# THE CONTACT SYSTEM OF THE BUTTE, ANACONDA & PACIFIC RAILWAY

By J. B. Cox

Railway and Traction Engineering Department, General Electric Company

The main divisions of the following comprehensive article on "The Contact System of the Butte, Anaconda & Pacific Railway" cover the following points: Reasons for selecting an overhead system, development of the mechanical details of the pantograph to fulfill the local conditions, method of crossing trolley wires at street railway intersections, sectionalization and layout of trolley wires, costs of material and labor, record of progress during construction period, and difficulties encountered and the means employed in overcoming them. —Editor.

A careful preliminary survey of the general problems involved in the electrification of the Butte, Anaconda & Pacific Railway had made it evident that an overhead contact system was unquestionably advisable; the two predominating reasons were that approximately 60 per cent of the tracks to be electrified consisted of yards and sidings with numerous switches and street crossings, and that a great portion of these tracks were in localities where it would be very difficult to protect against trespass by the public.

An analysis of the general traffic conditions had indicated that a locomotive unit with approximately 80 tons on the drivers and equipped with an aggregate motor capacity of approximately 2400 h.p., for maximum accelerating periods, would be the most economical and best suited to the general service conditions (two such units being operated in multiple as a single locomotive for the heavier freight trains). Such a locomotive would thus frequently have to collect from the trolley from 3000 to 3600 kilowatts, which would mean 6000, 3000 or 2500 amperes at 600, 1200 or 1500 volts respectively.

Trial estimates on the total initial costs and the final operating expenses had indicated that, for the general conditions, direct-current motors operating two in series from a 2400-volt trolley fed from two substations, one located at each end of the line in existing power supply buildings approximately 26 miles apart where no extra attendants would be required, would be expected to yield the most economic results. Higher trolley voltages were considered but were not found to be generally advantageous.

A double-unit locomotive with a capacity as described would, therefore, be required to collect from the 2400-volt trolley during acceleration from 1400 to 1500 amperes or 700 to 750 amperes for each collector, there being one collector for each unit.

While this was known to be well within the capacity of a single 4/0 trolley fed at frequent intervals from both directions, the successful collection of such a heavy current from a single trolley wire was a more serious problem.

Sliding pantographs of various types had been developed and made to operate fairly successfully for the collection of currents up to 150 or 200 amperes under similar operating conditions, but none had given any hopeful indications of collecting these heavy currents with a reasonably satisfactory life.

Rollers of various kinds had been tried as substitutes for the slider and one of these, made from steel tubing, had been found to give very satisfactory results.

On the whole this type of collector seemed to give the most promising prospect at the time, so that it was chosen for the moving contact device on the locomotives.

A Shelby steel tube 5 inches in diameter and 24 inches long was used for making up the roller. The thickness of this tube when machined inside and outside was approximately 1/8 inch. Originally, a wooden lining was forced inside the tube, which was expected to hold the tube together until the sparking had called attention to the necessity for its removal, in case the metal wore through.

Removable bearing housings of aluminum were fitted into each end of the tube, two phosphor bronze sleeve bearings being installed in each housing and between these was an oil chamber for containing the lubricant. The complete roller revolved about a 5/8 in. steel shaft which was fixed at each end by clamps to the pantograph frame.

The completed roller with lining, bearings, and spindle weighed approximately 31 lb., as against about 5 lb. for the corresponding contact element usually adopted for the sliding pantograph.

This comparatively heavy contact device could not be expected to respond so readily or so gently to hard or uneven spots in the trolley wire as the lighter slider. Besides the increase in weight, the rapid revolving of the roller at high speeds would tend to increase the difficulties unless the balance was almost perfect. These difficulties were foreseen from the beginning, and as it was realized that the weight of the roller could not be materially reduced it was decided to adopt practically the standard pantograph frame with such changes as were necessary for the substitution of the roller and then turn to the trolley line construction with a view toward removing the most serious objections to the roller, i.e., to eliminate the hard or uneven spots in the trolley line which seemed to be its greatest detriment.

The pantograph as originally installed on the locomotives is illustrated in Fig. 1. One such pantograph was mounted on each freight locomotive unit, and two on each passenger unit, though only one pantograph is used at a time. The extra one was to be held as a spare for use in case of trouble, thus avoiding unnecessary delay. All main line freight trains are operated by a double-unit locomotive with both pantographs in contact with the trolley wire. Both pantographs are connected in multiple by means of a bus line run on top of the locomotives, with a jumper connection between the two units.

In case of accident to either pantograph on these trains a single pantograph is capable of collecting the current for both units for the completion of the trip. The operation of this pantograph in service is described in detail later in this article.

In considering what might be done by way of improving the design of the overhead line construction, so as to make it more adaptable to the satisfactory operation of the roller pantograph, evenness and flexibility were recognized as being the qualities most desired. The introduction of catenary construction with hangers at frequent intervals had accomplished much in these directions, especially the first, and gradual improvements had been made toward simplifying and cheapening this type of construction, though perhaps the

**Fig. 1. Pantograph Trolley**

importance of flexibility had not been fully appreciated until the heavier types of collector became necessary.

Attention was directed to the redesigning of all hangers, pulloffs and other line material which tended to add unevenly distributed weight or local stiffness to the trolley wire, the result being the development of a new line of this material.

The new hanger was made up of a ⅝ in. by ⅛ in. flat strap having a malleable iron ear secured by a ½ in. by 1½ in. carriage bolt. This hanger allows the greatest possible vertical movement of the trolley wire, or more than the upward pressure of the two pantographs of a double-unit locomotive, operating with a tension of 35 to 40 lb. each against the trolley wire, will normally raise it. No resistance from the messenger wire will be encountered even up to this point, since the loop extends for almost the entire length of the hanger. The hanger is simple in construction and is easily installed, since the loop is merely thrown over the messenger and the two ears carried by the loop strap are secured by the single bolt which at the same time clamps the self-aligning jaws into the groove of the trolley wire.

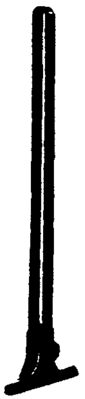


**Fig. 2. 28-in. Trolley Wire Hanger**

The design of the jaws gives liberal clearance for the roller and would readily permit the operation of a trolley wheel should such for any reason be desired.

The weight of the complete hanger varied from 14½ oz. in the case of the 8 in. to 1¾ lb. for the 28 in. or longest hanger. Fig. 2 illustrates this hanger.

As a very large percentage of the trackage to be electrified is of curve construction varying anywhere from a tangent to 22 deg. curvature, it was necessary to give most careful attention to the design of a new pulloff. The efforts in this direction created an entirely new pulloff by means of which the messenger and trolley wires are held in position by separate clamps. From each clamp runs an individual pulloff wire with a strut between them that maintains the pull parallel to the horizontal plane of the trolley wire. This arrangement allows of a free vertical movement independent of the messenger, see Fig. 3.

The double pulloff used where there was more than one track is shown in Fig. 4. This pulloff, while an improvement in some respects over former designs, was not as satisfactory as the single pulloff, as it proved to be heavier and less flexible than was desired and caused a slight sparking when a single pantograph passed underneath it at medium speeds. The design has been revised and in future construction will be considerably improved.

Rigid pulloffs, as shown in Fig. 5, were used at some points but were found to be subject to

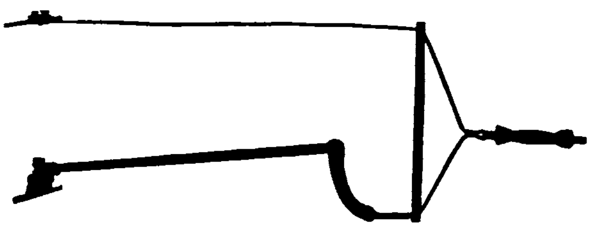


**Fig. 3. Flexible Pull Off for Pantograph Collector**

much the same objections as the double pulloffs because of the sparking due to similar reasons.

The splicing sleeve is made of sheet steel with a malleable iron removable shoe which gives a smooth underrun for the roller and may be replaced when worn out before the body of the holding member proper is injured.

The wire is securely held, without bending the wire or diminishing its tensile strength, by a drop-forged wedge with sharpened teeth.

Fig. 6 illustrates the form of wedge grip clevis used for dead-ending the trolley and messenger wires. This had double wedges with sharpened teeth similar to that for the splicing sleeve. These are readily installed with a hammer; which fact, together with their low manufacturing cost and ease of adjustment in service, makes their use economical as well as satisfactory.

The question as to the use of wood or steel poles for the supporting structure was not a difficult one owing to the general conditions and the nearness to the best of markets for good Idaho cedar poles which made their use more economical when compared with the cost of steel structures. Some consideration was given to the use of steel structures in some of the yard construction where as many

**Fig. 4. Double Flexible Catenary Pull Off**

as eight tracks were to be spanned, but even here it was finally decided to use the wooden poles though the general advantages were not so great as on the main line construction. However, steel supporting structures were used on the double track steel trestle running from the concentrator yards up over the ore storage bins alongside the concentrator buildings. These tracks are approximately ½ mile in length. The steel supporting structure was made up at the smelter and the cost of it is included in Table I.

A further item of unusual character in connection with the trolley line construction was that required for about ¼ mile of track alongside a slump pond from which the sediment is taken by means of a drag-line scraper bucket operated from a cableway suspended between two traveling towers mounted on rails on each side of the pond. As the track in question on which empty cars are placed for loading is located inside the area covered by the cableway, a trolley wire over the center of the track would interfere with the loading. It was desirable to use a standard locomotive for the handling of these cars, so the brackets which supported the

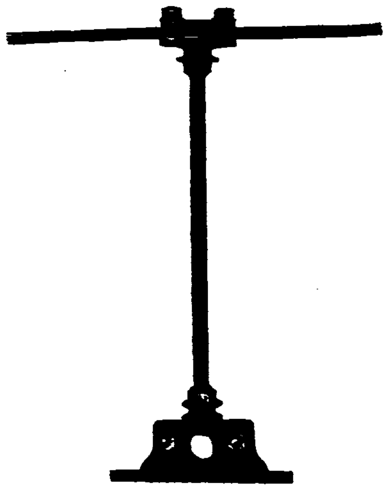


**Fig. 5. Rigid Catenary Pull Off**

trolley and messenger wire were hinged at the pole and a flexible wire cable, attached to the outer end and passing over a pulley anchored on top of the pole, was connected to a hand-operated windlass by which the brackets are swung upward carrying the trolley line from over the track and clear of the path of the bucket. When the loading is completed the trolley is lowered to the normal position while the loaded cars are removed and replaced by other empties.

The number of poles and costs will be found in Table II.

The matter of insulation was not a serious one as trolley voltage up to 11,000 volts had been in operation for a number of years and insulation difficulties for such pressures had been met quite satisfactorily. It was therefore simply a question of choice between wood and porcelain, the decision eventually being made in favor of wood as the dry climate in the locality was favorable to its satisfactory service with greater general economy.

The wooden strain insulators used are shown in Fig. 7 and the number employed and the costs are given in Table II.

Insofar as the general plan of trolley construction is concerned no decidedly radical departures from some of the later installations was attempted, but every effort was made to simplify and perfect what had been done before and to adapt the construction to the particular conditions.

A very important item tending toward economy and simplification was the omission of the use of any form of deflector at all special work. Some new departures were made in the manner of arrangement of the trolley wires at these points so as to insure the pantographs picking up and dropping them properly.

At switching points, in ordinary trolley wire construction, frogs are employed to make the trolley junction; and for use with pantographs deflectors are generally required.

Fig. 6. Wedge Grip Clevis

Fig. 7. Wooden Strain Insulator

These deflectors prevent the pantograph, when approaching such a junction toward a trailing switch, from raising its wire above that of the converging track, and thus avoid the damage that would result to either the pantograph or the trolley wire. Instead of this usual type of construction the trolley and messenger wires which were intended to follow the switching track were started several feet ahead of the switch, from a convenient point for dead-ending, and several inches above the horizontal plane of the

Fig. 8. Pantograph in Contact with Six Trolley Wires at a Switching Point

through wires and then gradually brought down to that plane a short distance ahead of the switching point from where they were gradually carried away following over the switching track. At some points in the yards, where the parallel tracks left the ladder track at close intervals, as many as six sets of wires are in the same horizontal plane and all the trolley wires make contact with the roller simultaneously. See Fig. 8.

This construction has proved entirely satisfactory and there have been no instances of trouble caused by the omission of deflectors. The construction adopted not only lessened the cost of the work but avoided much extra weight at points where the supporting structure was most taxed. Fig. 9 is an illustration of the construction described.

Air section insulation was used at all points where it was practicable and has been found to be advantageous from every point of view. Instead of inserting wooden insulators in the trolley line where sectionalization was desired, the ends of the wires of each section were made to overlap each other the length of a pole spacing. The two sets of wires are carried in approximately the same horizontal plane but about 12 inches apart for a few feet in the middle of the span, from which point the dead ends of the trolley wire are gradually carried above the path of the collector to its anchorage.

This construction avoids the use of heavy insulators and prevents hard or heavy spots in the line which are destructive to it and the pantograph alike. With this construction there is less objection to subdividing the line into a number of short sections which, with the elasticity provided by wooden poles and catenary suspension, overcomes to a great extent the difficulties arising from contraction and expansion due to changes in temperature.

These sections are passed at full speed without any noticeable effect on the line, or the pantograph, or the least interruption of contact.

Similar construction was used at all anchoring points for both the trolley and messenger and it has been found to be equally satisfactory there. Undoubtedly this type of sectionalizing will become much more general in the future and means will be devised for its adoption at points where it is now found difficult to install properly.

Tests were made by cutting the current off one section and running a locomotive from the live section onto the dead section at slow speed with heavy current to see if the arcing between the pantograph and the live trolley wire would be injurious. The arcing was surprisingly small and not of a nature to do serious harm to either wire or roller. Fig. 10 shows the general method of installation.

The effect of such an operation in the case of the wooden section insulators, used at street railway crossings and other points

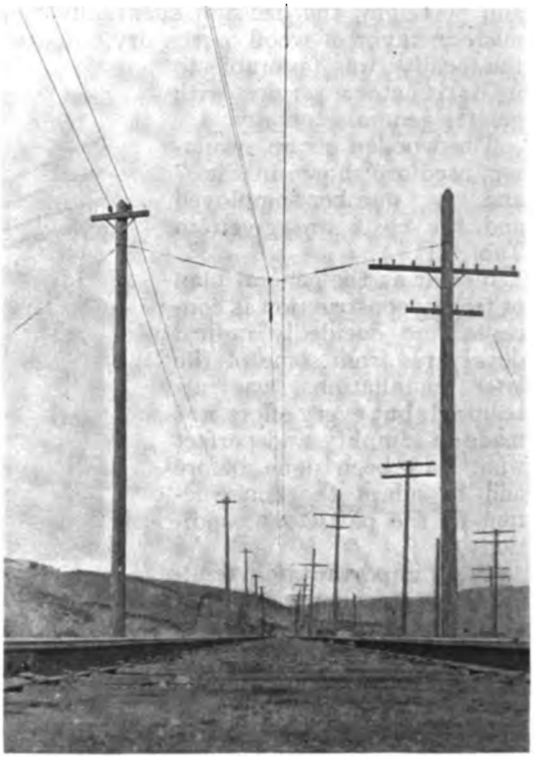


**Fig. 10. The Arrangement of an Air Section Insulator**

**Fig. 9. View of the Contact System at the Stock Bin Yard**

where it was not found convenient to install the air type, was quite injurious; and, though such tests were not meant to be given them and the insulators were not expected to stand such treatment repeatedly, some of those located at street crossings where considerable switching was done received the test too frequently and sooner or later broke down under the treatment.

At these street railway crossings it was necessary to use two such insulators about 75 feet apart in the 2400-volt line, the trolley section in between being called the protecting zone. This was made necessary on account of the operation of double-unit locomotives with a trolley of each in use and the two being connected by a bus line.

As the first insulator was usually about 100 feet from the switch and the safety section was not energized until a member of the train crew ran ahead and threw a commutating switch located on a pole near the street crossing (which cut off the commutating section from the normal 600-volt connection and energized it with the 2400-volt current so long as the switch handle was held in the full up position) it frequently happened in the earlier period of electrical operation, before the crews had learned from actual experience the damage that might result, that the member of the crew whose duty it was to run ahead and operate the switch did not get it thrown until the locomotive had passed under the first insulator. As this was often done with the power on the motors, the arcing that occurred when the roller left the live section of the insulator and ran onto the dead section carbonized the wood of the insulator, and the carbonization was extended with each repetition until the insulation was finally insufficient and the insulator had to be replaced. The insulator originally used at these points is shown in Fig. 11. These experiences suggested the advisability of a change in the design of the insulator so as to render the arcing in such instances less destructive. The overlapping metal contact strips which originally were attached directly to the bottom of the wooden insulators were therefore replaced by other strips which were carried out about four inches from the wood insulation, thus making the distance between the strips considerably greater. These strips were attached to the insulators by spring hinges, so as to lessen the blow to both the insulator and pantograph. The insulators were quite an improvement over the original ones but even they were not entirely free from injury when heavy currents were broken under the conditions heretofore described. Fig. 12 shows the general arrangement of the electrical connections for these street railway crossings.

The Butte, Anaconda & Pacific tracks cross local street railway tracks at six points,

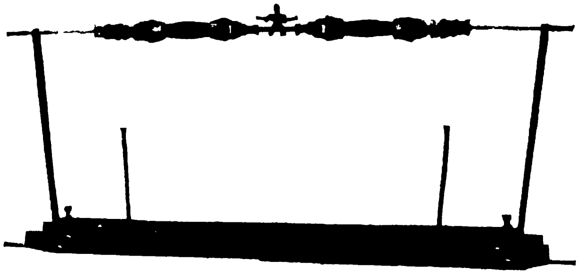


**Fig. 11 Section Insulator for a Pantograph Collector as Installed at a Cross Span**

four of which are at street level in Butte. Two are at the Anaconda end, but at these, not being street crossings, it was possible to avoid the use of the special switching devices by arranging with the street railway company to coast over the crossing. At two of the crossings in Butte watchmen were permanently employed to operate gates for protecting the traffic. The electrical switches for controlling the crossing at these points were placed on poles near the watchman's tower where he could operate them easily, and they were interlocked with the gates so as to make it impossible to energize the crossing with the 2400-volt current until the gates were closed or to open the gates while the switch was in the 2400-volt position.

Practically no trouble was experienced at these points after the watchmen became accustomed to their new duties, but at the less frequently used crossings where the train crews operated the commutating switches some troubles were experienced with the switches in addition to that already noted with the section insulators. These switches were not expected to open heavy currents for the operators were expected to hold them in until the locomotive had entirely cleared the protecting zone. Occasionally this was not done or to aggravate matters the switch was allowed to only partly open while the locomotive was still in the protecting zone, and when arcing was noticed in the switch box the handle was dropped and the switch badly burned. These commutating switches are shown in Fig. 13. At one point where this trouble occurred a second time, electrically

**Fig. 12. General Arrangement of the Electrical Connections at a Street Railway Crossing**

operated contactors were placed in series with the ordinary operating switch on both the 2400-volt and 600-volt circuits, the two sets of contactors being so interlocked as to render it impossible for both to be energized at the same time. See Fig. 14.

No further troubles were experienced from this cause after the installation of the contactors. These switches have been redesigned for future installations. After the men had become familiar with the operation of the switches there were very few instances of trouble even with the original switches.

The trolley line was sectionalized at intervals as shown in Fig. 15 which also shows the final feeder arrangement. The sectionalizing switches were placed in asbestos lined wooden boxes and located on trolley poles well out of reach from the ground. An operating lever was located at a convenient point on the pole, and at a suitable distance from the ground for ease in handling. It is provided with a standard track switch padlock so that no extra key is required by trainmen for its operation. The operating handle is connected with the switch blade by a wooden rod which provides adequate insulation.

In addition to the sectionalizing of the main line these switches were used at all yards and at most spurs and transfer tracks to connecting lines, and at such of these points as the service was infrequent the switch was normally left open. Such transfer connections were made with four other railway lines, viz., Great Northern, Northern Pacific, Chicago, Milwaukee & St. Paul, and the Oregon Short Line.

Eleven point suspension with 28 inch deflection was used throughout.

Approximately 10 per cent of the 91 miles of track electrified was bracket construction which was used on nearly all tangent single track. These stretches of tangent track were so short comparatively and the percentage and degree of curvature so great that it was unnecessary to make any special provision for staggering the trolley wire. Approximately 38 of the 91 track miles would be classified as route miles leaving about 53 miles—or roughly 58 per cent—of yards, sidings, spurs, etc. These 53 miles were made up principally of 8 yards located at Anaconda, East Anaconda, Silver Bow, Rocker, West Butte, and Butte on the main line and the Concentrator Bins, Storage Bins, and Butte Hill Yards on branch lines. Fig. 16 shows in

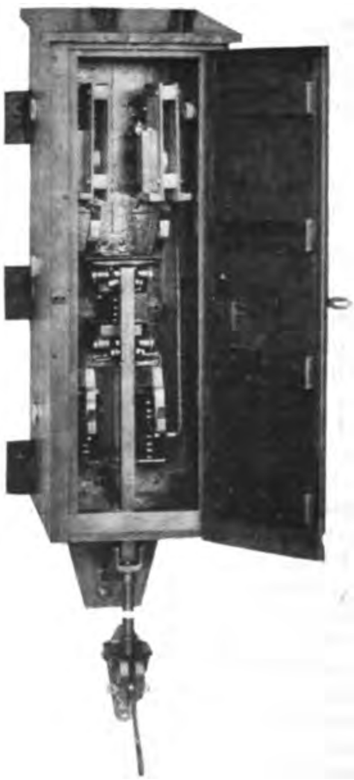


**Fig. 13. A Commutating Switch**

map form the relative location of these yards and spurs as well as the number and arrangement of the tracks, etc.

The East Anaconda Yards contained 12 tracks (including those of the main line) aggregating approximately 5 miles. These are the largest yards on the system. Eight of these tracks run almost the entire length of the yard which is approximately ½ mile in length. The eight tracks are spanned by double messenger span wires supported from a pole line on each side spaced approximately 110 ft. apart. The details of this construction with dimensions are given in Fig. 17.

At the western end of the yard there are four additional stub end tracks where a third pole line was erected to form the outside support for the wiring. This eight track span construction has stood up well and is quite satisfactory. All the construction in the yards and spurs is of the standard catenary type and entire freedom from any kind of trouble with it would seem to fully justify any additional expense that this may have required.

The construction work was practically completed in October, 1913, though some small extensions were made on Butte Hill in 1914.

Fig. 18 illustrates the form of weekly report that was made to indicate the progress and general condition of the work during construction. As this was the last such report made, it represents practically the completed construction and indicates how nearly the original estimates correspond with the final results in addition to giving many other details of useful interest relative to the nature of the work.

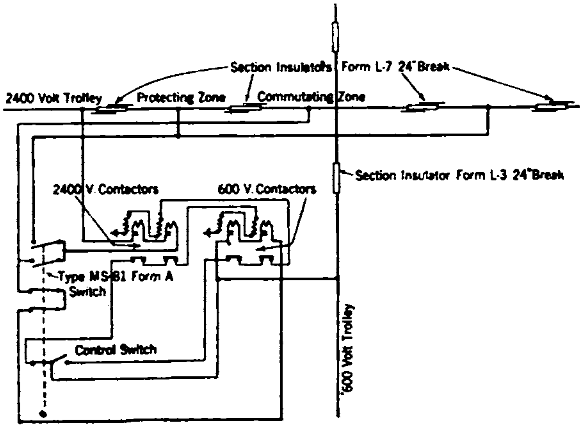



**Fig. 14. Diagram of Connections at a 600-volt Street Railway Crossing showing commutating arrangement and protection from 2400-volt System with Electrically Operated Contactors in Series with Regular Commutating Switch**

This report was not intended to cover other than the regular construction and, therefore, does not include the entire list of all the items mentioned; some further short extensions were made at a later date.

The total cost of the trolley and feeder system inclusive of bonding and all changes

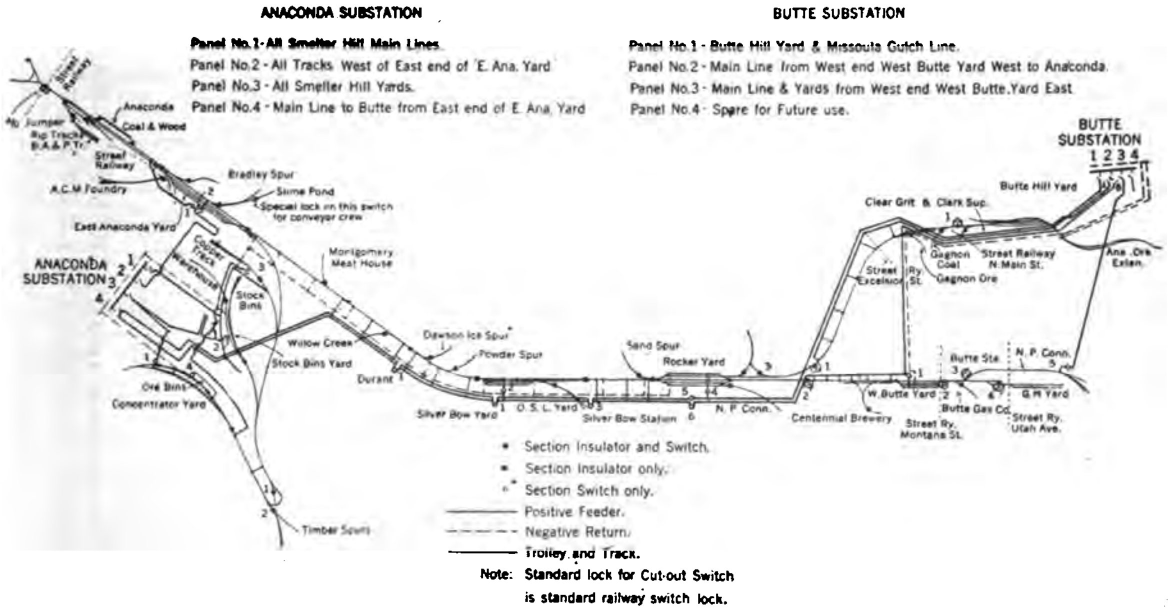



**Fig. 15. Diagram Showing Sectionalization of Trolley and Feeder Systems**

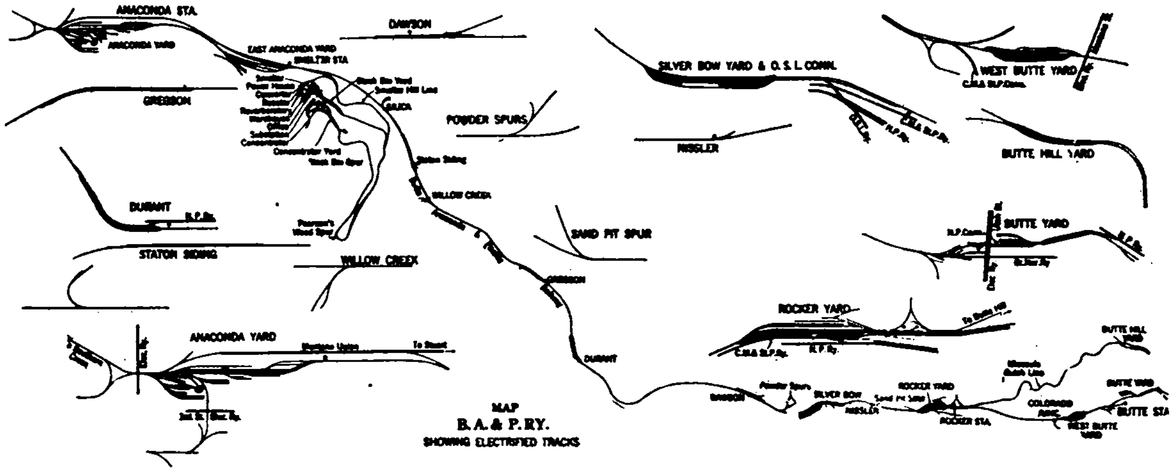



**Fig. 16. Diagram of the Electrified Section of the Butte, Anaconda & Pacific Railway**

**TABLE I**

**COST OF DISTRIBUTION SYSTEM**

**ELECTRIFICATION OF THE BUTTE, ANACONDA & PACIFIC RAILWAY**

| | Cost per Item | Cost Per Mile |
|---|---|---|
| Labor installing | **$129,027.56** | **$1417.89** |
| Feeder copper | 89,697.00 | 985.68 |
| Work train service | 64,268.31 | 706.25 |
| Trolley wire | 58,213.60 | 639.71 |
| Cedar poles | 27,739.21 | 304.83 |
| Galvanized strand wire | 26,807.47 | 294.59 |
| Copper bonds | 20,564.20 | 225.98 |
| Hangers | 7,596.27 | 83.48 |
| Crosby clips | 5,396.17 | 59.30 |
| Wood strain insulators | 5,385.22 | 59.18 |
| Engineering and superintendence | 5,289.30 | 58.12 |
| Tools | 3,811.30 | 41.88 |
| Anchor rods | 3,403.73 | 37.40 |
| Sectionalizing switches | 3,097.05 | 34.03 |
| Injuries and damages, etc. | 3,036.56 | 33.37 |
| Fitting up work cars | 2,292.61 | 25.19 |
| Steel and iron from stock | 2,043.87 | 22.46 |
| Lumber and timbers | 2,013.61 | 22.13 |
| Rental on work cars | 1,716.50 | 18.86 |
| Shop expenses | 1,418.59 | 15.59 |
| Lightning arresters | 1,271.02 | 13.96 |
| Paints and oils | 901.32 | 9.90 |
| Feeder and messenger insulators | 842.15 | 9.25 |
| Creosote and oil | 637.00 | 7.00 |
| Steel bond protectors | 570.00 | 6.26 |
| Splicing sleeves | 294.00 | 3.23 |
| Postage, car-fares, etc. | 238.62 | 2.62 |
| Guards and signs | 234.08 | 2.57 |
| Wedge grips | 130.01 | 1.43 |
| Dynamite and fuses | 121.36 | 1.33 |
| Gasoline, solder, etc. | 100.46 | 1.10 |
| Miscellaneous items | 33,629.50 | 369.55 |
| Total | **$501,787.74** | **$5514.15** |

made necessary in the way of clearance for poles, wiring, etc. (such as relocation of tracks, telephone, telegraph and light wires, etc.) up to the fiscal period ending June 30, 1914, as reported to the Interstate Commerce Commission was $501,787.74. This would make the average cost of the overhead system per track mile $5514.15 or per route mile $13,381.00.

An itemized list of these costs is given in Table I, while the amounts and unit costs of the principal items involved will be found in Table II. The total costs given are from the official records of the railway company, which are classified in accordance with Interstate Commerce Commission regulations as appears in Table III, which includes the entire cost of the electrification.

The whole of Accounts Nos. 12, 16, 19 and 22 and such portion of No. 1 as was directly in connection with the distribution system are taken as the total cost of that system.

The listed items in Table I are approximately correct though in some instances there was some question as to the proper allocation. However, the general results are as nearly correct as is practicable and even the slightest variations in local conditions would easily offset any likely discrepancy in the proportioning of these costs. The sum of the listed items was subtracted from the total cost and the remainder listed as miscellaneous thereby covering all items of materials and labor, etc., not definitely specified, leaving no question as to the total cost.

All this construction was done while the road was under full operation and under many conditions which tended to increase the cost above normal.

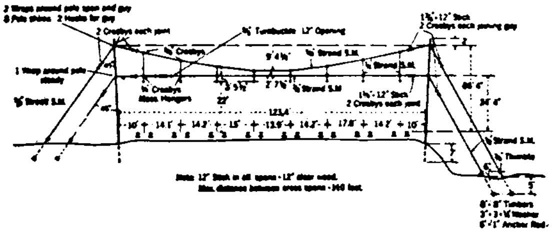
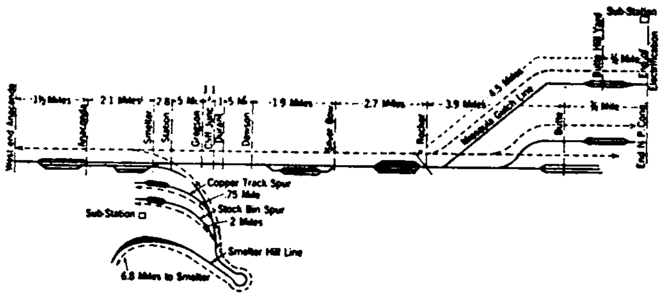


Fig. 17. Diagram showing Dimensions of a Cross Catenary Span for eight tracks

The principal items tending to increase the cost were the large percentage of curves and special work, the high price of all labor, the interference from foreign wires, the changes in location of tracks, walkways, platforms, buildings, trestles, bridges, etc., which was made necessary on account of the electrification, extra heavy traffic on the main line due to the use of fifteen miles of it by a transcontinental line for all traffic while a connecting link for this section was being built, strike of electrical wiremen, cold weather, variation of ground condition, number of street railway crossings, etc.




Remarks:
Great Northern work held up on account of moving freight house.
Construction work finished except:
Wiring of Great Northern Yard at Butte.
Foundry tracks at Anaconda.
Installing new lightning arresters.
Installing signals at railway crossings.

PROGRESS REPORT FOR WEEK ENDING OCTOBER 25, 1913

| | Poles | Pole bracket | Cross arms | Pole anchors | | Positive feeder | Negative feeder | | Trolley and messenger | | Spans | Back | Bonds | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Earth | Rock | 600 M. and 500 M. | 600M | 4/0 | Run out | built | | Bone | 10″ | 36″ | 48″ | Cross Bond | Long at Prog | Rock | Pole |
| | | | | | | miles | miles | miles | miles | miles | | | | | | | | | Guys |
| Estimated total for work | 4250 | 370 | 1600 | 4600 | 300 | 55 | 2 | 20 | 94 | 94 | 1700 | miles | 7800 | 2450 | 22800 | 450 | 300 | Holes | 7038 |
| Total previously installed | 4846 | 270 | 1408 | 5503 | 187 | 51 05 | 0.89 | 19 18 | 98 56 | 98 56 | 2580 | 32 21 | 7927 | 2408 | 19893 | 175 | 362 | 513 | 19 |
| Installed during current week | | | | | | | | | | | 4 | | | | | | | | |
| Total installed to date | 4846 | 270 | 1408 | 5503 | 187 | 51 05 | 0.89 | 19 18 | 98 56 | 98 56 | 2584 | 32 21 | 79 27 | 2408 | 19893 | 175 | 362 | 513 | 7C57 |

Fig. 18. A Tabulated Progress Report

It is not likely that the average steam road would encounter so many obstacles of this nature in undertaking the electrification of its lines, for seldom would there be found more complications than in this case where the nature of the work (being required for a mining and smelting industry of large magnitude) calls for many varieties of structures and conditions not usually to be encountered in ordinary railway electrifications.

The work was begun in the summer of 1912 and was just reaching a state of efficient organization when the electrical wiremen went on strike tieing up the entire work from June to October, about three months of the most favorable part of the year for such work, thus bringing the heavy part of the work in the winter when the weather at times was 20 degrees below zero. During the three months cessation of work the engineering and supervision force was continued at a very low percentage of efficiency and this delay contributed in various other ways to an increase in the cost of the construction.

Some of the items of expense in connection with changes made in existing construction and charged against the distribution system are shown approximately in Table VI. The new telephone lines listed in this tabulation were run on the trolley line poles and were for the purpose of enabling the train crews to communicate with the dispatcher from any locomotive on all of which telephone instruments were installed, together with a standard rod for making electrical connections with the wires at any point along the line.

Table VI is by no means complete, though it gives an indication of the various items represented in the total costs of the system.

Combining eleven pay rolls gives the classification of labor, see Table VII. These eleven payrolls represent the principal items of labor in connection with the erection of the trolley and feeder wires, and are those for the regular forces engaged in this work and charged against account No. 22, Table III.

**TABLE II**

**TABLE SHOWING AMOUNTS AND COSTS OF PRINCIPAL MATERIALS REQUIRED FOR BUTTE, ANACONDA AND PACIFIC DISTRIBUTION SYSTEM**

| | Total Units | Units Per Mile | Costs Per Unit | Total Cost |
|---|---|---|---|---|
| Feeder copper, lb. | 507,055 | 5,572 | 17.69 cents | $89,697.00 |
| Trolley copper, lb. | 343,030 | 3,770 | 16.97 cents | 58,213.60 |
| Cedar poles | 4,869 | 53.5 | 566.00 cents | 27,739.21 |
| Galvanized steel strand, feet | 1,553,750 | 17,074 | 1.73 cents | 26,807.47 |
| Copper bonds | 32,260 | 355 | 63.74 cents | 20,564.20 |
| Crosby clips | 61,911 | 680 | 8.72 cents | 5,396.17 |
| Wood strain insulators | 15,850 | 175 | 33.97 cents | 5,385.22 |
| Anchor rods | 6,123 | 673 | 55.57 cents | 3,403.73 |
| Splicing sleeves | 265 | 3 | 111.00 cents | 294.00 |
| Wedge grips | 680 | 7.5 | 19.13 cents | 130.01 |
| Total | | | | $237,630.61 |

**TABLE III**

**COSTS OF THE ELECTRIFICATION OF THE BUTTE, ANACONDA & PACIFIC RAILWAY CLASSIFIED IN ACCORDANCE WITH INTERSTATE COMMERCE REGULATIONS**

| | |
|---|---|
| Account No. 1—Engineering and superintendence (including general preliminary report) | $10,937.15 |
| Account No. 12—Roadway tools (used for construction 19 and 22) | 3,851.74 |
| Account No. 16—Crossings, fences, guards and signs, mostly for signs | 234.08 |
| Account No. 17—Interlocking and signal apparatus, new system required account of electrification | 22,367.62 |
| Account No. 19—Poles and fixtures (approximately 91 miles track) | 135,263.98 |
| Account No. 22—Distribution system (approximately 91 miles track wired) | 357,009.45 |
| Account No. 25—Substation building (existing building used) | 191.15 |
| Account No. 31, Account No. 36—Electrical Equipment (five 1000-kw. motor-generator sets and 17 locomotive units) | 671,764.78 |
| Account No. 41—Interest | 9,975.80 |
| Total | $1,211,595.75 |

Time and a half was allowed for all overtime and double time for Sunday work in the case of electrical workers.

Wages and perhaps most materials were somewhat higher in the locality of Butte than in any place east of it or in most places in the western states.

The operation of the overhead system as a whole has been quite satisfactory in every respect for there have been practically no troubles or delays to traffic on account of it. There were two instances of wires slipping in the splicing sleeves due to the wedges not being properly driven up. One of these instances was in connection with the trolley wire and the other with the messenger. In both cases the results were negligible for, in the first instance, the trolley hangers slid back along the messenger much as the rings hanging a curtain slide along the supporting wire until the tension was evened up, the trolley being held clear of the ground by the messenger; while, in the second instance, the messenger slid back through the loop of the hanger until the tension was relieved but was supported clear of the ground by the trolley wire so that no harm resulted. All that was necessary to remedy the trouble on

**TABLE IV**

**COST OF MAINTENANCE AND DISTRIBUTION SYSTEM, OCTOBER, 1913, TO MARCH, 1915, INCLUSIVE**

| | Poles and Fixtures | | Trolley | | Feeders | | Bonding | | Miscellaneous | | Total | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Labor | Material | Labor | Material | Labor | Material | Labor | Material | Labor | Material | Labor | Material | Labor and Material |
| Oct. 1913 | | | | | | | | | $291.85 | $7.50 | $291.85 | $7.50 | $299.35 |
| Nov. 1913 | .... | .... | .... | .... | .... | .... | .... | .... | 431.20 | 264.47 | 431.20 | 264.47 | 695.67 |
| Dec. 1913 | .... | .... | .... | .... | .... | .... | .... | .... | 426.35 | 114.74 | 426.35 | 114.74 | 541.09 |
| Jan. 1914 | .... | .... | .... | .... | .... | .... | $60.50 | .... | 390.30 | 88.72 | 450.80 | 88.72 | 539.52 |
| Feb. 1914 | .... | .... | .... | .... | $334.65 | .... | 65.95 | .... | 286.25 | 784.21 | 686.85 | 784.21 | 1471.06 |
| Mar. 1914 | .... | .... | .... | .... | 32.40 | .... | 64.95 | .... | 570.55 | 808.51 | 667.90 | 808.51 | 1476.41 |
| Apr. 1914 | .... | .... | .... | .... | .... | .... | 37.65 | .... | 313.65 | 348.95 | 351.30 | 348.95 | 701.25 |
| May 1914 | .... | .... | .... | .... | .... | .... | 40.20 | .... | 526.75 | 628.36 | 566.95 | 628.36 | 1195.31 |
| June 1914 | .... | .... | .... | .... | .... | .... | 24.00 | .... | 473.65 | 972.08 | 497.65 | 972.08 | 1469.73 |
| July 1914 | $599.95 | $14.43 | $449.25 | .... | 150.95 | Cr.235.64 | 104.65 | .... | .... | .... | 1304.80 | Cr.221.21 | 1082.59 |
| Aug. 1914 | 219.65 | 15.09 | 446.50 | .... | 23.15 | 320.57 | 47.40 | .... | .... | .... | 736.70 | 335.66 | 1072.36 |
| Sept. 1914 | 251.50 | 26.98 | 98.70 | $9.32 | .... | 206.25 | 24.05 | $66.22 | .... | .... | 374.35 | 308.77 | 683.12 |
| Oct. 1914 | 172.10 | .... | 389.15 | .... | 26.95 | 55.86 | 10.90 | .... | .... | 367.94 | 599.10 | 423.80 | 1022.90 |
| Nov. 1914 | 105.10 | .13 | 165.30 | .... | 70.90 | 4.64 | 43.10 | 64.57 | .... | .... | 384.40 | 69.34 | 453.74 |
| Dec. 1914 | 134.90 | 6.12 | 103.45 | .48 | 9.20 | 42.96 | 30.85 | 94.54 | .... | .... | 278.40 | 144.10 | 422.50 |
| Jan. 1915 | 115.55 | .... | 186.95 | 19.36 | 49.10 | .... | 94.90 | 99.68 | .... | .... | 446.50 | 119.04 | 565.54 |
| Feb. 1915 | 152.95 | 2.47 | 135.15 | 3.08 | 63.45 | 45.41 | 39.20 | 97.55 | .... | .... | 390.75 | 218.51 | 609.26 |
| Mar. 1915 | 163.55 | 6.58 | 141.15 | .50 | 67.05 | 91.04 | 58.40 | 66.02 | .... | .... | 430.15 | 164.14 | 594.29 |
| Total 18 months | 1915.35 | 71.80 | 2115.60 | 32.74 | 827.70 | 601.09 | 746.70 | 488.58 | 3710.55 | 4385.48 | 9316.00 | 5579.69 | 14895.69 |
| Rate per year | 1276.90 | 47.86 | 1410.40 | 21.83 | 551.87 | 400.72 | 497.80 | 325.72 | 2473.70 | 2923.65 | 6210.69 | 3719.79 | 9930.46 |
| Rate per mile per year | 14.03 | .48 | 15.50 | .22 | 6.06 | 4.40 | 5.47 | 3.58 | 27.18 | 32.13 | 68.25 | 40.88 | 109.13 |

**TABLE V**

| | Smelter Hill Service East Anaconda to Concentrator | | | | Main Line Service Rocker to East Anaconda | | |
|---|---|---|---|---|---|---|---|
| | Train No. 1 | Train No. 2 | Train No. 3 | Average | Anaconda to Rocker | Rocker to Anaconda | Average |
| No. of cars in train | 18 | 21 | 25 | 21.3 | 64 | 57 | 60 |
| Gross wt. tons | 1420 | 1580 | 1910 | 1633 | 1335 | 4150 | |
| Ton-miles, gross | 9940 | 11060 | 13370 | 11431 | 26700 | 83000 | 54850 |
| Schedule speed | 16.1 | 16.2 | 14.2 | 15.5 | 20.1 | 20.1 | 20.1 |
| Avge. amperes-total | 580 | 583 | 667 | 610 | 366 | 380 | 373 |
| Avge. volts | 2327 | 2277 | 2276 | 2293 | 2325 | 2345 | 2335 |
| Avge. kilowatts | 1350 | 1327 | 1518 | 1398 | 852 | 891 | 872 |
| Max. amperes | 860 | 640 | 800 | 767 | 624 | 640 | 632 |
| Maximum volts | 2456 | 2419 | 2456 | 2444 | 2475 | 2435 | 2455 |
| Max. kilowatts | 1951 | 1500 | 1733 | 1728 | 1368 | 1510 | 1439 |
| Total kilowatt-hours | 580 | 560 | 746 | 629 | 852 | 654 | 753 |
| Watthours per ton-mile | 61.4 | 50.6 | 55.82 | 55.02 | 31.91 | 7.87 | 13.73 |
| Minimum volts | 2250 | 2119 | 2100 | 2156 | 2175 | 2175 | 2175 |
| Max. drop per cent | 8.4 | 12.4 | 14.5 | 11.8 | 12.1 | 10.7 | 11.4 |
| Avge. drop per cent | 5.3 | 5.9 | 7.3 | 6.9 | 6.0 | 3.6 | 4.9 |

both occasions was to pull the parted wire back into position and properly wedge it into the sleeve. There have been two instances of the trolley wire parting due to the improper welding of the metal in manufacture and other similarly negligible instances common to such installations.

TABLE VI

| | |
|---|---|
| New telephone line on trolley line poles | $7,850.64 |
| Changing light, power, telephone and telegraph lines | 4,273.15 |
| Changing street railway crossings | 1,546.65 |
| Relocating railway tracks | 815.90 |
| Raising drip sheds | 785.54 |
| Changing station platforms | 693.29 |
| Raising wagon bridges | 361.52 |
| Total | $16,326.69 |

The most serious interruption that occurred was originated by the blasting out of some old bridge piles by the section men of a paralleling railway. A fragment of the pile was blown against a telephone wire carrying it across the 2400-volt trolley. This telephone wire ran through the switching board in all the stations along the line, some of which had not then been provided with the proper protecting devices. The result was that the arc set fire to some of the boards and in one, where the operator happened to be temporarily absent at the time, the building was burned setting fire to adjacent poles and parting both the trolley and messenger wires.

At the other stations involved, where the operators were present and could give prompt attention to putting out the arc, no serious damage resulted.

The maintenance men who took charge of the trolley system were put on October 1, 1913, and consisted of a foreman and two linemen who could requisition other assistance when an occasion demanded it. The cost of maintenance from this date up to and including March 31, 1915, covering the first 18 months operation, is given in Table V.

Beginning with July, 1914, these accounts were kept more in detail. These expenses include some rearrangements of feeder, etc., and the cost of some special instruments for bond testing, and tools. The average cost of maintenance of the distributing system inclusive of the track bonding for the 18 months has been at the rate of $109.13 per track mile per year.

Taking the last nine months during which the costs were segregated more completely gives the data listed in Table VIII.

To ascertain the rate of wear on the trolley wire, measurements were recently made on the Smelter Hill line where the traffic is heavier than at any other point and where the electric service has been in operation longest (just about two years).

The original diameter of the wire vertically was supposed to average about 0.482 of an inch. The minimum diameter found where the measurements were made was 0.470 of an inch. The average of a number of measurements was 0.475. It is usually considered safe to allow a 4/0 trolley wire to wear down to 0.350 thus allowing a wear of 0.132. If the maximum wear of 0.012 as found for the two years is taken as the average during the useful life of the wire, which is at the rate of 0.006 per year, the wire can be expected to last 22 years. At this portion of the line there has been an average of approximately 50 passages of pantograph rollers per day which for two years would be an aggregate of 36,500 passages or 18,250 per year indicating 3041 passages per thousandth of an inch wear.

TABLE VII

| | Days | Avge. Approx. Per Day | Total |
|---|---|---|---|
| Blacksmiths and helper | 27 | $3.08 | $110.58 |
| Boilermakers and helper | 26 | 3.76 | 97.78 |
| Carpenters and helper | 17 | 4.40 | 75.56 |
| Machinists and helper | 15 | 4.33 | 64.91 |
| Electricians and helper | 3,580 | 5.71 | 20,544.09 |
| Pipefitters and helper | 2 | 3.80 | 7.69 |
| Laborers | 3,035 | 3.56 | 28,611.53 |
| Teamsters | 35 | 3.25 | 106.96 |
| Electrical foremen | 835 | 6.35 | 5,300.62 |
| Foremen | 665 | 6.06 | 4,030.82 |
| Clerks | 500 | 3.35 | 1,670.42 |
| Totals | 13,737 days | $4.41 ave. | $60,620.96 |

It is perhaps questionable as to whether the first few months wear on the trolley wire would be at the same rate as after the contact surface had become greater. The outside surface of the wire might be slightly harder than the interior and thus the wear be less at the beginning, while on the other hand when the wire is new the contact area with the roller is quite small and the pressure per unit area together with the increased current density might cause more rapid wear. From such data as are at hand, it would appear that the rate of wear on the trolley is greater at the beginning and decreases as the contact area is increased. Extensive tests with a sliding contact, where the operating conditions were varied as to the amount of tension against the trolley wire and current collected, almost invariably indicated that the rate of wear decreased as the area of contact increased; and there seems no reason to suppose that the same would not be true in the case of the roller collector so that the average life of the trolley wire in this service should not be less than 20 to 25 years.

The roller collectors adopted for the service and described in the beginning of this article have performed their work in general equally as well as had been expected of them, though at the beginning of the electrical operation a number of minor improvements were found desirable. The rollers were operated against the trolley with an upward pressure of approximately 35 lb., the practice being not to readjust so long as the tension was not above 38 or below 33 lb., at the average operating height.

The first difficulties experienced with these rollers was from the sticking of the roller in the bearings, which resulted in their sliding along the trolley wire causing a flat spot or groove which rendered the roller unfit for further service (if not detected at an early stage).

This sticking was first due to the imperfect alignment of the clamping jaws which held the ends of the spindle passing through the roller and on which the bushings revolved. As the bearings consisted of four bushings 1½ in. long, being arranged in pairs one at each end with a space of 1 in. between the two bushings of each pair, thus making each lining substantially 4 in. in length, it was possible to clamp the ends of the spindle so tightly as to spring it out of line and cause it to bind in the bushings until it did not revolve with the ordinary friction offered by its contact with the trolley wire. This trouble was overcome by more care in the adjustment of the clamps. A little later the caps in the bearing heads began to loosen until they bound the roller between the clamps and caused them to slide as before. A set screw was provided which prevented the unscrewing of the caps and no more trouble from the sliding of the roller was experienced until extremely cold weather came and heavy frost accumulated on the trolley wire which, on being knocked off by the roller, lodged on top of the 2½ in. iron brace or hooker frame supported underneath the roller (having about $\frac{1}{16}$ in. clearance) piled up and finally clogged the roller causing it to slide with the same results as heretofore.

This difficulty was met by increasing the clearance of both the brace and the roller and inverting the **T** so that the web was on the bottom and thus did not offer so large an area for the collection of the frost.

Another defect that threatened trouble at an early stage was the removable cast iron wearing plates screwed to the pantograph

TABLE VIII

| | Poles and Fixtures | Trolley | Feeder | Bonding | Misc. | Total |
|---|---|---|---|---|---|---|
| Labor | $1915.35 | $2115.60 | $460.75 | $453.45 | $0.00 | $4945.15 |
| Material | 71.80 | 32.74 | 601.09 | 488.58 | 367.94 | 1562.15 |
| Total | $1987.15 | $2148.34 | $1061.84 | $942.03 | $367.94 | $6507.30 |
| Rate per year | 2649.53 | 2864.45 | 1415.79 | 1256.04 | 490.59 | 8676.40 |
| Rate per year per mile of track | 29.12 | 31.48 | 15.55 | 13.80 | 5.39 | 95.34 |
| Per cent labor | 96 | 98 | 43 | 48 | | 76 |
| Per cent material | 4 | 2 | 57 | 52 | 100 | 24 |
| Per cent of total | 31 | 33 | 16 | 15 | 5 | 100 |

head at each end of the roller and intended to guide the trolley wire smoothly from the horn onto the roller.

It was found quite difficult to keep this plate in proper alignment with the roller owing to the wearing down of the bushings and the increase in the end play of the roller, which allowed the trolley wire to hang in the gap between the wearing plate and the end of the roller. When this condition was not remedied promptly a groove was soon worn at this point which often made the replacement of the plate necessary and sometimes that of the roller tube as well. This difficulty was removed by the application of a new type of wearing plate which extended out slightly over the roller with a prong on either side gradually dropping below the line of the top of the roller so that the wire passed from one to the other so gradually that there was no point where the wire was inclined to catch. The lower end of this wearing plate extended out over the upper end of the horn in a similar manner and avoided the necessity of such careful fitting as had been required with the old type where butt joints were used. The new wearing plate is shown in Fig. 19.

The sleeve bearings with oil lubrication were fairly satisfactory in the freight service where the average speed was from 15 to 30 miles per hour but when the passenger service was started, requiring a schedule speed of 26 m.p.h. with maximum speeds of 45 to 50 m.p.h., the bushings wore out very quickly which allowed the oil to be carried out along the spindle and thrown off. It fell on the roofs of the locomotive and cars and made it necessary to replenish the oil at the beginning of each trip.

When the bushings became worn the roller vibrated considerably, causing more sparking at the contact with the trolley wire and often breaking the truss rods used for bracing the pantograph frame. In some instances these bushings were badly worn before they had made 200 miles.

Fig. 19. A Pantograph Folded showing Revised Wear Plate

Experiments were made with grease lubrication, which gave promise of good results and which led to some slight modification of the bearings and to a general substitution of grease for oil as a lubricant.

In the meantime tests were being made with Hyatt roller bearings and the results had been so encouraging that it was decided to substitute these for the sleeve bearings in all the rollers as fast as the latter wore out and required to be renewed. Fig. 21 shows their installation in the later rollers designed for this purpose.

The total locomotive miles made by the electric locomotives up to the end of March, 1915, was 927,234. The number of roller tubes received by the Railway Company up to that date was 123 including those that came on the locomotives and extra pantographs bought for spares.

On this data the roller tube stock was as shown in Table IX:

**TABLE IX**

| | |
|---|---|
| 5 | new rollers complete in pantographs |
| 29 | new tubes in stock |
| 20 | partially used tubes on locomotives |
| 10 | partially used tubes in stock |
| Total 64 | tubes used and unused, 34 of which are new and 30 partially worn, leaving 59 tubes that have been replaced. |

The master mechanic estimates that the 30 partially used tubes are, on the average, about half worn out, on which basis the average miles per roller would be $\frac{927{,}234}{79} =$ 11,750 or supposing that these tubes were two-thirds worn out the average mileage per tube would be $\frac{927{,}234}{84} = 11{,}030$ miles.

In this connection it should be noted that eleven of the 59 abandoned tubes were removed before they had been in service many miles on account of the rollers sticking and sliding along the trolley until a groove was cut in them as shown in Fig. 22. Some of

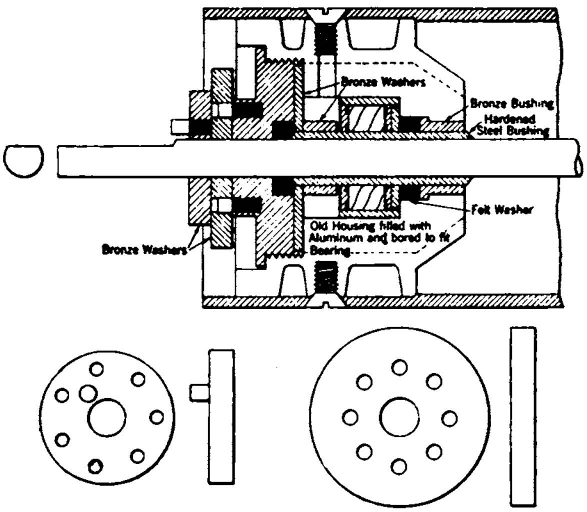



**Fig. 20. Original Pantograph Roller Housing Modified and Fitted with Roller Bearing**

these tubes were thus injured during the commencement of electrical operations before the defect had all been remedied, but most of them were caused by the frost freezing the roller to the **T** iron brace underneath, previously mentioned.

A large percentage of the above mileage was made before all the sleeve bearings were replaced by roller bearings or the clearance of the roller above the **T** iron had been increased.

Comparatively few rollers that were fitted with the roller bearings when new have yet

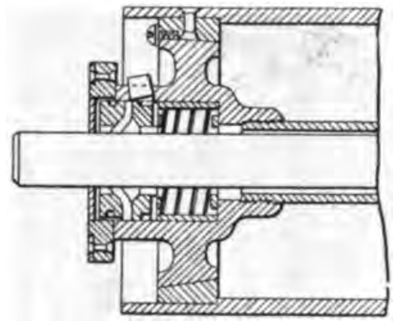


**Fig. 21. Latest Type of Pantograph Roller Designed for use with Roller Bearing**

had to be replaced. One roller which had been in the passenger service, where the average current collected is not so great as in the case of the freight service, though the speed is considerably higher, ran 26,880 miles before it was replaced. The average mileage of all tubes with roller bearings at the present time is approximately 16,000 miles which indicates that roller bearings are responsible for an increase of about 35 per cent in the average life of the rollers.

The old sleeve bearings with grease lubrication had to be renewed about each 5000 or 6000 miles, thus requiring about two sets of bushings during the life of a tube. The roller bearings after making 26,880 miles were in perfect condition and it is difficult to judge as to what mileage they will make but, from present indications, it is reasonable to expect that they will make at least 100,000 miles per set. It cost approximately $2.92 in labor and material to renew a set of the old bushings.

The cost of substituting the roller bearings for the bushings was approximately $2.20 for material and $2.25 for labor or $4.45 per roller. It will thus be apparent that the change was even more important from the point of saving in maintenance of bearings than from increased life of the rollers. The roller bearings require comparatively little attention, a small quantity of fresh grease being inserted at each regular inspection of the engine.

The general repairs to the entire pantograph have been likewise affected as the decreased vibration has stopped almost all pantograph troubles.

The repairs to other parts of the pantograph during the past six months consisted of renewing six wearing plates; the replacing of two horns and one cross bar.


**Fig. 22. View of Pantograph Rollers showing Injuries that have developed from sliding**

The average cost of maintenance of the original pantographs with the sleeve bearings was about $185 per month or approximately $3.20 per 1000 locomotive miles. The present corresponding cost of this maintenance is about $35 per month or 62 cents per 1000 locomotive miles which shows a decrease of approximately 81 per cent in this item.

It was found in practice that the wooden lining originally pressed inside the tube was unnecessary and this was omitted when the new bearings were installed.

The operation of these roller pantographs is, therefore, considerably more efficient than had originally been expected.

Two 500,000 feeder cables in multiple for the trolley and one 4/0 cable for the track circuits were run on the trolley line poles between the two substations; the other trolley feeder running to the yards which were fed separately or in pairs.

Voltmeter and ammeter readings were taken on a number of trains to ascertain the drop in voltage and energy consumption; a summary of these is given in Table V from which it will be seen that the maximum drop in voltage obtained was 14.5 per cent while the average drop for all readings was 5.6 per cent.

The readings making up the averages given were taken at 30 second intervals for the entire trips on the locomotives in regular service hauling normal trains under average operating conditions and are, therefore, fairly representative of general results. However, there has been a gradual increase in the weight of the trains which might slightly affect the average drop in voltage.

**Fig. 23. Section of Tangent Track, showing Pantograph Trolley Suspension as sketched in Fig. 17**

It may be of interest to note that repair work on the 2400-volt trolley line is done from an ordinary wooden work car without special insulation with full voltage on the line. There has been no serious cases of shock to the workmen.

In wet weather it is not considered safe to work from this car with full potential on the line but there should be little difficulty in constructing a tower car which would make it quite safe under any ordinary conditions.

The writer wishes to thank herein Mr. C. A. Lemmon, Chief Engineer and Mr. C. H. Spengler, Master Mechanic of the Butte, Anaconda & Pacific Railway, Mr. R. E. Wade, (now Ass't Electrical Engineer of the Chicago, Milwaukee & St. Paul) who had personal charge of the construction of the Butte, Anaconda & Pacific distribution system, and Mr. C. J. Hixson and staff for assistance kindly rendered in obtaining the data contained in this article.

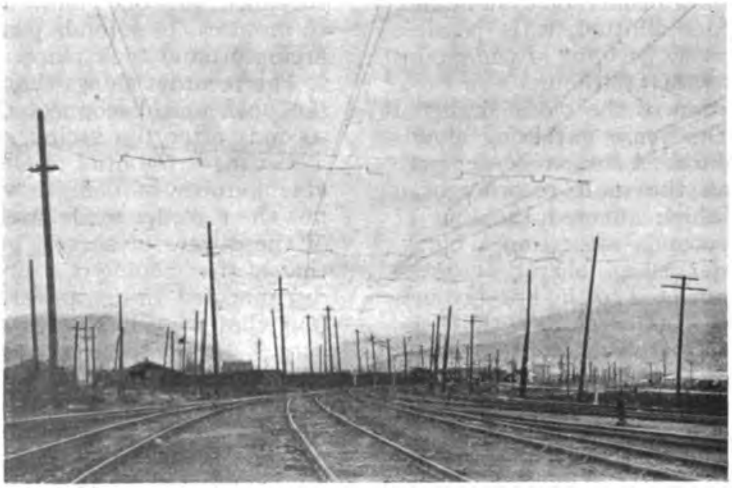


**Fig. 24. West End of East Anaconda Yard**