when descending grades and operate both locomotives in multiple unit but it was found to be entirely practical to leave the helper in the middle of the train and regenerate with both locomotives.

After the helper has been cut in, the air brakes are applied and released once, each car being inspected to see that they are operating properly. When this has been done the train is ready to start. The start out of Butte Yard is easy because the grade is not heavy and there are two locomotives in the train, but as the method employed in starting with two locomotives is interesting it will be described as used when starting on the heavy grades between Newcomb and Piedmont.

When ready to start, the train brakes have been released, the train being held by the independent brakes on the two locomotives. The engineer on the leading locomotive "Whistles off" (two long whistles) and the engineer on the helper locomotive answers with the same if he is ready. As soon as the engineer on the leading locomotive hears the signal from the helper locomotive, the controller is brought on to the 1st or 2nd notch and the independent brakes on the locomotive released. This amount of power applied keeps the locomotive from starting back against the train. As soon as the brakes release the controller is brought on slowly until the train starts or as near the wheel slipping point as advisable to go. This stretches all the slack in the train as far back as the helper locomotive. The engineer on the helper locomotive usually watches the drawbar of the car forward of his locomotive closely and as soon as this stretches out, brings the controller to the 1st or 2nd notch and releases the independent brakes. As soon as they have released he brings the controller out slowly and carefully until either the train starts or he has reached as close to the wheel slipping point as desirable to go. When the train starts both engineers watch their ammeters and accelerate as close to the wheel slipping point as desirable until they have reached the full parallel position.

If however, the train does not start in what the engineer on the leading locomotive considers a reasonable time, he notches back the controller very slowly and allows the train to move back very gradually against the helper locomotive. This is a signal to the helper locomotive to be ready to start and as soon as the jolt of the train bunching up is felt, the leading engineer again attempts to start as before. In cases where several attempts are made to start, this "rolling back" operation is usually repeated with increasing severity so that there may be no doubt on the part of the helper locomotive engineer as to what is required. If the latter sees the train dropping back against him as shown by the drawbar of the car ahead he holds himself in readiness to assist in starting by pulling the controller on to the 1st or 2nd notch and as the slack is pulled out of the car ahead, brings it out further.

As noted before, trains are very hard to start in severe winter weather and this difficulty is greatly increased on a heavy grade. The locomotives if overloaded, frequently slip their wheels when starting and this necessitates beginning over again. It is under these conditions that carefully laid out rheostat steps and ample rheostat capacity are of the greatest advantage. With these locomotives it is possible to accelerate at the ordinary wheel slipping current and consume as much as 20 minutes in going from off to full series position without heating the rheostats to a dangerous temperature and no trouble has been experienced from this cause.

If the engineer on the leading locomotive desires to stop he notches his controller off very slowly, the train slowing down meantime. This is shown on the helper locomotive by the needles of the ammeters going higher on their scales. The helper locomotive engineer observes this and shuts off the controller slowly keeping the current at a slightly lower value than that obtained while running. This operation he continues until the train comes to rest when he sets the independent brakes and shuts off the controller. The engineer on the leading locomotive does likewise and sometimes sets the train brakes to assist in stopping. This process of stopping a train requires just as much or more care than starting and the control on the locomotives must be arranged so that the same rheostat steps are obtained in turning off the controller as in turning on.

All freight trains are required to stop at or near the summit of the Rockies (Donald on the profile) and make another test of the air brakes. This is made by making a light reduction in the brake pipe pressure at the locomotive and this shows on a gauge in the caboose. When noted, a further reduction is made by means of the conductors valve in the caboose which shows on the engineers gauge. This insures that the brake pipe is continuous throughout the train. At the same time a stationary test of the regeneration on the locomotives is also made.

At this time retainers are also put into service or as commonly expressed "turned up" on some of the cars. Inasmuch as there has been considerable misunderstanding relative to the use of retainers on these trains together with regenerative braking, a description of their purpose will be given to make this matter clear. All cars are equipped with these retainers but their use is confined to descending mountain grades. The retainer is simply a valve connected in the exhaust pipe from the brake cylinder of the car. A cutout cock also forms part of the retainer which with its handle down, "turned down," allows the air from the brake cylinder to exhaust freely to atmosphere whenever the brakes are released. With the valve handle turned upward 90 deg. or, "turned up," the air from the brake cylinder, when the brake pipe is recharged, passes through the retaining valve proper which allows it to exhaust to atmosphere until the pressure in the brake cylinder has dropped to 15 lb. The valve then closes and keeps this remaining pressure in the brake cylinder. This pressure of course decreases due to leaks in the cylinder and piping so that under ordinary condition of the equipment the air will have leaked off entirely in from 7 to 15 minutes after the retaining valve has closed. It will be seen from the above that this arrangement keeps the brakes applied to a certain extent for some time after the engineer has started to recharge the brake pipe. This prevents the train speeding up too much during the time required to recharge the brake pipe between successive applications of the brakes.

During steam operation when the descent was made entirely with the air brakes, retainers were "turned up" on every car in the train so that the brakes were continuously applied during the descent. When used in connection with the electric locomotives retainers are "turned up" on 50 per cent of the cars at the head end of the train if consisting of loaded cars and on 40 per cent if empties. They do not in any manner assist the regeneration in holding the train except for the first few minutes after an air brake application has been made. The only reason for using them is to assist in controlling the slack action of the train in case a stop has to be made during the descent. After a stop has been made and the brakes released the rear portion of the train runs down against the head portion and tends to force this down against the locomotive. These retainers, however, hold back this action and allow the train to roll down against the locomotive slowly as they gradually leak off. In one case that the writer is personally familiar with where retainers were not used the train ran down against the locomotive with sufficient force to move it ahead nearly 10 feet with its brakes applied. This was while descending the grade between Donald and Piedmont. On the lesser grade between Donald and Newcomb, this action is considerably less. On the grades either way from Summit, (now called Loweth), retainers are not used.

If the train was stopped before it reached the summit of the grade for the above tests, it is started up and as the leading locomotive passes over the summit and begins to descend, the controller which regulates the regenerative braking is brought on gradually, leaving the main controller in the full parallel position, and the locomotive begins to regenerate. This bunches the train slack gradually as car after car starts down the grade and when the engineer on the helper locomotive sees the slack crowd back against his locomotive he too brings on the braking controller. The helper locomotive is supposed to hold back only enough so that the leading locomotive can readily control the speed of the train during the descent. The speed down from Donald to Piedmont varies from 18 to 25 m.p.h. depending on the weight of train. There are several places where it is necessary to run at the lower speed and the trains are slowed down by means of the regenerative braking. The variable speed feature of these locomotives, while regenerating, is one of their greatest advantages and will be discussed more fully later.

Should it be necessary to stop while descending the grade the engineer on the leading locomotive applies the air brakes on the train, keeping the independent brakes released and gradually shuts off the braking controller as the speed decreases. When regeneration has ceased he shuts off the main controller (to prevent motoring) and applies the train brakes further for the desired stop. The locomotive brakes are allowed to come on after regeneration has ceased. About the same procedure is followed on the helper locomotive. After being stopped the train is held by the independent brakes on the leading locomotive only, the train brakes being released.

When starting out again from such a stop the engineer on the leading locomotive releases the independent brakes and starts the train moving gradually, sometimes using power to do this. Considerable care is required in doing this not to allow the locomotive to start too fast or there will be enough shock near the middle of the train to pull out a drawbar. This is another example of the action of the train slack. The train is allowed to speed up to about 19 m.p.h. when a light application of the train brakes is made, the main controller is notched out quickly to full parallel position and regeneration commenced by means of the braking controller. As soon as regeneration begins to take effect the train brakes are released. Brakes are kept off the locomotive during this procedure. This application of the train brakes is a signal to the engineer on the helper locomotive who also commences to regenerate.

The helper locomotive is usually taken with the train from Butte Yard to Piedmont. Occasionally it becomes necessary to cut off the helper at Donald (the summit of the grade) and the leading locomotive takes the train down alone. One locomotive can control about 2400 tons on this grade by regenerative braking and with heavier trains the train brakes are applied occasionally to assist in controlling the speed.

The helper locomotive is cut out at Piedmont and the train proceeds on with one locomotive, the run being down grade to Lombard. Usually one half the locomotive is shut down entirely on this stretch.

Crews are changed at Three Forks, this requiring from ten to thirty minutes, although sometimes the trains are held here longer depending on other train movements. Under steam operation a roundhouse was maintained here for the engines and a force was also kept to inspect the brake equipment on all cars passing through, this inspection requiring about 2 or 3 hours. This has been entirely discontinued with electric operation, the regenerative braking feature having eliminated the necessity for repairs to the brake equipment. The force has been replaced by one electrician who examines and changes pantograph shoes when necessary and furnishes such supplies as the engineers may require.

No more significant fact could be cited of the results of electrification, particularly when coupled with regeneration, than is supplied by the sight of this empty and deserted roundhouse and a yard once busy enough to require the continuous services of a switch engine, now unused except for few cars handled by the way freight trains.

The trains taken east out of Three Forks are usually not over 2500 tons and are entirely handled by one locomotive. The grade from Lombard to Loweth is the longest one on the division but there are enough places where it lets up so that the locomotives can make use of the field shunting position of the controller and make good time. This field shunting feature adds greatly to the speed control of the locomotive without increasing the heating of the motors objectionably and saves a great deal of time on the lesser grades.

The descent from Loweth to Harlowton is made at considerably higher speed than that from Donald to Piedmont as soon as a very short grade just east of Loweth has been passed. The trains are run between 25 and 30 m.p.h. (this being the running speed limit of the freight locomotives). Usually one half the locomotive is shut down entirely, the other being sufficient to hold the trains by regeneration. In commencing regeneration it is not necessary to apply the train brakes first, as the slack action on these lesser grades does not require it. Also no retainers are used.

It is on these lesser grades that there is secured the greatest advantage of the variable speed form of regeneration used on these direct current motor locomotives. The speed may be controlled over nearly a two to one ratio (17 to 30 m.p.h.) efficiently and without interruption of the braking effort. Very material improvements in running time are thus made by adjusting the speed to the maximum permissible by grade curvature and train weight. This variable speed characteristic is inherent in direct-current motors without any additions to the equipment over that required for the minimum or full load speed.

The conditions and results so far described with regeneration have assumed the parallel connections of the traction motors, but it is also possible to regenerate with series connections over a range from about 9 to 17 m.p.h. This is occasionally used when one train is following another in the same block and it is desired to run slowly to let the first one get farther ahead or when track repairs are being made.

At Harlowton the trains are inspected before being taken on east. The locomotives are also looked over but nothing is done to them unless trouble has been experienced on the road.

The west bound trains from Harlowton are 2500 tons or less and are taken over the short heavy grade between Bruno and Loweth in two sections so that no helper is required. A helper locomotive is taken at Piedmont and very often shut down entirely while descending from Donald to Butte as one locomotive can easily handle 2500 to 2800 tons on this 1.66 per cent grade, particularly when the train friction is high due to many empty cars. Regeneration is usually used on one half of the locomotive only between Butte Yard and Deer Lodge this 0.6 per cent grade requiring but very little braking effort to control the train speed. Freight trains make 25 to 30 m.p.h. through this section, slowing down where necessary for curves, mostly by means of regeneration.

Passenger Service

The passenger train service on this division consists of two through and one local train each way each day. The cars used are all steel and are considerably heavier than the majority of steel passenger equipment. The standard through trains consist of nine cars weighing approximately 650 tons (see Fig. 2). One locomotive handles as many as 12 cars or approximately 875 tons eastbound over the entire division. Westbound, 10 cars or 725 tons are handled and with heavier trains a helper is used from Piedmont to Donald only. This has made a material reduction in the number of engine crews required, as during steam operation eastbound trains were double headed out of Deer Lodge over the entire division when consisting of 10 cars or over. This necessitated considerable double heading when westbound in order to return the locomotives to the proper terminals. All through steam trains had a helper from Butte to Donald eastbound and from Piedmont to Donald westbound. With this helper the speed up the 1.66 per cent grade between Newcomb and Donald was about 21 m.p.h. for a train of 8 cars and on the 2 per cent grade between Piedmont and Donald about 18 m.p.h. The electric locomotives make considerably faster time, the speeds being about 28 and 25 m.p.h. for the above sections and approximately the same speeds are made with heavier trains. The schedule running time between Deer Lodge and Harlowton is approximately 8 hrs. and has not been changed since the electric locomotives were put in service, but has been redistributed slightly to take advantage of the higher speeds now made up the grades and thus allow the trains to be handled at a more uniform speed. The electric locomotives are able to make up approximately 1½ hours over the scheduled time between Deer Lodge and Harlowton. This is of great advantage in maintaining good service as delays due to the physical conditions of the country passed through are common and unavoidable. This ability to make up time is due not only to faster speeds on grades but also to the elimination of stops for water and to take on and cut off helpers. Helper service over the short stretch of heavy grade near Loweth has also been eliminated as the electric locomotives are able to stand the overload occasioned by this short pull, lasting only 6 or 7 minutes.

In handling the trains considerable care is taken in starting to take the slack very gradually so that there will be no jolting of the train and in this respect the electric locomotives are much superior to steam. It is a noteworthy fact that there has never been a drawbar pulled by the electric passenger locomotives despite their much greater power, whereas this occasionally happened with steam engines especially when double heading. In commencing regeneration with the passenger locomotive it is not necessary to set the air brakes as in freight service, the train slack not being enough to require it. In descending either way from Donald it is customary to regenerate in series at about 20 to 25 m.p.h. most of the way on account of the curves. In all other places regeneration in parallel is used and the variable speed feature of these locomotives is especially noticeable and useful in passenger service. The speed range during parallel regeneration is from about 30 m.p.h. to 55 m.p.h. and this wide range has made it possible to use the electric brake for slowing on nearly all curves over the division in preference to using air brakes and has resulted not only in considerable power saving but in easier riding of the train.

The local passenger trains usually consist of 3 cars weighing approximately 210 tons. The locomotives used for these trains consist of one half of a standard passenger locomotive. See Fig. 3. These trains make a large number of flag stops in addition to 19 regular stops over the entire division. The running time is fast and this run was a hard one with steam engines, no helpers being used. The half locomotives used give good results and are able to make up considerable time due to their faster speeds on grades, the elimination of stops for water and their faster acceleration.

The passenger locomotives have proven very successful in operation particularly as regards riding characteristics. At speeds up to 65 m.p.h. the locomotives ride as smoothly as a coach, the rear end but slightly less so than the head end and there is absolutely no nosing on tangent track. The spring gears used on both freight and passenger locomotives practically eliminate the vibration usually noticeable with geared motors of large capacities.

The through passenger trains are all electric lighted, the head end system being used. On steam divisions this requires the running of a steam turbine and generator in the baggage car. On electric divisions the necessary power is supplied from the locomotive motor-generator set used for regenerative braking. The train batteries are charged while running on level track and on up grades, the lamps being fed from the batteries on such down grades as require both halves of the locomotive for regeneration. The system is a combined hand and automatic one and is taken care of by the fireman who also takes care of the oil fired boilers which are used to furnish steam for heating the train.

Mention has been made previously of the helper service which is used on the heavy grades between Newcomb and Piedmont and this is one place where the use of electric locomotives has had very noticeable results. Under steam operation, helpers from trains of all classes were run from Butte Yard to Donald and from Piedmont to Donald up the grades, sometimes descending the other side with the trains requiring four crews at Butte Yard and five crews at Piedmont. There was also a force at each place and sheds etc. to take care of the engines which were mostly of the Mallet or heavy Mikado types. The electric locomotives have eliminated the helper service for passenger trains except on very rare occasions out of Piedmont. Due to the fact that the electric locomotives do not require water, or fires cleaned, etc., it is possible to keep them in service more continuously and this has also permitted the elimination of the forces at both places for caring for locomotives. The locomotives are now taken care of by the enginemen in so far as oiling, etc., is concerned and after being in service as helpers for a week or ten days are exchanged with a road locomotive and sent into Deer Lodge for inspection. The number of helper crews has been reduced to 3, all being located in Piedmont, and only two electric locomotives are used in this service.

Helper service over this grade was eliminated entirely at one time by having the through trains reduce at Butte or Piedmont to the full tonnage for one locomotive, and increasing the train to full tonnage on the other side. A shuttle service was then operated between these points in order to handle the excess tonnage set out at these places. There were a number of advantages in this, such as the elimination of delays due to waiting for helpers, easier operation over the heavy grades due to less train weight and a lower peak load demand for power and higher load-factor. Only one locomotive was required for this service and two engine crews. However, the expense of the train crews and the objection to splitting up certain through freight trains led to its abandonment.

Instructions in operating the electric locomotives were given both by men riding on the locomotives and by a series of lectures and practical talks at one of the subdivision points by two traveling engineers of the division and three or four men from the General Electric Company factories. One of these latter was later taken off the road to give instruction at subdivision points as noted above. Two of the engineers were also on the road as instructors for about a month, at a time when the largest number of engineers and fireman were under instruction. All regular road instruction was discontinued about Sept. 1st, the steam engineers and firemen having picked up the operation of the electric locomotives very rapidly.

The power consumption of these locomotives including auxiliary apparatus is measured by a watthour meter in each half and is read by the fireman on leaving and arriving at each subdivision terminal and when regeneration is commenced and ended on descending grades. These readings are entered on a report which covers the performance of a locomotive for the day and is turned in daily. The meters are arranged to read backward while the locomotive is regenerating so that the meter always gives the net power consumed. While it is entirely beyond the scope of this article to go into a discussion of the power consumption, the following table may be of interest.

These percentages of power are made up from a number of different runs of through passenger trains with different engineers and different locomotives. It will be noted that the average for both directions is 14 per cent of the power used and does not include power saved in making slow downs etc.

There are a few points on other parts of the equipment not previously mentioned which the writer would like to bring out. The one probably of most interest is the pantograph. This is of the double pan sliding type, the pans being provided with copper strips to collect the current and to take the wear. Only one pantograph is used per locomotive, in ordinary weather this being able to collect the 800 to 1000 amperes required for one locomotive with absolutely no sparking and without overheating the frame. In cold frosty weather both pantographs are used in order to allow the head one to clear the frost, etc., off the wire. The pans are greased approximately every 100 miles at present, although in winter this distance has to be

TABLE SHOWING APPROXIMATE POWER SAVING ON THROUGH PASSENGER TRAINS DUE TO REGENERATION

Run	Direction	Power Used Between Stations in Per Cent	Power Regenerated on Heavy Grades in Per Cent of Power Used
Deer Lodge to Three Forks	East	100	25
Three Forks to Deer Lodge	West	100	7
Three Forks to Harlowton	East	100	11
Harlowton to Three Forks	West	100	9
Total	East	100	19
Total	West	100	8
Total	Both	100	14