The Electrification of the Butte, Anaconda & Pacific Railway.

The Butte, Anaconda & Pacific Railway is in many ways one of the most remarkable examples of steam-railroad electrification in this country. Besides being the first 2,400-volt direct-current railway, it is also credited with being the first steam road operating both freight and passenger schedules to electrify its lines purely for reasons of economy. A number of steam railway electrifications have been made because of peremptory factors, such as terminal and tunnel operation or for rapid suburban service. This Montana road, however, cannot be classed as an "enforced electrification," since no such special limitations were the determining factors.

Electric locomotives were first put in service on this line on May 28, 1913. During the first seven months of service, they made approximately 201,000 miles and hauled about 2,365,000 tons of ore. The electric locomotives were described at length in the ELECTRICAL REVIEW AND WESTERN ELECTRICIAN of June 14, 1913, pages 1292 to 1294.

The steam-locomotive crews, consisting of engineman and fireman, easily acquired proficiency in handling the electric locomotives; in fact, two or three days' instructions from a competent electrical man were ordinarily sufficient. The change from steam to electric haulage was made without any change in the personnel of the train crews and without any delays or alterations in the schedule. The enginemen, without exception, have expressed themselves as being greatly pleased with the easy operation of the locomotives.

The electrified lines of this system extend from the Butte Hill yard to the smelter at Anaconda, a distance of 32 miles. There are numerous sidings, yards, and smelter tracks that have been equipped with overhead trolley, making a total of about 95 miles on a single-track basis.

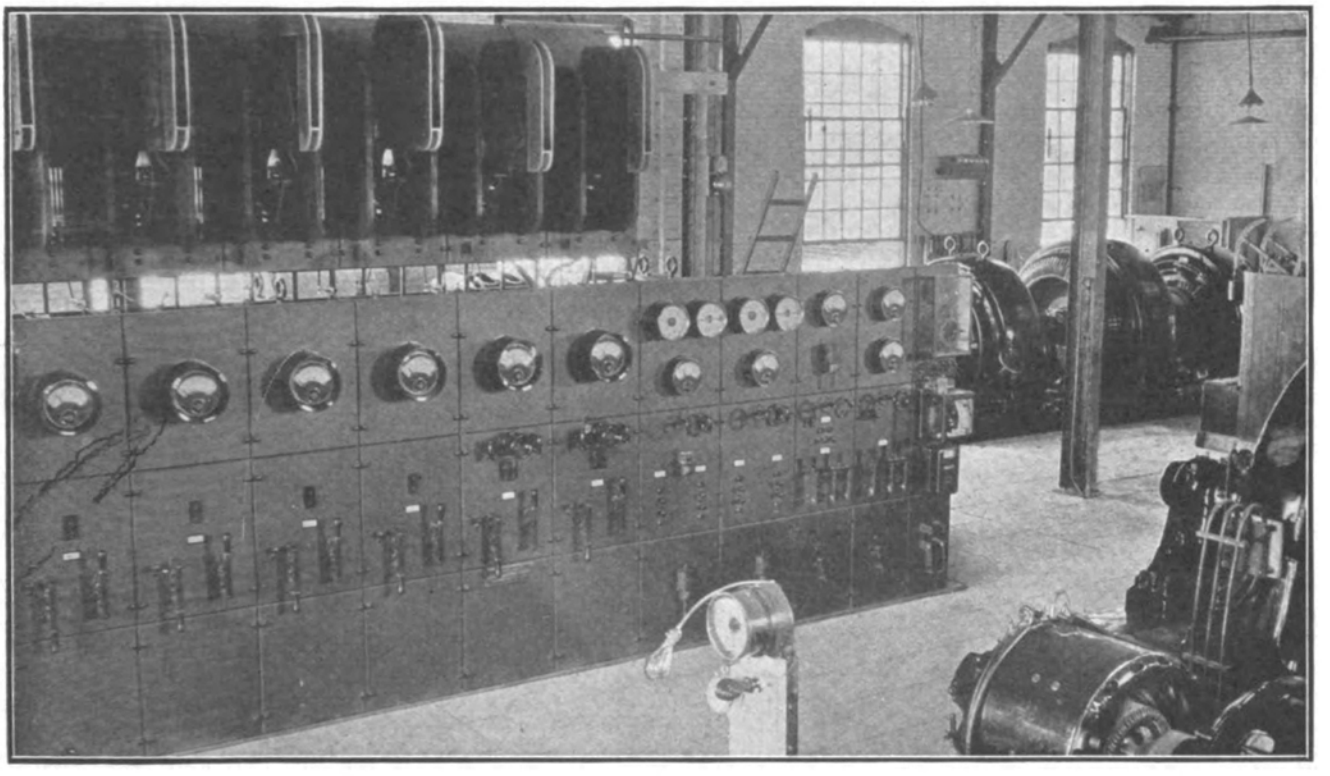
The Butte, Anaconda & Pacific Railway is essentially an ore-hauling road, the freight traffic from this source originating at the copper mines located near the top of Butte Hill. From the mines, the ore trains are lowered down the mountain a distance of 4.5 miles to the Rocker yards located a few miles west of the city of Butte. At this point, new main-line trains are made up for transportation to the smelters at Anaconda. The main-line division extends through a rough mountainous country, a distance of about 20 miles, with grades as high as 0.3 per cent.

At East Anaconda, the main-line trains are broken up and hauled up Smelter Hill to the stock bins, where each car is run over the scales and weighed. The shifting of cars in connection with weighing and subsequent delivery to the concentrators is done by single locomotives.

The east-bound traffic consists in returning empty cars to the mines and the transportation of copper ingot to the Butte yards, where it is shipped over other roads to refineries.

Between the cities of Butte and Anaconda, at the ends of the electrified portion of the system, there is considerable local traffic, both passenger and freight. The city of Butte and vicinity has a population of about 65,000, and Anaconda about 10,000. At Butte this railway connects with three transcontinental railways and for a distance of 16 miles it is paralleled by two of these lines, the Northern Pacific and the Chicago, Milwaukee & St. Paul. The last-named railway company has already contracted for power for the operation of electric trains from Harlowton, Mont., to Avery, Idaho, a distance of 440 miles.

The maximum curvature on the system (20 degrees, 285-foot radius) occurs on the Butte Hill line. On this part of the road there is an average curvature of 6 to 10 degrees. The locomotives are designed with sufficient flexibility to take a curve of 31 degrees (180-foot radius) at slow speed.



View in Anaconda Substation, Showing 2,400-Volt Direct-Current Switchboard and Motor-Generator Set.

The freight traffic consists largely of copper ore and amounts to more than 5,000,000 tons per year. This material is handled in steel ore cars weighing about 18 tons and having a capacity of 50 tons each. Trains of 30 loaded cars weighing 2,000 tons are made up at the Butte Hill yards and hauled by two-unit locomotives to the Rocker yards, where 4,000-ton trains are made up for the main line. At the East Anaconda yards, the trains are again broken up and 1,400-ton trains are sent up Smelter Hill to the ore bins. All of the shifting and spotting of cars, at the smelters and in the sorting yards is done by single locomotive units.

Eight passenger trains per day are operated between Butte and Anaconda, four in each direction. The main-line trains

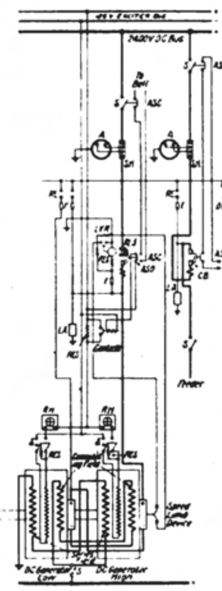
Michael Sol Collection

were first hauled by electric locomotives on October 1, 1913, and promptly demonstrated their ability to make better time than was possible with steam engines. Single locomotives are used, hauling trains of from three to five passenger and baggage cars.

Energy for the operation of electric trains is purchased from the Great Falls Power Company. The generating plant is located at Great Falls, Mont., on the Missouri River, and has for some time been supplying electric power for the operation of the mines and smelters at Butte and Anaconda. Six hydroelectric units are installed, having a nominal rated capacity of 21,000 kilowatts. The machines are of the horizontal type, generating 6,600 volts, three phase, at a frequency of 60 cycles. The power is stepped up to 102,000 volts for transmission to the transformer substation at Butte, a distance of 130 miles, over two separate parallel lines constructed on the same right of way. An extension of the system transmits power at 60,000 volts to a second transformer station at Anaconda, 26 miles farther on.

The Butte substation forms the center of the extensive power system operated by the Montana Power Company. Besides the Great Falls 102,000-volt transmission lines, there are several 60,000-volt transmissions terminating at this point, which form a part of the Montana Power Company's system. These lines bring in power from the Hauser Lake, Canyon Ferry, Madison and Big facilities. It is estimated that the additional load from this source is approximately 20 per cent of the railway, industrial and lighting load furnished by the street railways, mines, and smelters at Butte and Anaconda.

The two existing substations at Butte and Anaconda were used to house the



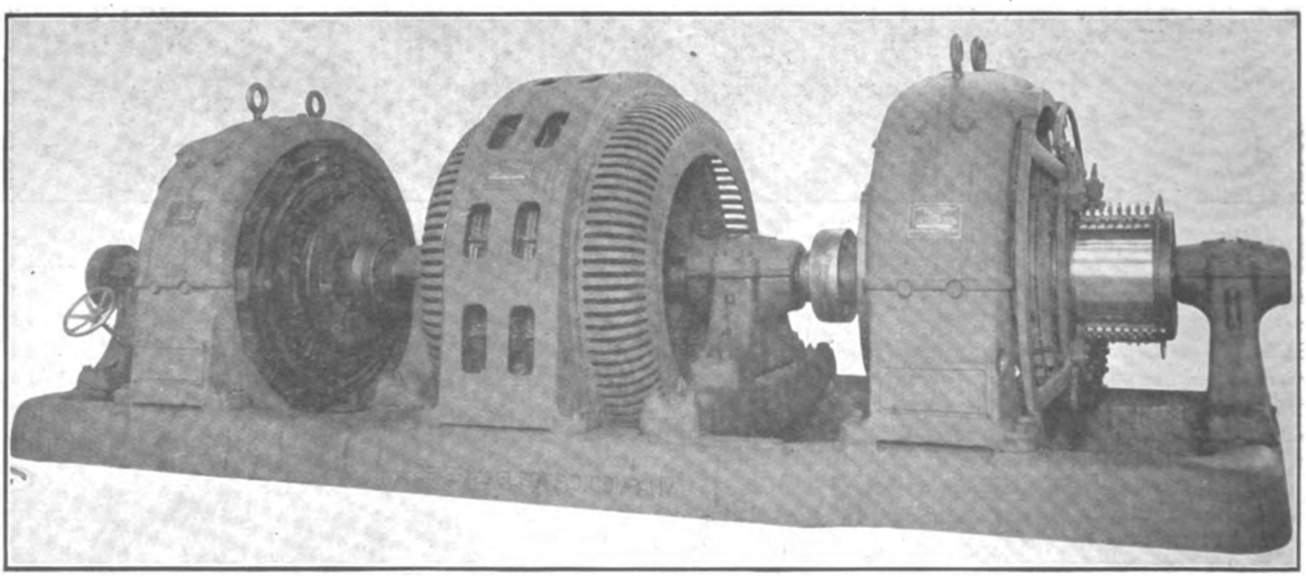
Direct-Current Wiring of Substation.

2,400-volt equipment required for operating the electric trains, so that no additional buildings were constructed for this purpose. Power is furnished by two 1,000-kilowatt, 3-unit motor-generator sets in each substation, taking power from the nected to operate in series for 2,400 volts. The generators are compound-wound and have both commutating poles and compensating pole-face windings. These fields are connected on the grounded side of the armature, and the main fields are separately excited. The 1,200-volt generators are provided with heatproof insulation and, owing to their unusually good commutating characteristics, will carry three times normal load for periods of five minutes, as well as the usual 50 per cent overload for two hours.

An automatic voltage regulator is used to maintain an approximately constant voltage at the terminals of the motor by power-factor regulation. The motors are protected against overload by inverse-time-limit relays, which are set to open at four times normal load. These relays have been adjusted to open under sustained overload in about two seconds and upon short-circuit their action is practically instantaneous.

Excitation for the two generating units in each substation is obtained from two induction-motor-driven sets, rated 50 kilowatts each at 125 volts. One set is used for supplying current to the synchronous-motor fields and is controlled by the automatic voltage regulator. The second unit supplies current to the separately excited fields of the direct-current generators.

The 2,400-volt switchboards for controlling these sets are said to be the first direct-current boards to be constructed for this voltage. In general, they are



One of the Substation Motor-Generator Sets—2,300-Volt Synchronous Motor and Two Series-Connected 1,200-Volt Direct-Current Generators.

Hole plants. At the Butte substation this power is stepped down to 2,400 volts, three-phase, and all of these lines are tied in on the 2,400-volt bus. Ample protection is therefore afforded from interruption of service.

It is an interesting fact that the railway load was taken on without any increase in the high-tension transmission 2,400-volt alternating-current buses. These units operate continuously 24 hours per day, seven days of the week, to supply the necessary current for train operation. Each set consists of a three-phase, 60-cycle, synchronous motor running at 720 revolutions per minute and direct-connected to two 500-kilowatt, 1,200-volt direct-current generators, insulated and con- similar to the standard 600-volt types with increased insulation and special provision for interrupting the 2,400-volt current. The circuit-breakers and switches are also arranged for remote control, and all apparatus on the panels is provided with ample insulation to insure safety to operators.

The 2,400-volt circuit-breakers and

Michael Sol Collection

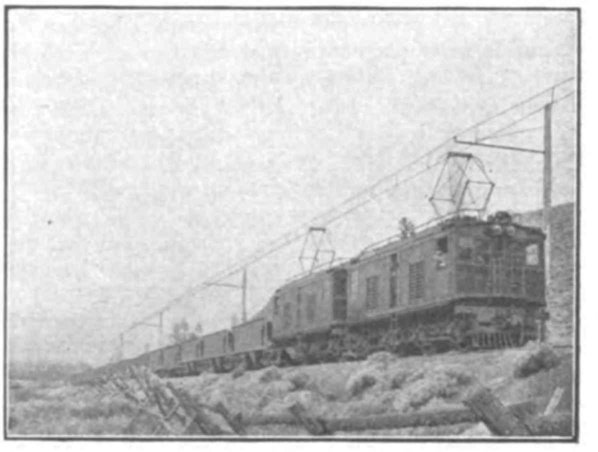
switches are installed on separate panels above and back of the main panels, and are operated by connecting rods from handles mounted on the front of the main switchboard. These handles are similar in appearance, and to avoid confusion the circuit-breaker handles are inverted. The breakers are equipped with special magnetic blowouts and arc chutes, and provision is also made for automatically inserting a high resistance in the generator field at the same instant the main circuit-breakers open, thus reducing the generator voltage.

The alternating-current switchboard contains two panels for controlling the synchronous motors by means of remote-control, solenoid-operated oil switches; there are also two panels for the motor fields, and a panel for the automatic voltage regulator. These panels also contain other necessary instruments, including frequency and synchronism indicators, ammeters, wattmeters and relays.

The overhead construction for this system was especially designed to give the flexibility necessary for satisfactory operation of the pantograph trolleys used on the locomotives. The No. 0000 grooved copper trolley used over all tracks is supported by an eleven-point catenary suspension from a stranded-steel messenger cable. Both side-bracket and cross-span construction are used as required by the local conditions. There is a large amount of special work on account of the many yards and sidings, and in one case 12 tracks are spanned. The cross-span construction used at this point is supported by a third pole between the eighth and ninth tracks. The hanger used on the straight-line construction is a rolled-steel strap looped over the messenger wire. This loop is closed at the ear and the wire is clamped in place by a single bolt. Special pull-offs are used to increase the flexibility of the suspension.

The section breakers were designed for the 2,400-volt service, and at six points insulated crossings are necessary at the intersection of the 2,400-volt trolley with the 600-volt trolley of the city street-railway system. On the main line a very simple section insulator is used. This consists of paralleling the two trolley wires from the ends of each section at a suitable distance for insulation so that the pantograph bridges the two circuits for a short distance, thus avoiding interruption of the power supply to the locomotive. The construction in the yards and sidings is simplified by paralleling the trolley from the side tracks for a short distance along the main line. This avoids the use of switch plates or similar devices. At some of these junction points the pantograph engages as many as six trolley wires.

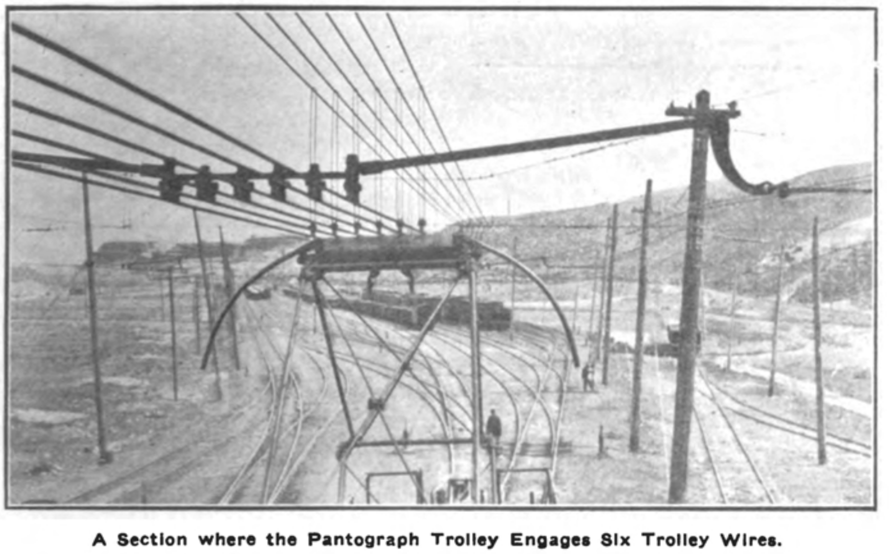
Single-Unit Locomotive with Passenger Train.



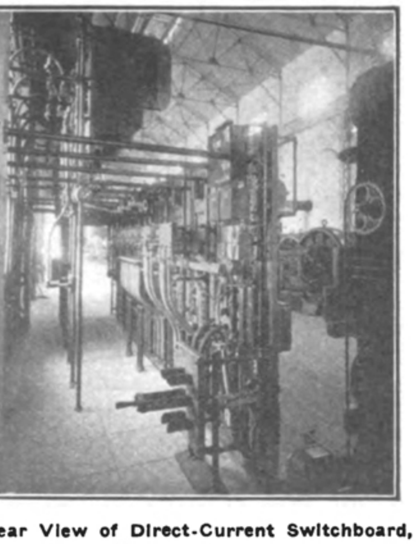
Two-Unit Locomotive Hauling Ore Cars.

The overhead lines are protected from lightning by 2,400-volt direct-current arresters installed on poles at intervals of one-third of a mile the entire length of the system.

As feeders, the No. 0000 trolley is reinforced between the substations with two 500,000-circular-mil bare copper cables tapped to the trolley at intervals of 1,000 feet. A No. 0000 negative return wire is also installed between Rocker and East Anaconda. This wire is carried on the trolley poles and is connected to the cross bonds at intervals of 1,000 feet. The rails are connected by No. 0000 bonds at every joint. The substations are normally connected together by these feeders, allowing an interchange of current. In emergency either station can supply current to the entire system.



A Section where the Pantograph Trolley Engages Six Trolley Wires.



Rear View of Direct-Current Switchboard, Butte Substation.

The locomotive equipment consists of

Michael Sol Collection

17 80-ton units, 15 for freight and 2 for passenger service. The freight locomotives are geared for slow speed and are operated in pairs for the main-line service. The maximum free-running speed is 35 miles per hour. The two passenger locomotives are of the same construction as the freight units, but are geared for a maximum free-running speed of 55 miles per hour. A speed of 45 miles per hour is made with three passenger coaches on straight level track.

These locomotives are of the articulated double-truck type with all the weight on drivers. The cab contains an engineman's compartment at each end and a central compartment for control apparatus.

The four motors are of the GE-229-A commutating-pole type, wound for 1,200 volts and insulated for 2,400 volts. This motor was designed for locomotive service and is provided with forced ventilation. The double-unit, 160-ton locomotive is capable of giving a continuous sustained output of 2,100 horsepower. The motors are connected to the driving wheels by twin gears similar to those used on the Detroit River Tunnel, Baltimore & Ohio, and the Great Northern locomotives.

The control equipment is Sprague-General Electric Type M, multiple unit, operating the four motors in series and in series-parallel. The 1,200-volt motors are permanently connected in series. The controller provides ten steps in series and nine in series-parallel. The transition between series and series-parallel is affected without opening the motor circuit, and there is no appreciable reduction in tractive effort during the change. The transfer of circuits at this point is made by a special change-over switch, which is operated electro-pneumatically.

Current is collected by overhead roller pantographs, pneumatically operated and controlled from either engineman's compartment by an air valve. A 2,400-volt insulated bus line runs along the center of the cab roof. These bus lines are connected together by couplers between the two freight units, so that current may be obtained from either one or two collectors.

For operating the control equipment and air compressor and for lighting the locomotive and cars, 600-volt current is supplied from the 2,400/600-volt dynamotor installed on each locomotive. This machine is similar in construction to the 1,200/600-volt dynamotor, having two distinct sets of armature coils wound on the same core and brought out to a commutator at each end. One of these windings is designed for 1,800 volts and the other for 600 volts, the two commutators being connected in series across the 2,400-volt circuit. The load current is taken from the 600-volt commutator.

The mechanical load furnished by the direct-connected blower supplies sufficient curent in the series-field windings to provide for the necessary excitation, so that no shunt windings are required. The blower which supplies ventilating air to the motors consists of a multivane fan mounted on an extension of the dynamoter shaft.

Further details of the locomotive design were given in the preceding article already referred to. All of the locomotives have been maintained by the regular shop force with the assistance of one man experienced in electrical apparatus.

Standard 600-volt lighting fixtures are used on the cars, and each passenger and baggage coach is wired for five groups of five lamps in series. The lights in each car are controlled by a suitable master switch and fuse with snap switches in the individual circuits. 36-watt railway type Mazda lamps are used, giving about 26-candlepower at 110 volts per lamp. Lighting current is taken from a 600-volt train-line bus, which is connected to the dynamotor on the locomotives

Trestle at Washol Smelter, Showing Typical Bridge Construction

All of the passenger and baggage cars now used between Butte and Anaconda will be heated as well as lighted by electricity as soon as the equipment can be installed. The cars will be heated from a single heating unit installed underneath the car floor and supplied from a 2,400-volt bus connected directly to the 2,400 volt bus on the locomotive This unit will have a maximum capacity of 25 kilowatts and will be used to heat the air which is distributed to different parts of the car by means of a small motor-driven blower. Cool air will be drawn into the insulated case inclosing the heating units from some point on the roof of the car. After passing over the heating coils the air will be carried through ducts under the floor of the car to radiators placed between alternate seats. The blower has a capacity of from 500 to 1,000 cubic feet of air per minute, and the motor is connected in series with the heating units.

In order to increase the range of the heating equipment to meet the requirements of varying temperatures, provision is to be made for connecting the coils to give a total consumption of 10, 15, 17.5 or 25 kilowatts. The temperature of the car is to be regulated by a thermostat.

All apparatus for the electrification of this railroad was furnished by the General Electric Company, Schenectady, N. Y.

Brady Medals for Safety Work on Electric Railways.

Three medals, of gold, silver, and bronze, to be known as the Anthony N. Brady Memorial Medals, will be awarder for the first time this year by the American Museum of Safety for the best work done during the year by an electric street railway in America in accident prevention and industrial hygiene. The medals have been donated by Nicholas F. Brady, son of Anthony N. Brady, who succeeded his father as president of the New York Edison Company. They will be awarded at the next annual meeting of the Museum of Safety, and thereafter each year.

The gold medal is to be awarded to the railroad which makes the best record. The silver medal will be given to the department of the railroad winning the gold medal which, in the judgment of the railroad's directors, has done the most in obtaining the results for the award of the gold medal. The bronze medal will be presented to the employee who individually, in the judgment of the directors, has done the most to promote safety of life and conditions for good health.

Normal Conditions Restored After Los Angeles Storm.

The transmission and distribution systems of the electric power companies serving Los Angeles, Cal., are rapidly being restored to normal condition after the severe washouts experienced during the recent heavy rainfall. The Southern California Edison Company, which was the most seriously affected, has built a temporary line to take care of its 60,000-volt power line between the Long Beach steam plant and Los Angeles. The 60,000-volt Kern River line has been permanently rerouted so as to do away for all time with the towers which were formerly located on the banks of the Los Angeles River.

Michael Sol Collection