OPERATING RESULTS FROM THE ELECTRIFICATION OF THE TRUNK LINE OF THE C., M. & ST. P. RY.*

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Railway officials and the engineering fraternity the world over have evinced great interest in the electrification of the Chicago, Milwaukee & St. Paul Railway and statements giving comparative results between steam and electrical operation will be subject to careful study. In an article in our issue of November 1916, Mr. C. A. Goodnow, Assistant to the President of the Chicago, Milwaukee & St. Paul Railway, gave a general summary of the advantages which have been secured by electrification, which constituted an unqualified endorsement of the project. While the data included in Mr. Beeuwkes' article cover a period of only three months each for the years 1915 and 1916, the information is given in such detail as to allow a very satisfactory comparison. In several cases the author has noted the fact that the data given are perhaps too favorable for steam operation. From the apparent willingness of the Railway Company to authorize the publication of operating data, it may be expected that after a full year of electrical operation figures will be published which will still further emphasize the superiority of electricity over steam for trunk lines railways.—Editor.

The first electric locomotives were placed in operation on the Rocky Mountain Division of the Chicago, Milwaukee & St. Paul Railway on December 9th, 1915, between Deer Lodge and Three Forks. In April 1916 electrical operation was extended to Harlowton on the east and early in 1917 the entire 440 miles was equipped for electrical operation.

The 440-mile electrified section is now divided into two operating divisions of which only one, the Rocky Mountain Division, has been running long enough to get reasonably

Fig. 1. Substation at East Portal showing Snow Conditions in the Bitter Root Mountains

Fig. 2. Substation and Bungalows at Avery, the Western End of the Present Electrification

reliable data concerning operation. I may say, however, that on the Missoula Division we have been handling 3000-ton trains as a standard through the worst winter months, and the entire operation is working out very successfully.

Although the figures for electric operation are very favorable, it should be remembered that they can hardly as yet be considered as final, because the steam figures represent the results of many years of effort and experience, while those for electricity are based on the use of apparatus that is entirely new in important respects, and on an operating experience of less than a year.

With regard to the operating organization, substation operating forces and line and locomotive maintenance forces have been added, but otherwise no change, except in the way of reduction as will be described, has been made in the original steam organization and personnel. This includes the engineers and their helpers on the locomotives.

The change from steam to complete electric operation was made in the course of a few months with remarkable facility, its rapidity being governed entirely by the rate at which the manufacturer was able to supply the electric locomotives. The instruction of the engineers was done by having four or five General Electric men on the ground who had assisted in testing the locomotives at the works and who were thoroughly familiar with the electrical details. These men spent all their time for some months riding the different locomotives and explaining their electrical operation to the engineers, this being done on trains in regular operation.

Harlowton is the eastern terminus of the Rocky Mountain Division and the station where electric operation begins. Here are located the usual roundhouse facilities, a portion of which has been partly reconstructed

* Paper read March 16, 1917, before the New York Railroad Club.

to accommodate the electric locomotives. Three Forks separates the division into the East and West sub-divisions, and was a former steam engine division point. Deer Lodge is the western terminus of the Rocky Mountain Division.

Under steam operation engines were changed at Deer Lodge, Three Forks and Harlowton; thus, a steam locomotive made about 113 continuous miles. At the end of this run it was put in the roundhouse or shop to have it cleaned, boilers washed, etc. and for any light repairs. All heavy repairs were made at Deer Lodge. This necessitated a large roundhouse and shop force at each of the three points mentioned. Freight trains were tied up in the yards and there were the other usual costly and vexatious delays. All train and engine crews changed at each of the through subdivision points mentioned except passenger train crews, who ran through from Deer Lodge to Harlowton. Under steam, the cabooses and many of the engines were assigned, which of course made it necessary to take the caboose from the train at each subdivision point.

With the introduction of electricity we were able to double what I may call the cruising radius of our locomotives. As far as the railroad is concerned we have eliminated Three Forks entirely. All locomotives run the entire 226 miles from Deer Lodge through to Harlowton with only a light inspection of bearings and pantographs at Three Forks. The shop and roundhouse are entirely closed down, seven or eight miles of tracks have been removed, and the comparatively large roundhouse force previously employed has been replaced by a single electrician. All locomotives and cabooses are pooled, the men being given suitable locker space to store their lanterns, flags, tools, etc. Through freight trains do not leave the main track and often are not switched at all. At Harlowton the engine is given a rough inspection and any light repairs made that are necessary. Detailed inspection and maintenance work is done at Deer Lodge.

The same change in operation has been effected on the Missoula Division, Avery to Deer Lodge; in this case Alberton being the steam engine division point which has been eliminated.

Comparison of Passenger Train Delays

Table I shows, for the Rocky Mountain Division, a comparison of passenger train delays for October, November and December under steam operation in 1915 and electric operation in 1916. These data are considered important not merely because they indicate the comparative reliability itself of service under the two systems, but because the item of reliability has such an important bearing on the general relative performance and economy.

The data are given for passenger service only, as freight records are not kept in such shape that such data can readily be derived from them.

The passenger service consists regularly of two heavy steel 8-car through trains each way per day, and one 3-car local each way between Butte and Harlowton.

In considering the data, two points should be borne in mind; first, that the schedule time of the through trains under electricity was reduced forty minutes from that under steam; second, that the table shows, for both systems, net minutes delay only; i.e., all delays or portions of delays that were made up do not appear.

Comparative data are shown for only three months, as complete electric passenger service only went into effect shortly before October. For some of the items listed, particularly an item of the nature of "Accidents and Derailments," this is entirely too short a period on which to base reliable comparisons, and these items are included merely to make the records complete.

It should also be borne in mind that during the months of electric operation the amount of freight business done was for one month 40 per cent and for three months 29 per cent greater than the corresponding months of steam operation, a circumstance which renders the electrical showing, as shown on the slide, all the more favorable.

It will be noted from Item 31 that the number of trains run under steam and electricity, respectively, is practically the same.

The first four items indicate, among other things, that the dispatcher is better able under electric operation to plan and predict train movements. This may be accounted for on the basis of less variation in speed, fewer number of trains for a given business (that is, freight trains), and fewer trains delayed. In any event, in these three corresponding months steam passenger trains waited for the right-of-way 1910 minutes as against 254 minutes for electric trains.

Item 5 is Extra Mail, Baggage and Express, meaning that the trains were delayed the time shown because it took longer to load or unload the baggage, mail or express than the time allotted.

Item 6, Extra Cars, means simply extra heavy trains. Delays on this account were only one ninth as great under electricity as under steam. Our electric engines will handle ten or eleven steel cars on the 2 per cent Piedmont grade very comfortably.

Item 7, Excess Time Switching Cars, is self-explanatory. The cars referred to are generally extra coaches or business cars.

Items 8 and 9, which are respectively Extra Stops for Passengers and Railway Crossings, are self-explanatory.

Item 10, Electric Block Signal at Danger is included for the sake of completeness. The original direct current signal system, as already stated, had to be changed to alternating current when we changed to electricity for operating, and the new signal system is not yet in final working order or completely installed.

Item 11, Slow Orders, has the usual significance.

TABLE I

ELECTRIFICATION DEPARTMENT

Passenger Train Delays under Steam Operation in 1915, and under Electrical Operation in 1916

Rocky Mountain Division Time in Minutes	October		November		December		Total	
	Steam	Electrical	Steam	Electrical	Steam	Electrical	Steam	Electrical
1. Blocked Behind Passenger					57		57	
2. Blocked behind freight	42	15	8		274	15	324	30
3. Meeting passenger	102	17	504	45	647	162	1253	224
4. Meeting freight	73		77		126		276	
5. Extra mail-baggage express			26		327	167	353	167
6. Extra cars	37	15	9		149	26	195	41
7. Excess time switching cars	48		99	20	93	98	240	118
8. Extra stops for passengers					25		25	
9. Railway crossing	26		5		167		198	
10. Electric block signal at danger			67		10	82	77	82
11. Slow orders	14				5		19	
12. Bad weather conditions			235		210		445	
13. Poor coal	—		36		80		116	
14. Hot bearings engine		112	58	14	21	515	79	641
15. Other conditions, engine	98	42	205	200	230	555	533	797
16. Hot bearings, car			54	40	65	95	119	135
17. Other conditions, Car	270	15	47	100	345	225	662	340
18. Accidents and derailments	1302	767	357	895	391	1425	2050	3087
19. Other causes, Note 1		618		394	177	128	177	1140
20. Total minutes delayed	2012	1601	1787	1708	3399	3493	7198	6802
21. Total number of trains delayed	24	17	49	24	84	40	157	81
22. Total number of trains making schedule time	121	118	98	105	81	84	300	307
23. Total number of trains making up time	43	51	33	50	21	62	97	163
24. Total time made up	885	1436	547	1691	378	1640	1810	4767
25. Due mechanical features, locomotive heaters		139		14		710		863
26. Due electrical features locomotive		25		100		45		170
27. Due overhead		335		90		108		533
28. Man failures with electrical apparatus		200						200
29. Total due electric operation		699		204		863		1766
30. Per cent electrical to total delays		43.6		11.9		24.9		26.0
31. Passenger train miles	39426	40169	41276	40549	38628	38519	119330	119237
32. Minutes delay per 100 train miles, total	5.1	3.99	4.35	4.22	8.70	9.05	6.03	5.70
33. Minutes delay per 100 train miles, electrical		1.74		.50		2.24		1.48

Note 1, Bad order trolley—failure of power—snow or rock obstructions—failure of gas at terminals, etc.

Item 12, Bad Weather Conditions. In speaking of bad weather conditions in our electrified territory we generally have in mind extremely low temperature, sometimes forty or fifty degrees below zero in places for days at a stretch, or the heavy snows which occur in the Bitter Root Mountains.

Under steam operation the cold weather conditions were at times very serious, resulting in entire temporary suspension of service, particularly freight on account of reduction of steaming capacity or the freezing up of locomotives. The electric locomotives on the contrary, as was to be expected, are not affected by the cold weather, and the contrast with steam operation is truly remarkable and a source of great gratification to our operating department. Instead of the capacity of the electric locomotive being reduced on account of the cold, it is increased on account of the lessened heating of the motors. It might have been expected that such low temperatures would result in many trolley and transmission troubles due to contraction of wires and cables, but the construction is particularly suited to such conditions and we now have but little trouble on this score.

The table shows 445 minutes delay to passenger steam engines, although during the cold weather many of the trains had to be run double-headed. We have never, under any conditions, required the use of more than one electric engine on any passenger train.

Item 13, Poor Coal. Electric operation is not influenced by this condition.

Item 14, Hot Bearings, Engine. Of the 555 minutes charged to electric operation in December, 70 are due to one case where a cellar pin came out of one of the bearings of the leading truck, so that the figures do not really represent average comparative results. We have had more trouble with electric motor bearings than we expect to have ultimately, as there has been some difficulty in obtaining proper lubricant and the packers have had to acquire new experience in handling the high speed bearings involved.

Fig. 3. 100,000-Volt Transmission Tower for Long Span

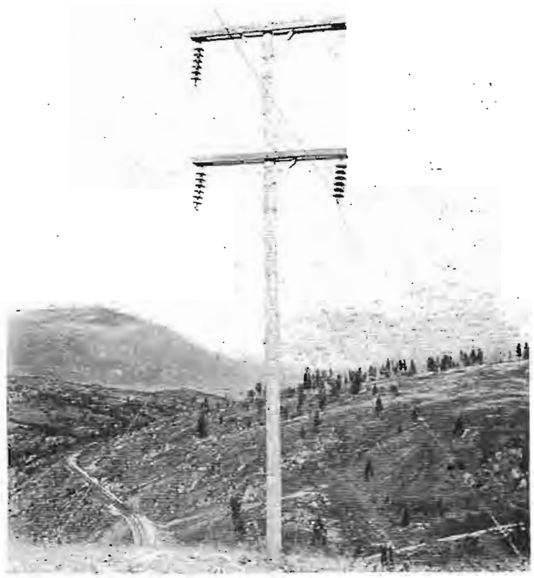


Fig. 4. Standard 100,000-Volt Wood Pole Transmission

Item 15. This includes miscellaneous conditions not included in the preceding items. In connection with the electric engines, much of the delay was due to difficulties with the flash boiler and parts used for train heating. A great deal of experimental work has been and is still being done on this apparatus, which is the only portion of the locomotives not as yet entirely successful. In Item 15 are also included time lost due to inattention on the part of round-house attendants, resulting in insufficient supply of oil or water for the heating apparatus, time lost on account of using freight locomotives for hauling passenger or milk trains and the like, or trouble with electrical or mechanical parts.

Item 16, Hot Bearings, Car. Self explanatory.

Item 17, Other Conditions, Car. On account of regenerative braking there has been a marked reduction in delays due to repairing brake rigging and changing shoes.

Item 18, Accidents and Derailments. These, of course, are accidents and derailments occurring to other trains and delaying the passenger trains. This item is very much higher for electricity than for steam, which would be expected, considering the longer trains, the newness of the electric operation, and the fact that the existing great shortage of freight cars has required keeping or putting in service equipment whose condition would ordinarily not warrant its use. The real facts, however, are, that these accidents and derailments occur so seldom that a much longer period than 3 months must be taken to arrive at any accurate comparative results.

Item 19, Other Causes. Other things being equal, this item would necessarily be higher for electricity than for steam, as it includes delays due to all troubles in the electric system exclusive of the locomotives. Of these electrical troubles most are due to the pantograph in some way fouling the overhead construction either because of the trolley wires or the track getting out of alignment, or one track rail being low. Failure of power, either on trolley or transmission side of sub-stations, except for the interval required to throw in an automatically opened circuit breaker, is practically negligible.

It will be noted from Item 21, that the minutes delay attributable to the electric system, outside of the locomotives, amounts to about 8 per cent of the whole.

In this connection it might be stated that the best organization of maintenance forces and means of transporting these forces to the location of troubles has not yet been determined upon and the percentage of delays due to trolley troubles is therefore considerably higher than we ultimately expect it to be. Also the troubles themselves should diminish, as not only were our poles set in all kinds of weather conditions, but also much new rail was laid and ballasting done during the process of electrification, and it will take some time before the poles and track get finally settled into permanent position.

Item 20, Total Minutes Delayed. It will be noted that the total minutes delayed is about the same for the two systems, but the number of trains delayed, Item 21, is reduced about 40 per cent under electricity. (Of the trains delayed under electricity about 85 per cent were delayed about the same length of time as the average steam train was delayed, the remaining 15 per cent suffered considerable delay mainly on account of accidents and derailments to other classes of trains.) Item 22 shows that about the same number of trains ran in schedule time under steam and electricity, while the number of trains making up time increased about 60 per cent and the time made up about 150 per cent under electricity.

Item 25, Due Mechanical Features of Locomotive; Item 26, Due Electrical Features; Item 27, Due Overhead (Meaning the electric system outside of the locomotives); and Item 28, Man-failures, give the delays due to electric operation in more or less detail as reported by the electrical master mechanic.

The mechanical features include mainly train heaters, as already referred to, bearings, pantographs and air system. Delays due to electrical features are comparatively slight, a rather surprising and gratifying fact considering the number of new features, such as the use of 3000 volts direct current and direct current regeneration, which are incorporated in the locomotive, and further, considering that only a year ago the engineers operating these locomotives were all driving steam engines.

Item 27, Due Overhead, has already been referred to. I might say in this connection that the double trolley wire construction as used by us has proved very successful, absolutely sparkless collection of current being obtained under all conditions of speed and amount of current. Items 29, Total Due Electric Operation, and Item 30, per cent Electrical to Total Delays, show that 26 per cent of the total delays were attributable to the electric system as a whole.

The general inference to be drawn from the data given is that the electric service is at least as reliable as the steam and bids fair to ultimately become considerably more reliable.

Comparison of Steam and Electric Locomotive Performance

Table II shows, for the Rocky Mountain Division, a comparison of locomotive performance for October, November and December under steam operation in 1915 and electric operation in 1916. It should be understood that the figures given, while sufficiently correct for comparative purposes, as they are taken from the same report forms, are not to be considered as strictly accurate when considered individually, the forms being those from which the data could most conveniently be obtained in the short time available.

Taking first the passenger data: As already described, passenger service in this division consists of two through trains each way daily and one local each way. The local ran between Deer Lodge and Harlowton during one part of these three months and between Butte and Harlowton during the remaining part. This fact, and the running of special trains, accounts for the slight variation in Train Miles of Item 1. It will be noted that the total miles under steam and electricity were almost exactly the same.

Item 2, Helper Engine Miles, increased under steam as the temperature decreased; but this service with its extra crew cost, switching delays, etc., has been eliminated under electricity. It should be noted that the figures given do not contain any allowance for return trips of helpers down the mountain.

Item 3, Number Engines. This is the number actually assigned to this service, both on the road and in shops, by the district master mechanic. The electric engines include five double units and two split locomotives and the number can probably be reduced when train heating apparatus is got into shape and minor electrical improvements completed, which matters have required more shopping than will ultimately be necessary. The number of steam engines, on the other hand, is a minimum, as freight engines in helper service were often used to help passenger trains, a fact which is not taken into account in the figures shown. Therefore, less than half as many electric as steam engines are required for the same service.

Item 4, Train Miles per Engine, is derived from the preceding figures, and on the basis of what has just been said, the figures are high for steam and low for electricity. Our record for an electric engine is 9052 miles, made in June 1916.

TABLE II

ELECTRIFICATION DEPARTMENT

Data on Operation under Steam in 1916, and under Electricity in 1916

Rocky Mountain Division	October		November		December		Total	
	Steam	Electrical	Steam	Electrical	Steam	Electrical	Steam	Electrical
PASSENGER								
1. Train or train engine miles	39426	40169	41276	40549	38628	38519	119330	119237
2. Helper engine miles	4738		7966		12048		24752	
3. Number engines	13	7	13	7	13	7	13	7
4. Train miles per engine	3040	5730	3180	5800	2970	5510	9190	17040
5. 1000 kw-hr. at power co's meters		1217	—	1109.5		1152		3478.5
6. K.w.h. per train mile		30.3		27.4		29.9		29.1
7. Coal, total tons	3380		4150		3730		11260	
8. Coal, lbs. per train mile	171		201		193		188	
FREIGHT								
9. 1000 ton miles	98512	125522	93228	130848	91122	107717	282862	364087
10. Train miles	60666	65400	58014	63299	58257	57311	176937	186010
11. Helper engine miles	16605	7022	20422	7544	19336	5591	56363	20157
12. Number engines	42	15	41	15	44	15	43	15
13. 1000 ton miles per engine	2405	8370	2270	8720	2070	7170	6745	24260
14.* Number subdivision trains	535	585	532	583	526	543	1584	1711
15.† Ton miles per train mile	1625	1920	1605	2070	1563	1880	1600	1960
16. Total time, hours	6094	5022	5946	5084	5785	4429	17825	14535
17. Minutes per 1000 ton miles	3.70	2.40	3.83	2.33	3.81	2.47	3.78	2.39
18. 1000 Kw-hr. at power co's meters		4696		5119		4528		14343
19. Kw-hr. per 1000 ton miles		37.4		39.1		42.0		39.4
20. Total Tons coal	12150		13670		13230		39050	
21. Lbs. coal per 1000 ton miles	247		294		291		276	

NOTE: * Subdivision train—one train over one subdivision; divide by 2 for trains over entire division.
† "Ton-miles per engine mile" equals tons per train with one electric engine and short helper service, or with one steam engine and longer helper service: In this connection consider Item 17.
Total regeneration over entire division, month of November, equals 11.3% of consumption at motors.
Passenger on 2% grade, Jan. 21-27, 1917—regeneration = 42.8% of consumption at motors.
Passenger on 1.66% grade, Jan. 21-27, 1917. Regeneration = 23.1% of consumption at motors.

Item 5, Thousands of Kilowatt-hours at Power Company's Meters, shows the actual electric energy purchased and chargeable against this service. Every electric engine is equipped with a kilowatt-hour meter, which on each trip is read at points of commencement of motoring and again at commencement of regeneration, thus giving a record of the engineer's performance as regards use of power. The figures shown in the table are the net energy read at the locomotive, increased by a suitable amount for line and substation losses. The efficiency of the system, Power Company's meters to locomotives, is running now at 67 to 70 per cent.

Items 6, kilowatt-hours per Train Mile, and Item 7, Coal, pounds per Train Mile, are self-explanatory. The coal figure is only approximately correct.

Considering the freight data: Item 1, Thousands of Ton Miles, shows an average increase during the months of electric operation of 28.8 per cent over that of steam; for November, the increase was 40 per cent. In this connection the superintendent of the division has stated that to handle the 1916 business with steam, double tracking would have been necessary. The latter would still, of course, have required extra motive power. Possibly, the superintendent did not intend that his statement should be taken literally. but in any event it is reasonable to assume that under the business conditions which existed during the electrical months, and the resulting congestion, the figures for steam would be too favorable.

Item 10, Train Miles. This is used in obtaining item 15 below.

Item 11, Helper Engine Miles. The figures show that for the same ton miles there would be over three times as many helper engine miles under steam as under electricity. No account is here taken of the return trips of helpers or their otherwise running light. This is a considerable item under steam, but is small for electricity.

Item 12, Number of Engines, is possibly a little high for steam on account of some of these engines being at times used in passenger helper service, as already explained. The number of electric engines given is the number purchased for this service and is considered sufficient. We are unfortunately obliged to use our judgment in this matter, as many of the locomotives purchased for the Missoula Division, not then under electrical operation, were available and used. Twenty-eight locomotives are now easily handling business for the two divisions.

Using the figures as they stand and deducting Item 13, Thousands of Ton Miles per Engine, we find that the electric engine handles about 3½ times as many ton miles per month as the steam engine, and from Item 17, Minutes per Thousands of Ton Miles, that the electric engine cuts 30 per cent from the time to do a given business, partly by faster running, partly by heavier trains.

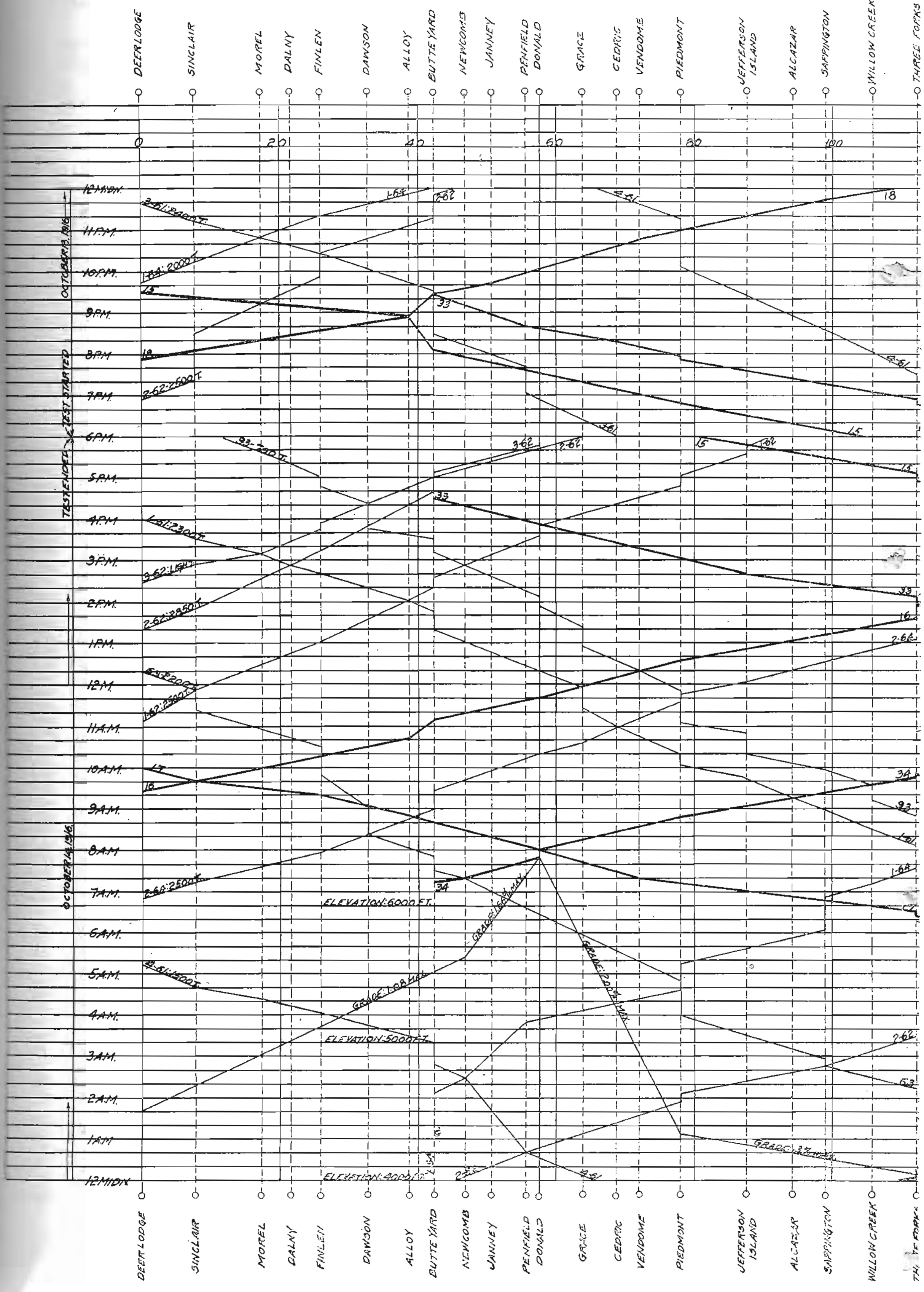
Item 14, Number Subdivision Trains, shows for the three months that there were an average number of division trains involved of 8.6 for steam and 9.3 for electricity.

Item 15, Ton Miles per Train Mile. This is about the same as tons per train, and 22 per cent greater for electricity than steam. The electric train, it might be considered at first glance, ought by comparison to be heavier, but it should be remembered that the steam train for a considerable part of the time has two locomotives on it. The tonnage of the through freight is greater than shown, the average figures being considerably lower on account of the comparatively light local freights being included.

Items 18 and 19, showing consumption of electric energy, are derived in the same manner as previously described for passenger service, and later in conjunction with items 20 and 21 give a comparison of relative amounts of coal and electricity used by us to handle a given business. Under present conditions we are paying for electricity on a kilowatt-hour basis, and it is costing considerably less than coal did.

As to the effects of regeneration on the power consumption, this varies more or less, but it will be noted that for the month of November, the amount of regenerated power measured at the locomotives was 11.3 per cent of the total power consumed at the motors. Some of this power goes over the trolley direct to locomotives which are motoring, and the rest goes through the substations, reversing the motor-generators and either flowing into the Power Company's transmission system or along the Railway Company's line to other substations.

The power-saving feature of regeneration, I may say, is not considered by us so important as the increased safety and ease with which trains are handled on the heavy mountain grades and the saving in wear and tear on brake shoes and equipment. So much has already been said by others about


DEER LODGE
SINCLAIR
MOREL
DALNY
FINLEN
DAWSON
ALLOY
BUTTE YARD
NEWCOMB
JANNEY
PENFIELD
DONALD
GRACE
CEDRIC
VENDOME
PIEDMONT
JEFFERSON ISLAND
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12 MIDN.
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1 A.M.
12 MIDN.
OCTOBER 13, 1916
TEST ENDED
TEST STARTED
OCTOBER 14, 1916
ELEVATION: 6000 FT.
ELEVATION: 5000 FT.
ELEVATION: 4000 FT.
GRADE: 1.08 MAX.
GRADE: 1.66 MAX.
GRADE: 2.0% MAX.
GRADE: .3% MAX.

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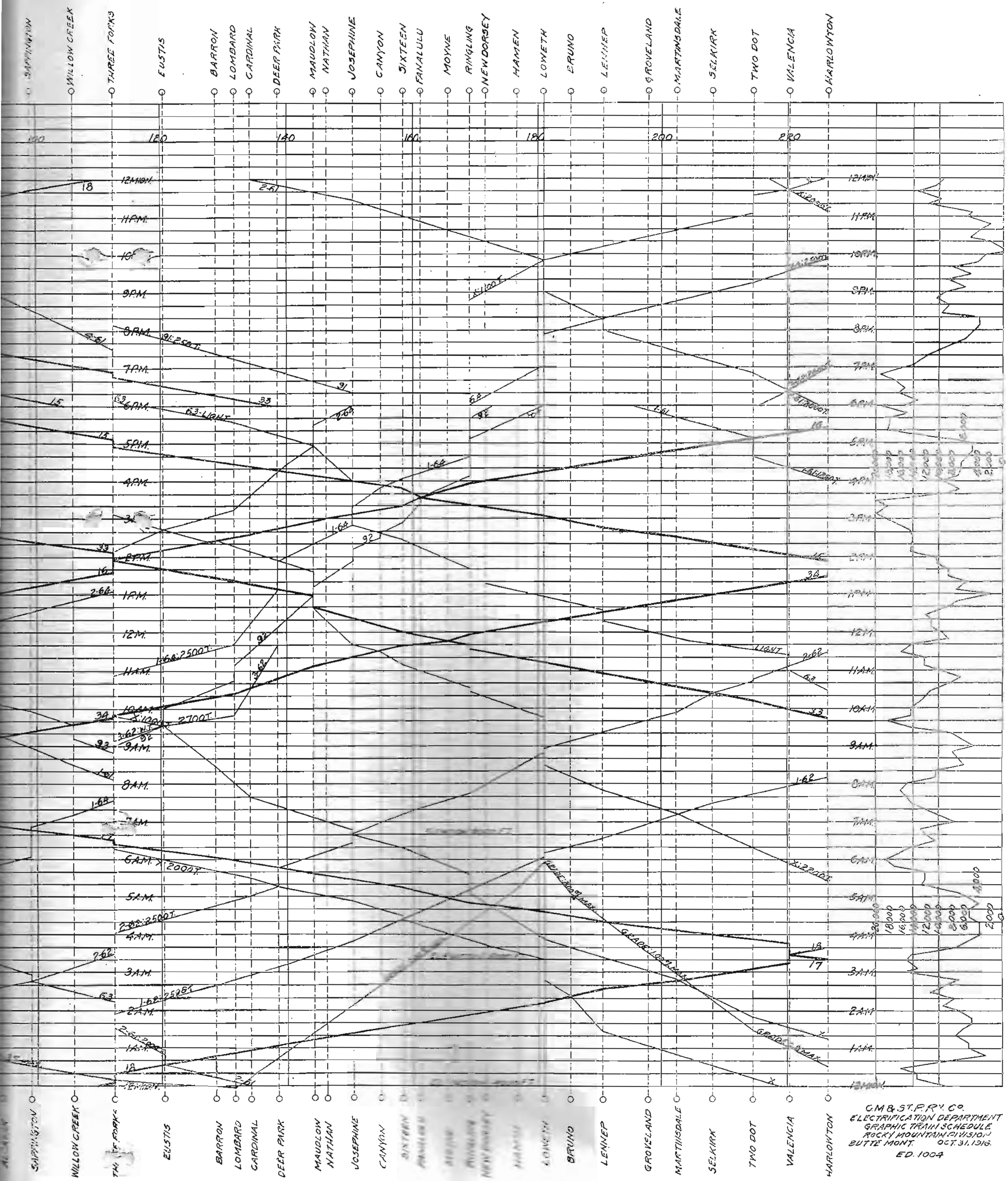

this feature of our installation that I will not go further into the matter here.

The Train Sheet is a graphic time-table for twenty-four hours of operation on the Harlowton-Deer Lodge Division. The horizontal scale shows the stations, many of them only passing track locations, in their proper relative positions, and the vertical scale the hours of the day. Each slanting line represents a train, the heavy lines being passenger trains and the light lines freight or work trains. This chart therefore gives an idea of the typical number of trains and the business done, for which the figures in the accompanying tables apply. It also shows the exact location of each train on the division for each moment of the day.

On the right of the train sheet is an electric load curve which shows at any moment the amount of electric power delivered to the system at any instant and the corresponding locations of the different trains. A profile along the lower side of the diagram shows the grade at each point on the line and is of interest in checking up the power demands as shown by the load curve.

For example, it is shown that the amount of power consumption varies from a maximum of 20,000 kw. at 3.08 p.m. to a minimum of less than zero at 10.10 p.m., at which time the regenerative braking was taking place to a sufficient extent to supply all of the power losses on the railway system and actually return some power to the Power Company's supply system; how much we cannot tell, as the curve drawing meters do not register negative kilowatts.

Following is a synopsis of the conditions at 3.08 p.m. when the power demand was greatest. Locating the trains from right to left, we find:

1. No. 15, Through 8-car, steel, passenger, about 650 tons, west bound, just pulling up to the summit of the Belt Mountains on the 2 per cent grade, heavy motoring.
2. No. 92, Local Freight about 1000 tons, eastbound up the 1 per cent grade.
3. No. 16, Through 8-car steel passenger, about 650 tons, eastbound up the 1 per cent grade, light motoring.
4. 1/64 Through freight, 2500 tons, eastbound on a siding at Josephine.
5. 2/64 Through freight, 2500 tons, eastbound down the 0.3 per cent grade, light motoring.
6. Extra freight, westbound, 2200 tons, just pulling into Three Forks up the 0.3 per cent grade, light motoring.
7. No. 33 Local passenger, westbound, about 250 tons up the 2 per cent grade.
8. 1/62 Through freight, eastbound, 2500 tons up the 1.66 per cent grade.
9. No. 93, Local freight, westbound, 750 tons, just pulling into Butte yard, light motoring.
10. 2/62 Through freight, eastbound, 2850 tons up the 1.08 per cent grade.
11. 1/61 Through freight, westbound, 2300 tons down the 1.08 per cent grade, light regeneration.
12. 3/62 a light engine on the siding at Morel.

This gives us 10 trains moving, of which two are drawing heavy power, seven light power, and one returning a little power to the line.

Now let us examine conditions at 10.10 p.m.

1. Extra freight, eastbound, 1100 tons down the 1 per cent grade, light regeneration.
2. 2/61 Through freight, westbound, 2000 tons, down the 1 per cent grade, light regeneration.
3. 4/61 Through freight on a siding at Piedmont.
4. No. 18, Through 8-car steel passenger, eastbound, about 700 tons down the 2 per cent grade, heavy regeneration.
5. 3/61 Through freight, westbound, 2400 tons, down the 1.08 per cent grade, light regeneration.
6. 3/62 Through freight, eastbound, on siding at Finlen.
7. 1/64 Through freight, eastbound, 2000 tons up the 1.08 per cent grade, light motoring.

Thus we have five trains feeding power into the line and one taking power from the line, the net result being that the railroad actually gives power back to the Power Company.

Under the present conditions, we are running with a monthly load factor—ratio average load to maximum load—of about 40 per cent, but expect within a few months to have installed a so-called power indicating and limiting system, which will automatically indicate to the dispatcher the exact amount of power which the whole system is drawing at any instant and will automatically within certain limits hold the maximum down to a certain pre-determined amount, this with the object of keeping as low as possible the maximum amount of power which we have to contract for with the Power Company, and on basis of 60 per cent of which amount our minimum power bill is based.