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THE ELECTRICAL OPERATION OF THE BUTTE, ANACONDA & PACIFIC RAILWAY

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ABSTRACT OF PAPER

Of a total of ten notable instances of steam railway electrification in this country, the Butte, Anaconda & Pacific was the first if not the only one in which the prime cause for the change in motive power was an expected decrease in operating expenses sufficient to give immediately a satisfactory earning on the new investment of capital required for the improvement.

The preliminary investigations and estimates had indicated a probable annual saving amounting to about 17.5 per cent on the total investment, of which 11 per cent was expected to result from the partial substitution of electrical energy, costing about 0.552 cent per kw-hr. at the secondaries of the substation transformers, for coal of 12,250 B.t.u. calorific value and costing $4.25 per ton delivered. The remaining 6.5 per cent was expected from reduced cost of locomotive maintenance, engine house expense and enginemen's wages.

On this prospect, an expenditure of $1,201,000 was made in the electrification of 90 miles of track and in replacing 22 steam locomotives by 17 electric locomotive units which now operate about 80 per cent of the total locomotive-miles.

The actual results as indicated by the first six months of full electrical operation show the total net saving in operating expense to be at the rate of $242,209.12 per year or an earning of 20.02 per cent on the investment, of which the decrease in the cost of coal and power is 12.5 per cent.

Other savings are due to decreased cost of locomotive maintenance, engine house expenses, lubricants, supplies and trainmen's wages.

The average tons per train hauled by the electric locomotives has increased 33 per cent, the average time per trip decreased 30 per cent, the delays to traffic decreased 41 per cent, the number of trains decreased 25 per cent and the number of engine and train crews decreased 25 per cent.

THE AUTHOR wishes, at the outset, gratefully to acknowledge the assistance of Mr. H. A. Gallwey, general manager, Butte, Anaconda & Pacific Railway Company. It is through his coöperation and effort that the operating data given herein are made available. Information of this character has seldom been published and that it is here given to the public is a tribute to the broad-minded policy of the railway company.

The Butte, Anaconda & Pacific Railway was built in 1892 principally for the purpose of conveying the ore from the mines at Butte to the Washoe smelter which had been located at Anaconda, 26 miles west of Butte, where an abundant supply of water, so necessary in the reduction of the ore, was obtainable. The tracks connecting Butte and Anaconda constitute the main line, which is approximately 25.7 miles in length. As the mines are mostly around the top of Butte Hill and the shafts through which the ore is hoisted to the surface are scattered over a considerable area, yards were built at a convenient point on Butte Hill for the concentration of the cars containing the ore from these shafts, as well as to serve as a distribution point for the supplies to the mines, and a branch locally known as the Missoula

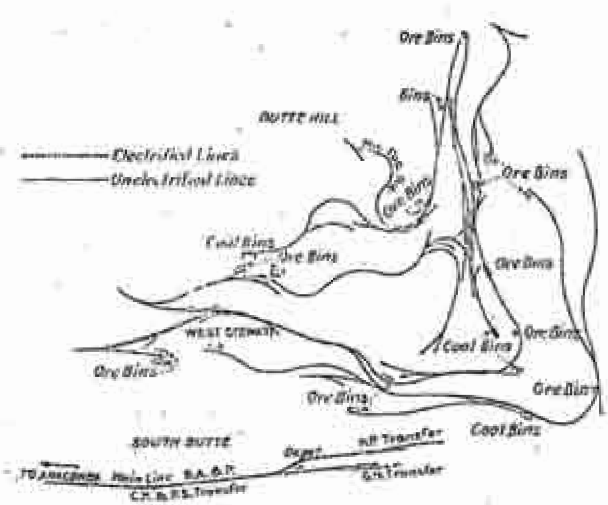


FIG. 2—OUTLINE MAP OF RAILWAY LINES ON BUTTE HILL FOR COLLECTION OF ORE AND DELIVERY OF SUPPLIES

Gulch line, Fig. 3, was built from these yards to connect with the main line at Rocker, where yards were also established.

Since the concentrator at the smelter is also on a hill at an elevation of approximately 340 ft. above the main line, it was advisable to establish another yard at East Anaconda from which to distribute the ore and other supplies to the different centers on Smelter Hill. The lines from these yards at East Anaconda to the smelter are known as the Smelter Hill lines, the longest branch of which is that leading to the concentrator, which is about $7\frac{1}{4}$ miles in length. Two spurs lead off from this main track, one to the stock bin yards and the other to the copper tracks, Fig. 4.

From the Butte Hill yards spur tracks radiate about Butte Hill to the shafts of the various mines and other points where supplies are to be delivered, Fig. 2. Bins for receiving ore as it is hoisted from the mines are located near each shaft and from these bins the ore is loaded into hopper-bottom steel ore cars of 50 tons capacity each, these loaded cars being delivered to the Butte Hill yards, where they are made up into trains and taken down to the Rocker yards, where they are made up into still larger trains and taken over the main line to East Anaconda yards. Here the trains are broken up to be transported in smaller units up Smelter Hill to the concentrator yards. Thus practically all of the ore cars are handled by five different engine crews between the ore bins at the mines and the receiving bins at the concentrator.

FIG. 3—MAP OF MISSOULA GULCH LINES, ROCKER TO BUTTE HILL YARDS, BUTTE, ANACONDA AND PACIFIC RAILWAY

A total of 27 steam locomotives was owned by the railway company, classified as follows:

Switching	7
Consolidation	8
Mastodon	10
Passenger	2

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

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

Three of the steam switching locomotives listed above were

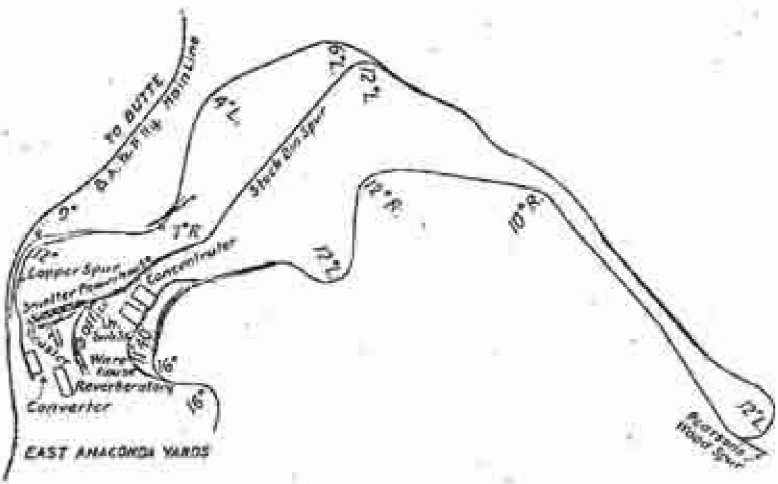


FIG. 4—MAP OF SMELTER HILL LINES, BUTTE, ANACONDA AND PACIFIC RAILWAY

used daily on Butte Hill collecting ore from and delivering supplies to the various mines from the Butte Hill yards.

The Georgetown extension to Southern Cross, 22.0 miles west of Anaconda, was underway at the time, but as it was expected that a few trains per week would take care of the traffic over this branch for some time, its electrification was not seriously considered in the original study.

It is fair to assume that a vital consideration leading to the electrification of this railroad was the rapid development and physical consolidation of a network of hydroelectric power plants in the territory tributary to the railroad.

A contract for the power for the operation of the road was made with the Great Falls Power Company, which, operating under the same management and in physical connection with the system of the Montana Power Company, was enabled to guarantee an ample supply of power at all times with exceptional freedom from interruptions to service, and at a reasonably low price.

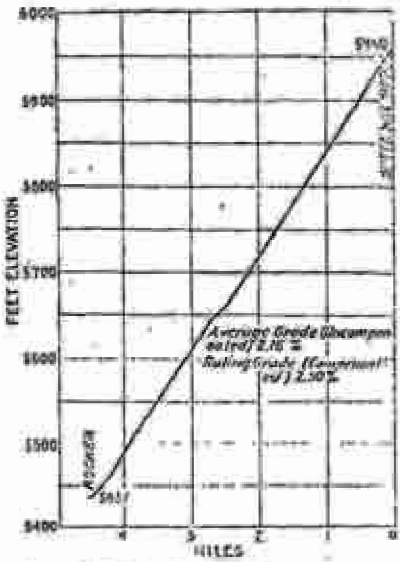


FIG. 5—CONDENSED PROFILE OF MISSOULA GULCH LINE

The tracks recommended to be electrified totaled approximately 90.5 miles, all of which are supplied with power from two substations, one being located in the Missouri River Power Company substation on Butte Hill and the other in the substation building on Smelter Hill, from which electrical power for operating the machinery there is distributed. At each of these substations there was vacant space for the location of the extra apparatus required for the operation of the railway, and the transformer capacity already installed at each place was

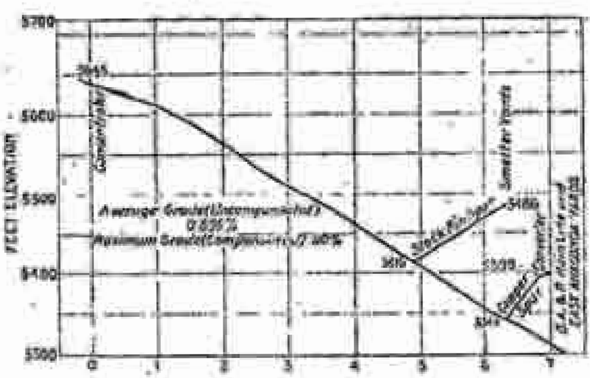


FIG. 6—CONDENSED PROFILE OF SMELTER HILL LINES

sufficient to meet the extra demand required for the operation of the railway.

The Anaconda substation is connected with the Butte substation by three high-tension trunk lines. The Butte substation receives power over five separate transmission lines from six hydroelectric stations of the following rated capacities:

Big Hole Development........	3,000 kw.	60 ft. head.
Madison River "	9,000 "	110 " "
Canyon Ferry "	7,500 "	35 " "
Hauser Lake "	14,000 "	60 " "
Black Eagle "	3,000 "	44 " "
Rainbow "	21,000 "	110 " "
Total........	57,500 "	

There is also now under construction the Great Falls Development, 60,000 kw., 155-ft. head. (Fig. 7.)

FIG. 7—PLANTS FROM WHICH ELECTRIC POWER IS PURCHASED BY THE BUTTE, ANACONDA AND PACIFIC RAILWAY.

All these plants are on the Missouri River water shed, all operate with free interchange of power, and all, except the first, are located in a series below the new Hebten reservoir, now being completed on the head waters of the Madison river, with an available capacity of 300,000 acre-ft. of storage.

The individual plants are also provided with storage reservoirs aggregating 125,000 acre-feet of total available storage capacity. All of these reservoirs operating under one control are capable of developing from stored water alone, in addition to the power otherwise available from the natural flow of the river, the equivalent of about 100,000 electrical horse power for a period of 100 days.

In view of this development, the generally recognized advantages of purchasing electric power from a large operating system instead of developing the required power independently were readily apparent in the case of the B. A. & P. railway. The railroad was relieved of all first cost of development and transmission of power and of all operating expense up to the point of delivery of power to the two substations. The cost of the delivered power is less than it would have been from an independent development, because the power company is enabled to operate large generating stations at relatively high load factor (about 75 per cent), whereas an independent plant purely for the operation of the railway would have to operate in this case at about 30 per cent load factor, with correspondingly high fixed and operating charges per kilowatt-hour actually used. The large number of generating stations and complete network of transmission lines already developed by the power company afford ample insurance against interruption to railroad service due to possible failure of any part of the generating or transmitting system of the power company, and the enormous inertia or flywheel effect of the motor loads connected to the power system maintain extremely steady speed and voltage under the most extreme variations of load on the railroad.

The original equipment of each substation was practically the same, consisting of two 1000-kw., three-unit motor-generator sets with the necessary starting and operating devices. Each motor-generator set consists of a 1450-kv-a., three-phase, 60-cycle, 720-rev. per min. synchronous motor coupled direct to two 500-kw., 1200-volt direct-current generators, one at either end, the two generators operating in series and supplying 2400-volt direct current to the trolley lines. The generators are compound-wound and have compensating pole face windings as well as commutating poles. The series fields are connected on the grounded side of the armature, while the main fields are separately excited from a 125-volt circuit. The motor-generator sets are capable of carrying overloads up to three times normal load momentarily, and 50 per cent overload for two hours. The value of this characteristic will be appreciated when it is noted that each electric locomotive unit has a continuous rating of approximately 900 kw., almost equal to that of a single motor-generator set, and frequently 16 of the

17 units are in service simultaneously, 11 of which are concentrated at the Anaconda end at intervals.

Seventeen 80-ton electric locomotive units were purchased, originally, fifteen of which are being operated in freight service and two in the passenger service. These units are practically interchangeable, with the exception of the gearing, the passenger locomotive being geared to operate normally at 40 or 50 mi. per hr. while the freight locomotives are geared to operate at from 15 to 25 mi. per hr., the maximum free running speed being approximately 35 mi. per hr. The continuous tractive

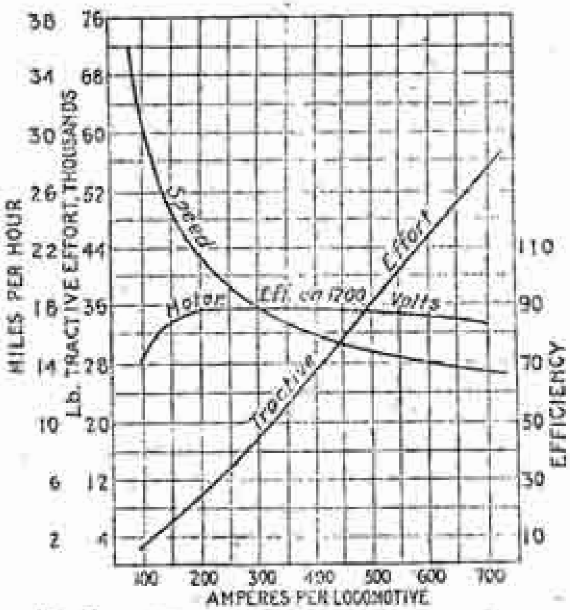


Fig. 12—Characteristic Curves of Freight Locomotives

effort of the freight units is 25,000 lb., at 15 mi. per hr., but they are capable of exerting a maximum tractive effort of 48,000 lb. for five-minute intervals, based on a coefficient of adhesion of 30 per cent.

All the locomotive units are of the articulated, double-truck type with twin gears mounted on projections provided on the wheel centers for the purpose, and in general mechanical design are similar to the electric locomotives in operation on the Great Northern railway, the Detroit River Tunnel railway and the Baltimore & Ohio railway. Each unit is equipped with four commutating-pole motors wound to operate at 1200 volts each, but insulated for 2400 volts, so that two are connected permanently in series and the four arranged in pairs, thus securing the usual two running points, with the difference that on the series position all four motors are in series, and in multiple the two pairs are connected in series-parallel.

The standard rating of each motor is approximately 300 h.p., making the hourly rating of each locomotive unit about 1200 h.p. The control equipment is of the multiple-unit type and provides a total of 19 steps, ten of which are in series and nine in series-parallel. The 2400-volt contactors, switches, fuses, etc., are located in enclosed compartments where they can be reached only by deliberate effort. The current for the operation of the control equipment, the air compressor, and the lights on the locomotive as well as the lights on the passenger coaches, is supplied by a 2400/600-volt dynamotor located in the main compartment of each locomotive unit.

A blower is direct-connected to the armature shaft of this dynamotor which provides artificial ventilation for the main motors and the rheostats. The principal data and dimensions pertaining to the electric locomotives are as follows:

Length inside of knuckles	37 ft. 4 in.
Length over cab	31 "
Height over cab	12 " 10 "
Height with trolley down	15 " 6 "
Width over-all	10 "
Total wheel base	26 "
Rigid wheel base	8 " 8 "
Track gage	4 " 8½ "
Total weight	160,000 lb.
Weight per axle	40,000 "
Wheels, steel tired	46 "
Journals	6 " 13 "
Gears, forged rims, freight locomotives	87 teeth.
Gears, forged rims, passenger locomotives	80 "
Pinions, forged, passenger locomotives	18 "
Pinions, forged, freight locomotives	25 "
Tractive effort at 30 per cent coefficient	48,000 lb.
Tractive effort at one hour rating	30,000 "
Tractive effort at continuous rating	25,000 "

Work on the electrification began in the spring of 1912, and the first electric locomotive was run in Anaconda on May 14th, 1913, about a year later.

On May 27, two ore trains were hauled up Smelter Hill on trial trips with electric locomotives and on the following day a double-unit electric locomotive took over the regular day service of hauling the ore from East Anaconda yards to the concentrator yards, the distance between which is approximately seven miles, the ruling gradient being 1.1 per cent compensated, and the grade fairly uniform through the entire distance, Fig. 6. The steam locomotives used in this service were of the Mastodon type, weighing 108 tons, 83 tons of which was on the drivers. The weight of the tender loaded was approximately 55 tons, making the total weight of locomotive and tender about 163 tons, which would average closely to the weight of the double-unit electric locomotive superseding it. The steam locomotive made ordinarily six round trips per shift, hauling 16 loaded ore cars per trip, equaling 96 cars per shift.

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

One of the regular steam engineers had been given special instructions on the electric locomotives during the experimental running in order that he might become competent to act as instructor to the other engineers until they were sufficiently familiar with the electric locomotives to be left alone.

The load per trip in this service was gradually increased from 16 cars to 25 cars, which is to be the standard for the present. The average time for the up-hill trip with 25 cars is about 26 minutes so that eight trips per shift are easily made, making a delivery of 200 cars possible or an increase of slightly more than 108 per cent over what had been possible for the same crew with steam locomotives. These loaded ore cars average from 70 to 72 tons each, making the trailing load for a 25-car train from 1750 to 1800 tons.

On arrival at the concentrator yards the ore trains are taken by a switching engine called the "spotter", which places one car at a time over the weighing scales, after which they are rearranged for placement over the concentrator bins from which the ore is fed by gravity to the crushers.

On June 20th this spotting service was taken over by a single-unit electric locomotive and on July 2nd the night service up Smelter Hill was taken over by the double-unit electric locomotive. The steam locomotive used for the spotting service was of the consolidation type and weighed 93 tons, 83 of which was on drivers, the tender weighing loaded 62 tons, making the total weight of engine and tender 155 tons. The steam locomotive used in the night service on Smelter Hill was similar to that used in the day service. When the electric engines were put on the night service all the handling of ore between East Anaconda and the concentrators was done electrically, and the hauling capacity per crew was so much greater that it was no longer necessary to have a "spotter" crew on the night shift so that this crew was eliminated, and the night crew hauling the ore up Smelter Hill did their own spotting on arrival at the concentrator yards, it being no longer necessary to make the regular number of trips. Thus, where formerly during steam operation four engine and train crews had been required, now with electric locomotives three similar crews were able to do the same work and in less time, thereby reducing the number of crews required in this particular service 25 per cent.

On July 9th the stock bin engine was replaced by an electric unit. This engine is engaged mostly in a switching service, placing cars of coke, coal and other supplies at the smelter. The type of steam engine used here was the same as that used for the "spotter" service described above.

Another engine locally known as the "tramp" because of the irregularity of the time or place of its service was partially replaced on July 24th. As some of the tracks over which this engine had to operate at times had not been equipped with overhead wires, the infrequency of their use not warranting the expense when other conditions made it necessary to keep one or more steam locomotives in operation, the service of this

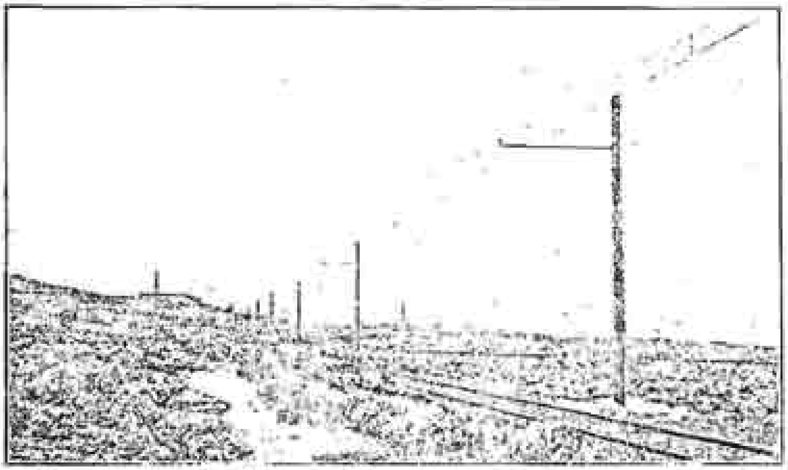


FIG. 13—BRACKET TANGENT CONSTRUCTION ON SMELTER HILL. FOR

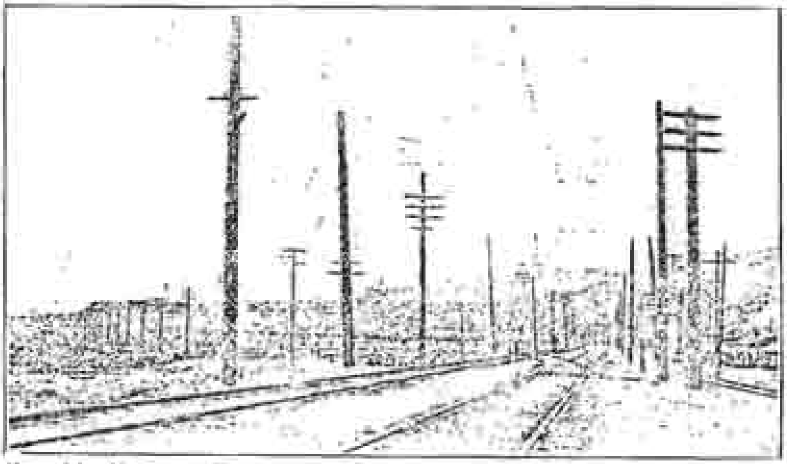
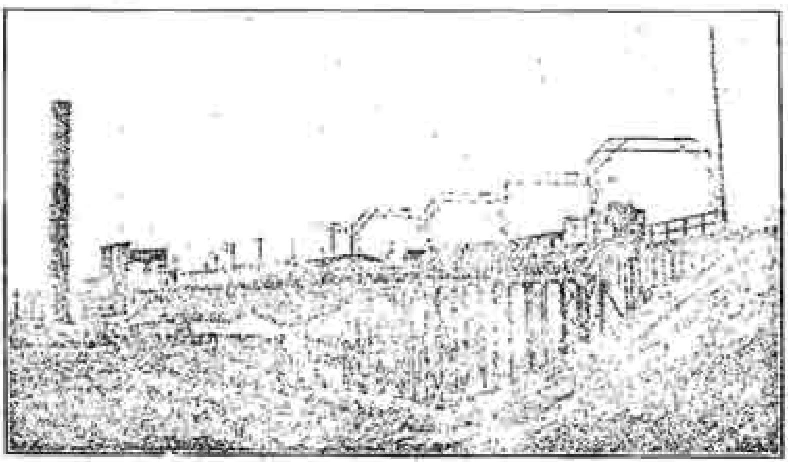


FIG. 14—DOUBLE TRACK SPAN CONSTRUCTION ON MAIN LINE AND GENERAL VIEW OF SMELTER HILL FROM WEST OF EAST ANACONDA YARDS



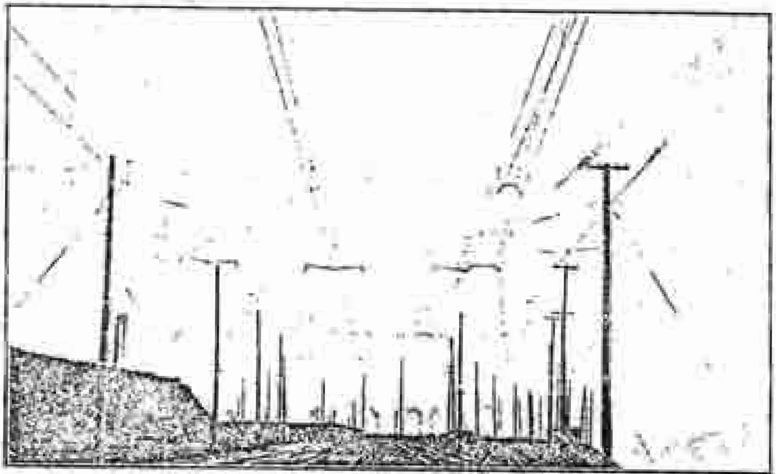


FIG. 16—CONCENTRATOR YARDS [COX]

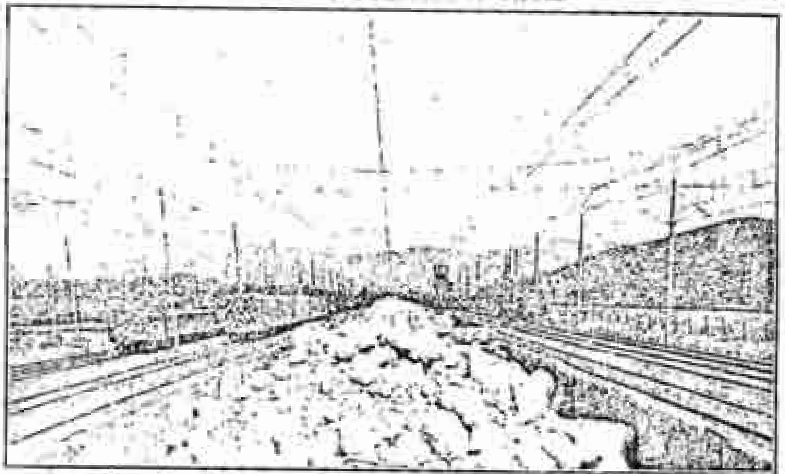


FIG. 17—OVERHEAD CONSTRUCTION IN ROCKER YARDS [COX]

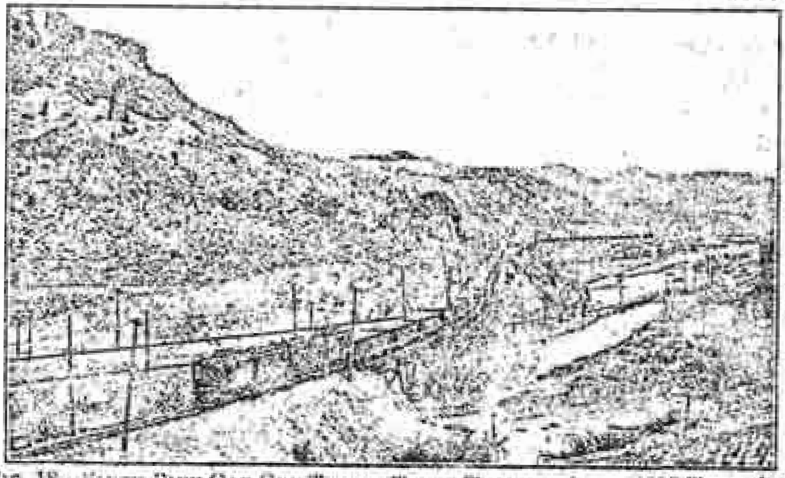


FIG. 18—SIXTY-FIVE CAR ORE TRAIN—TOTAL TRAILING LOAD 4550 TONS [COX]

electric unit was intermittent. This practically completed the electrification of the Smelter Hill service and no further extension of electrical operation was made until October, as the trolley construction on the main line was not completed until that date.

On the forenoon of Sept. 30th an inspection trip was made over the main line from Anaconda to Butte and in the afternoon a special train carrying officials and visitors from a neighboring road was taken from Butte to Anaconda and return by one of the electric locomotives intended for the passenger service. On October 1st the regular passenger service between Butte and Anaconda was taken over for electrical operation. The steam locomotives used in the passenger service weigh approximately 80 tons, 60 tons of which are on drivers, the tender loaded weighing 52 tons, making the total weight of engine and tender 132 tons. The distance between the stations—Anaconda to Butte—is 25.7 miles, the schedule time for the trip, one hour. No change has been made in this time, though a reduction of 20 per cent would be possible with the electric locomotives were such desired. The standard passenger train consists of one mail and baggage coach and two to four passenger coaches, but as many as 12 passenger coaches are handled by a single electric unit on special occasions, such as excursions and on holidays.

The baggage coaches average approximately 40 tons in weight and the passenger coaches 45 tons each making, the gross weight of the three-car electric train approximately 210 tons, whereas that of a similar steam train was 262 tons, showing a reduction of 19 per cent in favor of the electric locomotive with approximately 33 per cent more weight on its drivers. As had been done in the freight service, the steam enginemen in the passenger service were transferred from the steam to the electric locomotives with but little previous instruction, and after the first day or so were left mostly to themselves. It may be of interest to note here that on the day shift, averaging four trips per day, during the first five months the passenger train did not come in late a single time on account of engine trouble. A comparison of the delays to the passenger trains for the month of June, 1913, steam operation, with the same month, electrical operation, 1914, as shown in Table V, results as follows:

	No. of Trains	Delays on Account of				Total Delays
		Meeting Points	Power	Engine Failure	Lost Run Time	All Causes
		Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.
Steam, 1913..........	272	15 : 49		44	4 : 13	20 : 46
Elec., 1914..........	280	3 : 54	27	24	25	5 : 10
Decrease..............	8*	11 : 55	27*	20	3 : 48	15 : 36
Percentage of saving due to electrical operation..........	2.94*	75.33		45.45	90.10	75.12

* Increase.

June was taken at random for a comparison, as that month's records were still in the office file but the results are considered representative of general performances.

On October 10th a double-unit electric locomotive was put in the day freight service on the main line between East Anaconda and Rocker, a distance of 20.1 miles. The steam locomotive replaced in this instance was of the Mastodon type weighing 103 tons, 77 tons of which was on drivers, the tender loaded weighing 55 tons, making the total weight of locomotive with tender 158 tons. The standard train hauled on the trip west was 50 to 55 loaded ore cars weighing approximately 3500 to 4000 tons gross and the average running time of such trains where no stops were made was about 1½ hours, corresponding to an average speed of approximately 13.4 miles per hour. In the beginning the electric locomotive took only the standard train but made the trip without stop in about one hour, corresponding to an average speed of 20 mi. per hr. The ruling gradient on the westward trip is 0.3 per cent and about half the distance is down grade. On the 0.3 per cent grade with a 55-car train, the steam locomotive made about seven mi. per hr. The electric locomotives with similar train now make about 16 mi. per hr. on the same grade.

The weight of the trains hauled by the electric locomotives on this run has been gradually increased up to 65 loaded ore cars averaging about 71 tons each, making the gross weight trailing about 4620 tons. Adding 160 tons for the weight of the double-unit electric locomotives and 20 tons for the caboose makes a gross train weight of approximately 4800 tons.

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

Table IV gives comparative results of the month of June 1913 steam operation vs. the same month, 1914, electrical operation of this main line service, showing that with a slight increase in the total tons of ore hauled the average tons per train was increased from 1761 to 2378 or 35 per cent, thus decreasing the average number of trains per day from 12.5 to 9.3, or 25.6 per cent.

Table III, giving a comparison of the time per trip for these trains, is representative of the gain in this direction to be added to the decrease in the number of trains. The average time per trip during steam operation was approximately two hours and 25 minutes, while with the electric locomotive it was approximately one hour and 45 minutes, showing a decrease of 40 minutes, or 27.5 per cent. These figures represent the time put in by the crews between Rocker and Anaconda, the distance being 21.8 miles.

The result of these improvements is indicated in Tables I and II, which show that the overtime in this particular service has been decreased 73.5 per cent and the total time 42 per cent, resulting not only in greater economy to the railway company but in shorter and easier hours for the crews.

The service on the Missoula Gulch line running between Rocker and Butte Hill yards was taken over for electrical operation on October 20th. This line is 4.5 miles in length and the ruling gradient 2.5 per cent, Fig. 5. The steam locomotives used on this line were of the Mastodon type, weight 106 tons, 87 tons of which were on the drivers, the tender loaded weighing 56 tons, thus making the total weight of engine and tender 162 tons. Two complete crews had been required to handle this service during steam operation, averaging six trips per day each. A single crew with a double-unit electric locomotive has been doing this work successfully. Thirty-five to 45 loaded ore cars are taken down from Butte Hill yard to Rocker, and about an equal number of empties taken up. In addition to the empties, large quantities of timber and supplies for the mines are delivered over this line.

TABLE 1

NUMBER OF HOURS ENGINE CREWS WERE EMPLOYED IN VARIOUS SERVICES—JUNE 1913 STEAM OPERATION

	Anaconda Yard		Butte Hill Yard		Local		Road	
Date	Regular	Over	Regular	Over	Regular	Over	Regular	Over
	Time Hr.	Time Hr.	Time Hr.	Time Hr.	Time Hr.	Time Hr.	Time Hr.	Time Hr.
June 1	80	14	20	4.50	20	3.25	30	13.75
2	90	6.50	20	6.50	20	5.75	40	17.25
3	50	5	—	—	20	5.25	40	15
4	70	11.75	20	8.25	20	9.75	30	11.50
5	80	11.75	20	5.00	20	6.00	30	12.25
6	70	9.25	20	9.00	20	10.00	30	14.50
7	80	13.75	20	8.75	20	6.50	30	11.25
8	70	8.00	20	8.75	20	4.75	30	12.25
9	70	10.50	20	11.50	20	8.25	30	11.50
10	80	5.75	20	7.75	20	2.00	30	9.00
11	80	13.	20	10.25	20	7.00	30	10.50
12	70	7.00	20	2.00	20	5.25	30	12.00
13	40	5.25			10	1.00	30	9.75
14	70	12.25	20	11.25	20	7.50	30	9.50
15	70	10.25	20	8.75	20	5.25	30	11.00
16	80	8.75	20	9.75	20	16.00	30	9.25
17	80	7.75	20	9.00	20	11.00	30	15.25
18	70	12.25	20	7.50	20	10.75	30	12.50
19	70	9.50	20	9.00	20	3.75	30	8.00
20	80	12.00	20	10.75	20	5.75	30	8.75
21	80	9.75	20	10.25	20	3.00	30	12.75
22	70	5.50	20	7.75	20	5.75	30	10.00
23	70	7.00	20	8.25	20	6.75	30	8.75
24	80	7.50	20	4.50	20	8.00	30	9.00
25	70	9.25	20	6.00	20	9.00	30	11.50
26	80	10.25	20	6.00	20	7.00	30	13.27
27	70	7.75	20	7.50	20	7.00	30	10.25
28	70	5.50	20	2.50	20	4.75	30	6.00
29	80	6.00	20	1.50	20	3.75	30	9.75
30	80	8.75	20		20	7.00	30	9.50
Total	2200	274.50	570	208.50	600	194.25	910	335.50

Tons Ore Hauled During Month—311,480.

On November 25th, the last of the electric locomotive units went into service, thus completing the electrification originally intended. The full electrical service has, therefore, now been in operation more than nine months and that on Smelter Hill more than 15 months, so that the total locomotive-miles operated would be approximately close to an average year's performance.

TABLE 11

NUMBER OF HOURS ENGINE CREWS WERE EMPLOYED IN VARIOUS SERVICES—JUNE 1914 ELECTRICAL OPERATION

Date	Anaconda Yard		Butte Hill Yard		Local		Road	
	Regular Time	Over Time	Regular Time	Over Time	Regular Time	Over Time	Regular Time	Over Time
June 1	70	7.25	20	1.25	20	2.00	30	2.25
2	70	8.25	20	4.00	20	2.50	30	5.00
3	70	9.50	10	1.00	20	4.00	30	1.25
4	60	7.25	10	2.00	20	2.75	30	4.25
5	60	13.50	10	2.00	20	2.75	20	2.50
6	60	7.25	10	2.00	20	2.50	20	2.25
7	70	8.25	10	2.00	20	2.00	20	6.25
8	60	8.75	10	1.75	20	2.75	20	3.00
9	60	10.50	10	1.50	20	4.75	20	4.75
10	60	11.25	10	1.75	10	1.00	20	1.75
11	60	5.00	10	1.50	20	1.75	20	1.25
12	60	9.00	10	1.00	20	2.00	20	1.25
13	30	1.75	10	1.00	10	1.00	10	4.00
14	60	5.50	10	1.25	20	2.25	20	1.25
15	60	6.50	10	1.00	20	2.75	20	1.50
16	60	4.00	10	1.50	20	2.00	20	2.00
17	60	7.75	10	1.00	20	3.00	20	2.75
18	60	8.75	10	1.75	20	2.25	20	1.50
19	60	7.25	10	3.00	20	2.25	20	2.25
20	60	10.75	10	1.75	20	3.25	20	5.75
21	60	8.75	10	1.75	20	2.25	20	1.25
22	30	5.50	10	1.00	20	2.75	20	2.25
23	60	8.75	10	1.00	10	1.50	20	3.50
24	60	11.25	10	1.50	20	3.00	20	3.50
25	60	7.75	10	1.50	20	2.25	20	5.25
26	60	5.75	10	1.25	20	2.50	20	1.75
27	60	8.50	10	1.25	20	2.00	20	3.75
28	60	4.25	10	2.00	10	1.75	20	2.00
29	60	8.00	10	1.00	10	1.75	20	5.50
30	60	10.50	10	1.25	20	2.25	20	3.50
Total	1800	233.00	320	48.50	550	73.50	600	85.00
Decrease	400	42.50	250	100.00	50	121.75	280	246.50

	Regular	Over	Total
Total time 1913—Steam	4250.00	1012.75	5262.75
" " 1914 Electric	3300.00	442.00	3743.00
Decrease	980.00	570.75	1540.75
Percentage of decrease	22.80%	56.20%	29.28%

Tons ore hauled during month—315,700

This was the first installation of 2400-volt direct-current apparatus for the operation of a railway in this country, 1500 volts being the highest heretofore installed for such a purpose.

The results have been more satisfactory than had been anticipated and the development charges due to such imperfections as usually appear during the first year of operation have been perhaps smaller than is customary with an undertaking of like magnitude, even where standard apparatus is used.

TABLE III

COMPARISON OF TIME REQUIRED PER TRIP OF FREIGHT TRAINS. BETWEEN ROCKER AND ANACONDA—FIRST 2 DAYS OF JUNE 1913, STEAM OPERATION, WITH CORRESPONDING 3 DAYS ELECTRICAL OPERATION.

		1913 Steam				1914 Electric			
East Bound.				West Bound		East Bound		West Bound	
Train	No.	Tons	Time	Tons	Time	Tons	Time	Tons	Time
			Hr. Min.		Hr. Min.		Hr. Min.		Hr. Min.
	1	255	1:13	1705	2:00	240	1:02	2015	2:00
	2	1010	1:50	2848	2:05	314	1:15	3002	2:00
	3	1010	3:20	3700	2:10	1326	1:45	4088	1:20
1st	4	915	3:40	3420	2:30	1290	1:40	3030	1:10
	5	1047	2:30	2844	3:45	1240	1:40	4000	2:05
	6	1000	2:30	2235	2:05	--	--	--	--
	7	1010	4:00	--	--	--	--	--	--
	1	415	1:07	3110	3:40	416	1:10	3100	2:00
	2	1010	2:10	3760	2:10	1154	1:40	3220	1:25
2nd	3	1010	2:45	2894	2:00	1298	2:00	3752	2:20
	4	1010	3:00	3420	2:00	438	1:43	4020	2:10
	5	1104	2:20	3420	2:00	1232	2:00	3720	2:20
	6	1000	3:00	2010	2:30	1190	1:53	2840	2:35
	1	350	1:02	3380	2:30	470	1:04	2315	1:15
	2	1010	1:50	1030	2:45	1280	1:40	3904	1:10
3rd	3	902	2:30	200	2:00	1208	2:05	4008	1:30
	4	884	2:20	0	1:30	482	1:40	3700	1:40
	5	1046	2:40	3150	2:30	1074	2:10	3138	2:30
	6	1084	3:15	2770	2:40	1200	2:15	0	1:10
Totals	19	17192	46:12	18-48246	43:20	17-16083	28:45	17-56070	30:40
Av'ge per Train.....		905	2:26	2680	2:24	946	1:41	3298	1:48

Grand Average. 1708 tons per train, time per trip 2.25; 2150 tons per train, time per trip 1:45.

Result. 20.0% increase in tonnage per train, 27.58% decrease in time per trip.

*On June 5th, 1914, one main line crew was taken off and the tonnage of the remaining trains increased so as to handle the regular business.

Difficulties especially attributable to the higher potential have been negligible, and while there have been occasional instances of arcing and flashing or short circuits due to ordinary causes, the resultant damages have been really smaller than might be expected from a like occurrence on a 600-volt installation of equal capacity.

The original brushes supplied in the motors chipped badly

TABLE IV

COMPARISON OF FREIGHT TRAIN MOVEMENTS BETWEEN ROCKER AND ANACONDA. STEAM OPERATION FOR MONTH OF JUNE 1913 WITH ELECTRICAL OPERATION FOR SAME MONTH 1914

	1913 Steam				1914 Electric			
	East Bound		West Bound		East Bound		West Bound	
Date	No. Trains	Total Tons	No. Trains	Total Tons	No. Trains	Total Tons	No. Trains	Total Tons
1	7	6247	6	17012	5	4500	5	17934
2	6	5549	6	17591	6	5748	6	20001
3	6	5490	6	13130	6	5900	6	17425
4	7	5584	6	14032	6	6127	6	18282
5	7	5848	6	13025	5	5266	5	17155
6	7	5877	6	19471	4	4801	4	17303
7	7	5608	6	22021	5	6579	5	19673
8	7	6388	7	17021	3	6063	5	14170
9	5	5508	7	12507	5	5796	4	15292
10	5	5039	6	19240	5	6057	5	19020
11	6	5381	5	16675	4	5013	4	12502
12	5	4376	6	18117	5	5670	3	17881
13	5	3705	5	6795	2	2822	1	3042
14	5	4912	6	7944	4	4638	4	15063
15	7	5052	7	17291	5	5202	4	15761
16	6	5180	7	17318	4	5116	4	16408
17	6	5475	6	16040	5	6421	3	20281
18	6	5453	5	16692	4	5141	4	17312
19	7	6003	6	18301	5	6061	5	18459
20	7	5277	6	22382	6	6708	5	17993
21	7	5737	6	19096	4	6120	4	11532
22	7	5082	6	15404	5	6017	5	15612
23	6	5456	6	11511	4	4137	4	15030
24	6	5958	6	14210	5	6550	5	18917
25	7	5644	7	17102	5	6531	5	16855
26	7	5600	6	18334	5	6742	5	18523
27	7	5935	6	14761	4	4362	4	18918
28	7	3754	5	17297	4	5917	4	14884
29	6	6105	6	11609	5	6155	5	17941
30	6	5221	6	17584	5	6677	5	18128
Total.......	193	163,130	182	407,124	141	167,700	138	495,097
Average....	6.4	845	6.1	2,237	4.7	1,190	4.6	3,582

Grand Average 12.5 trains per day, 1761 tons per train. 9.3 trains per day, 2378 tons per train.

Results—25.6% less trains. 35.0% greater tonnage per train.

and before all these had been replaced it was often found when the units were brought in for regular inspection that some of the brushes were broken entirely into pieces, and while there was evidence that a flash-over might have occurred at some time, no harm had resulted other than the blowing of the motor fuse, on the replacement of which the engine was continued in service until its regular time for inspection, when the cause of the fuse blowing would first be discovered.

The fact that the locomotives continued in service thus is sufficient evidence of the harmlessness of the arc-over and in no instance of the kind has any real damage been done. The locomotives have made from 25,000 to 50,000 miles each and without exception the motors are in excellent condition. The wear on the commutators is imperceptible and the general performance of the entire equipment is quite as satisfactory and promising as that of any railway equipment with which we have had experience in similar service.

The overhead construction has been quite satisfactory and a recent examination of the trolley wire shows no indication of unusual wear. The roller pantographs are operating quite successfully, the average life of these being from 10,000 to 12,000 miles per roller. Where a double-unit locomotive is operated, the two pantographs are connected electrically by a main bus line, and the average current collected by each, when ascending the grades with standard loads, is from 350 to 400 amperes. Two pantographs operating in multiple thus will collect more than double the current that can be successfully collected by a single pantograph for the reason that sparking is usually due to the momentary breaking of contact between the trolley wire and the roller caused by hard spots in the line. When two pantographs are operated in multiple both do not encounter these hard spots at the same instant, hence one of the two is more apt always to be making good contact, so that the flow of current is not so frequently interrupted and consequently the sparking is greatly reduced. The double units operating on Smelter Hill were run experimentally for several days with only a single roller making contact with the wire, the operation being quite successful with the single roller collecting an average of 650 to 750 amperes while running at 16 to 17 mi. per hr. and 800 to 1000 amperes during the accelerating period in multiple. The sparking was not serious except at hard points in the line, and with two rollers in multiple there should be no difficulty in collecting 500 to 600 amperes per roller, which at 2400 volts should be equal to the requirements of any ordinary locomotive unit.

The bearings first used in the rollers were provided with ordinary bushings lubricated with oil but when the bushings became slightly worn the oil was thrown out along the spindle and had to be replenished at comparatively frequent intervals. This was not serious in the operation of the freight locomotives but became more so when the passenger service was started, as the higher speed caused the oil to be thrown out more quickly, resulting in very short life of the bushings. Slight changes were made in the bearings and grease was substituted for the oil as a lubricant, which proved quite satisfactory. However, the vibration which results from too much play in the bearings of the roller when operating at high speeds made it desirable to increase the life of these bearings as much as possible, so that, later, roller bearings with grease lubrication were installed with excellent results. As yet, these have not been in operation a sufficient length of time to indicate definitely how long they may be expected to last, but it would appear that the bearing will last much longer than the roller and that the attention required for the adjustment and lubrication of the bearing or the roller will be negligible.

On account of a decision of the mining company to divert to the Washoe smelter, at Anaconda, the shipment of approximately 3000 tons of ore per day that had previously been sent to the smelter at Great Falls, which will increase the ore traffic over the Butte, Anaconda & Pacific approximately 25 per cent, an extra motor-generator set, a duplicate of the original sets, has been installed in the Anaconda substation as a spare set, and four additional electric locomotive units were ordered and will be delivered within the next three months. These units will be duplicates of the original ones except that they are to be arranged for operating with an extra tractor truck attached when desired. This tractor truck will be a duplicate of the standard truck used under the regular units, with two standard motors mounted upon it with the necessary arrangements for coupling, both mechanically and electrically, so that the standard unit and the tractor truck may be operated as a single unit. The motors of the tractor truck are connected with those on the standard unit in such a manner as to place all six motors in series on the series points of the controller, and with a series-multiple connection with three motors in each series, on the multiple position of the controller. This arrangement will make the tractive effort of the new unit 50 per cent greater than that of a standard unit for the same input, with a reduction in the free running speed of about 33⅓ per cent.

This arrangement was made advisable because of the increase in the weight of the trains taken up Smelter Hill, amounting to approximately 56 per cent. A single unit when used in the "spotting" service is taxed close to the slipping point of its wheels when accelerating these heavier trains on the 0.5 per cent grades under ordinary conditions of weather, and has to be handled very carefully with the continuous use of sand when the condition of the rails is unfavorable. Connecting the additional motors in series will also result in considerable power economy, since with a single unit the controller is seldom off the series resistance points, on account of the heavy trains handled and the short movements required.

Small change in the personnel of the maintenance or operating departments of the railway has been made on account of the electrification, nor has there been any reduction in salaries or wages. An extra man with electrical experience was placed in the shops to supervise the electrical repairs to the locomotives and three linemen were retained for the maintenance of the trolley system.

The three steam switching locomotives used for concentrating the ore at and distributing supplies from Butte Hill yards are continued in this work for reasons heretofore stated. Another steam locomotive is used on the Georgetown branch and a fifth one operates at intervals over unelectrified tracks at the Anaconda end. Approximately 20 per cent of the total locomotive-miles now being operated is by these five steam locomotives, the cost of which, as shown in Table VI, is upwards of 40 per cent of the total cost of all locomotive performance.

The electrification of the remaining tracks on Butte Hill has been recommended and no doubt will be commenced at an early date. Table VI referred to was made up from the regular monthly locomotive performance sheets of the railway company, from which the principal saving resulting from the electrification may be noted. The saving from the partial substitution of electric power for coal is the chief item, being at the rate of $150,727.04 per year, which is remarkable when it is considered that more than 39 per cent of the total combined costs for fuel and power for the period considered was for coal and charged against electrical operation. In this instance the saving on this item alone would undoubtedly justify the

Operating Expenses, ... of the Street Railway Company ...

		December	January	
Maintenance of way and structures	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Increase	[illegible]	[illegible]	[illegible]
Maintenance of equipment	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Decrease	[illegible]	[illegible]	[illegible]
Traffic expenses	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Decrease	[illegible]	[illegible]	[illegible]
Transportation expenses	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Decrease	[illegible]	[illegible]	[illegible]
General expenses	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Decrease	[illegible]	[illegible]	[illegible]
Total Operating Expenses	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Decrease	[illegible]	[illegible]	[illegible]
Net operating revenue	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Increase	[illegible]	[illegible]	[illegible]
Taxes	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Increase	[illegible]	[illegible]	[illegible]
Operating Income	1913	[illegible]	[illegible]	[illegible]
	1914	[illegible]	[illegible]	[illegible]
	Increase	[illegible]	[illegible]	[illegible]

* Increase
* Decrease

expenditure covering the entire cost of electrification. It is to be noted that with a single exception, that for depreciation of equipment, every item of expenditure in the locomotive performance sheet shows a substantial percentage of decrease in favor of electrical operation.

It is the practise of the railway company to adjust depreciation charges on all locomotives at the beginning of each half year. The amount to be charged to the depreciation of a new locomotive for the first half year it is in service is determined by taking a fixed percentage of its cost to the company, one-sixth of this amount being charged against the locomotive each month for the half year, at the end of which the amount of the depreciation for the period is deducted from the original cost of the locomotive to give a new value, of which the original fixed rate of percentage is taken in determining the amount of the depreciation for the following half year, and so on.

The Interstate Commerce Commission ruling does not permit a depreciation charge until the locomotive actually becomes the property of the railway company and as the electric locomotives were not formally taken over by the company until March, 1914, the proper monthly charge begins only with that month in the regular monthly performance sheet from which Table VI was compiled. In fairness to the performance sheet, only the proper monthly depreciation charges were made, but as some of the locomotives had been in service eight months before these charges began, an adjustment was necessary to make a proper distribution of the back depreciation, so that while Table VI shows only the proper monthly charge for the six months compared, amounting to $8,471.84, in Table VII under "maintenance of equipment" the total back charges were included, amounting to $20,047.48. It is evident that the depreciation reckoned on this basis for the first months of service would be comparatively high.

The total saving from locomotive performance alone as indicated by Table VI is at the rate of $237,581.82 per year, to which should be added the credit of handling an increase of traffic at the rate of 13,938,130 ton-miles per year or 8.77 per cent more than was handled by the steam locomotives during the period compared. To this saving from locomotive performance should be added the saving from trainmen's wages, which is at the rate of $31 146.30 per year, or a decrease of approximately 21 per cent, due largely to the elimination of overtime (Tables I and II), making the total saving from these two items $268,728.12 per year. From this should be deducted $10,839.12 for maintenance of the distribution system, leaving $257,889 as the net operating saving per year due to electrical operation.

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

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

Item of Operating Expenses	Steam 1913	Electric 1914	Decrease 1914	Per cent decrease
Fuel and power	$315,235.74	164,508.70	150,727.04	47.81
Repairs	124,787.90	92,278.08	32,509.82	26.05
Enginemen's wages	104,491.18	71,225.88	33,265.30	31.81
Enginehouse exp.	29,907.80	18,648.38	11,259.42	37.66
Water	4,953.66	1,193.70	3,759.96	75.90
Lubricants	9,751.44	4,942.32	4,809.12	49.30
Other supplies	5,823.52	4,552.36	1,271.16	21.83
TOTAL LOCOMOTIVE PERFORMANCE	$594,951.24	$357,369.42	237,581.82	39.93
Trainmen's wages	147,632.30	116,486.00	31,146.30	21.10
GRAND TOTAL	742,583.54	473,855.42	268,728.12	36.19
Ton-miles hauled	158,917,720	172,855,856	13,938,136*	8.77*

*Increase

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

If a correction be made for the item of depreciation in Table VI, charging the regular monthly amount of $2711.13 begun in March for each of the six months, making the total of this item for the period $16,266.78 instead of $8,471.84 as it stands on the performance sheets, the total saving per year from locomotive performance would be reduced to $221,991.94, making the total net saving $242,299.12, which is equivalent to 20.02 per cent on the entire cost of the electrification, to say nothing of the increased capacity of the lines, the improvement in the service and more regular working hours for the crews, as is indicated in Table V, comparing the delays to traffic, and Tables I and II, showing the decrease in overtime.

From Table VII it will be seen that if taken on the basis of the increase shown in net operating revenue, or operating income, this percentage is slightly greater, the rate of increase per year for these items being $288,150.80 and $282,016.96, respectively.

The estimate on which the decision to proceed with the electrification of the road was made, placed the annual net saving expected at 17.5 per cent of the cost, so that the results financially have been quite as satisfactory as the general performance of the equipment.