INDUSTRIAL

ELECTRIFICATION OF THE BUTTE, ANACONDA & PACIFIC RAILWAY.

The Butte, Anaconda & Pacific Railway is, in many ways, the most remarkable example of steam road electrification in this country. Besides being the first 2400 volt direct current road, 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 preemptory factors, such as terminal and tunnel operation or for rapid suburban service. This road, however, cannot be classed as an "enforced electrification," since no such special limitations have been the determining factors.

The first electric locomotives were put in service on this line 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 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 engineers, 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, 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. The main line division extends through a rough mountainous country, a distance of about twenty miles, with grades as high as 0.3 per cent. 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.

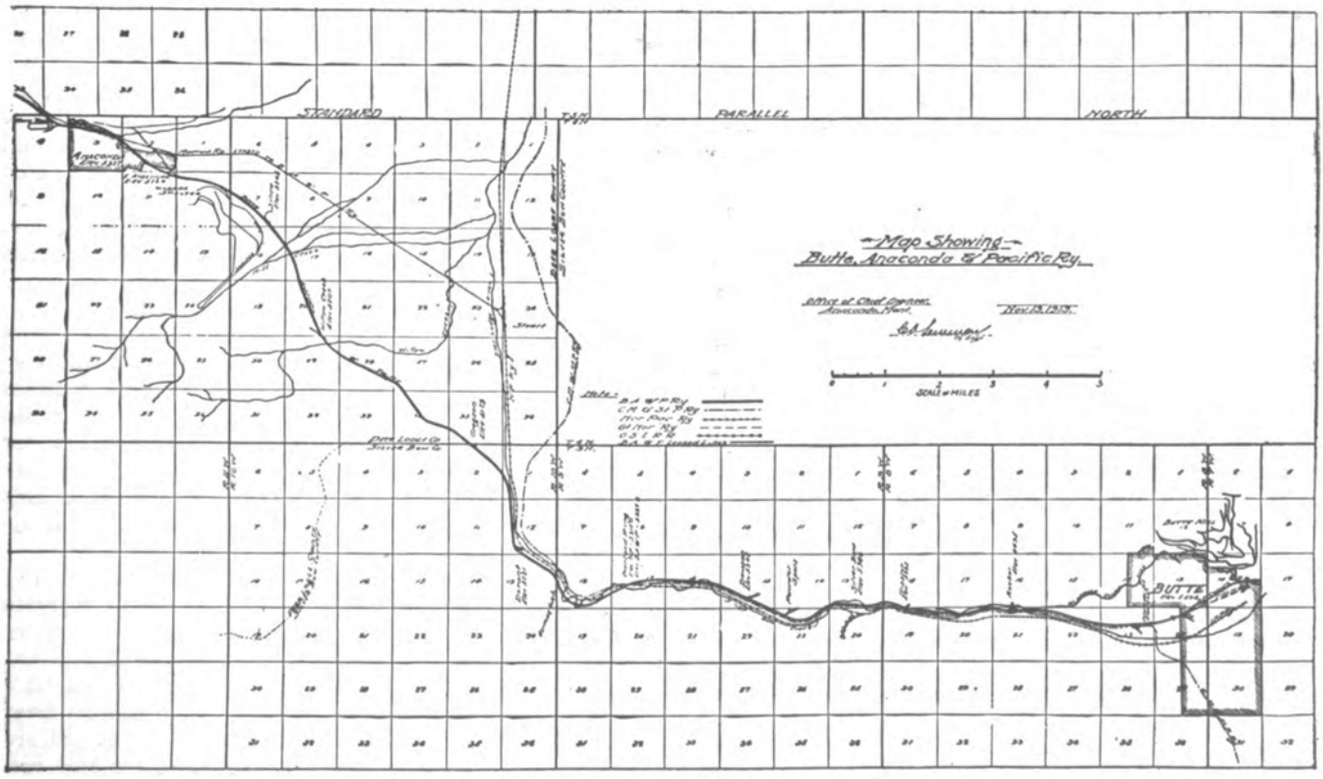
Between the cities of Butte and Anaconda there is considerable local traffic, both passenger and freight. At Butte, the Butte, Anaconda & Pacific connects with the Great Northern Railway, the Northern Pacific, and the Chicago, Milwaukee & St. Paul Railroad; and at Silver Bow, about six miles from the city, connection is made with the Oregon Short Line.

For a distance of 16 miles, the Butte, Anaconda & Pacific Railway is paralleled by the transcontinental lines of the Northern Pacific, and the Chicago, Milwaukee & St. Paul. The last named company has already contracted for power for the operation of electric trains from Harlowton, Montana, to Avery, Idaho, a distance of 440 miles.

The maximum curvature on the system (20 degrees, 285 ft. 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 ft. radius) at slow speed.

Condensed Information of Freight Movement.

	West Bound.			East Bound.		
	Butte Hill Line.	Main Line.	Smelter Hill.	Smelter Hill.	Main Line.	Butte Hill Line.
Trailing load in tons..	2000	4000	1400	1000	1260	650
Number of cars.....	30	60	20	55	70	35
Number of 80-ton locomotives per train ...	2	2	2	2	2	2
Approx. grade against load	2.5%	0.3%	1.1%	1.1%	1%	2.5%
Approx. speed on level tangent track, m.p.h.		21			25	
Approx. speed on Max. grade	12	16	16	20	16	16
Average trolley voltage	2200	2200	2200	2200	2200	2200
Length of run in miles.	4.6	20.1	7	7	20.1	4.6



Map of Electrified Section,—Butte, Anaconda & Pacific Railway.

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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 kw. The machines are of the horizontal type, generating 6600 volts, 3-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 station 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 Hole plants. At the Butte substation, this power is stepped down to 2400 volts, 3-phase, and all of these lines are tied in on the 2400 volt a.c. bus. Ample protection is therefore afforded from the interruption of service.

The two existing substations at Butte and Anaconda were used to house the 2400 volt motor-generator sets required for operating the electric trains, so that no additional buildings were constructed for this purpose. Power is furnished by two 1000 kw., 3-unit motor-generator sets in each substation, taking power from the 2400 volt a.c. 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 3-phase, 60 cycle, 1450 k.v.a, 720 r.p.m. synchronous motor direct connected to two 500 kw., 1200 volt generators, insulated to operate in series for 2400 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 from 125 volt exciters.

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 kw. each at 125 volts.

The 2400 volt switchboards for controlling these sets are first direct current boards to be constructed for this high the voltage. In general, they are similar to the standard 600 volt types with increased insulation and special provision for interrupting the 2400 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.

Overhead Construction.

The overhead construction for this system was especially designed to give the flexibility necessary for satisfactory operation of the pantograph trolleys used. The 4/0 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 twelve tracks are spanned.

The alternating current switchboard contains two panels for controlling the synchronous motors by means of remote 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 car 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 2400 volt service, and at six points insulated crossings are necessary at the intersection of the 2400 volt trolley with the 600 volt trolley of the city 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.

The overhead lines are protected from lightning by 2400 volt d.c. type ME arresters installed on poles at intervals of one-third of a mile the entire length of the system.

Locomotives.

The locomotive equipment consists of seventeen (17) 80 ton units, fifteen for the freight and two 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 m.p.h.

The two passenger locomotives of the same construction are geared for a maximum free running speed of 55 m.p.h. A speed of 45 m.p.h. is made with three passenger coaches on straight level track.

A continuous tractive effort of a single 80 ton freight locomotive is 25,000 lb. at 15 miles per hour. The maximum tractive effort for a period of five minutes is 48,000 lb. based on a tractive coefficient of 30 per cent.

The motors are of the GE-229-A commutating pole type, wound for 1200 volts and insulated for 2400 volts. This motor was designed for locomotive service and is provided with forced ventilation. The method of ventilation is similar to the well known ventilated motors, but the volume of air circulated is increased by the use of an auxiliary blower. The gear reduction on the freight locomotive is 4.84 and on the passenger locomotive 3.2. The double unit, 160 ton locomotive is capable of giving a continuous sustained output of 2100 h.p. The motors are connected to the driving wheels by twin gears.

The control equipment is Sprague-General Electric Type M, multiple unit, operating the four motors in series and in series-parallel. Two 1200 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 effected 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.

The 2400 volt contactors are operated from the 600 volt control circuit, and are specially constructed to separate the 2400 volt parts from the coils and interlocks which carry the 600 volt current. The necessary insulation is obtained by large clearances and by the use of porcelain and mica insulation. The armature is connected to the contact lever by a wooden rod. The contacts, magnetic blowout and arc chutes are also especially designed to rupture the 2400 volt arc.

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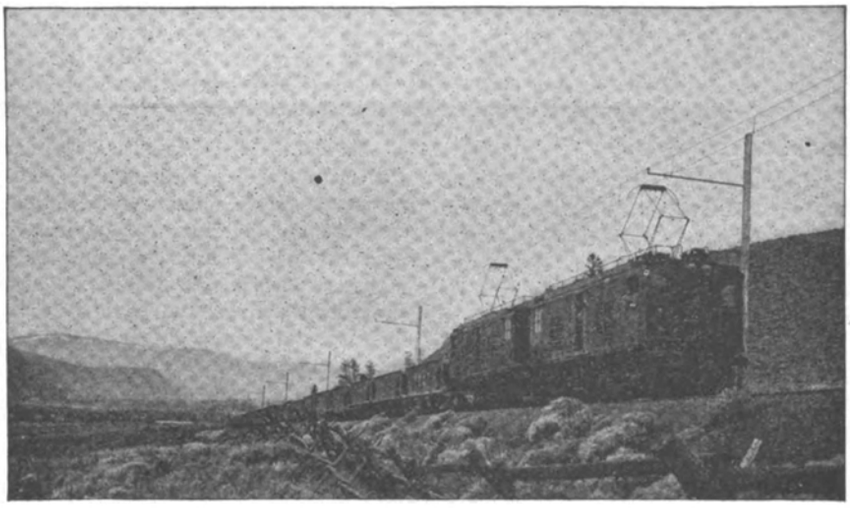

Two Unit Electric Locomotive Hauling Freight Train.

Current is collected by overhead roller pantographs, pneumatically operated and controlled from either engineer's compartment by an air valve. A 2400 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. The air brakes are the combined straight and automatic type; and the compressor is of the CP-26, 600 volt type, having a piston displacement of 100 cu. ft. of air per minute when pumping against a tank pressure of 135 pounds. Radiating pipes are provided on the roof of the cab for reducing the temperature of the compressed air before it reaches the high pressure cylinder.

For operating the control equipment and air compressor and for lighting the locomotive and cars, 600 volt current is supplied from the 2400/600 volt dynamotor installed on each locomotive.

The load furnished by the direct connected blower supplies sufficient current 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 dynamotor shaft. It has a capacity of 7200 cu. ft. per minute at 4 in. pressure.

The principal data and dimensions applying to the locomotives are the following:

Electric Locomotive Data.

Length inside of knuckles	37 ft. 4 in.
Length over cab	31 ft.
Height over cab	12 ft. 10 in.
Height with trolley down	15 ft. 6 in.
Width overall	10 ft.
Total wheel base	26 ft.
Rigid wheel base	8 ft. 8 in.
Track gauge	4 ft. 8½ in.
Total weight	160,000 lb.
Weight per axle	40,000 lb.
Wheels, steel tired	46 in.
Journals	6 in.x13 in.
Gears, forged rims, freight locomotives	87 teeth.
Gears, forged rims, passenger locomotives	80 teeth.
Pinions, forged. freight locomotives	18 teeth.
Pinions, forged, passenger locomotives	25 teeth.
Tractive effort at 30 per cent coefficient	48,000 lb.
Tractive effort at one hour rating	30,000 lb.
Tractive effort at continuous rating	25,000 lb.

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 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. Thirty-six watt railway type Mazda lamps are used, giving about 26 c.p. at 110 volts per lamp. Lighting current will be taken from a 600 volt train line bus, which is connected to the dynamotor on the locomotives.

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.

All apparatus for the electrification of this road was furnished by the General Electric Company of Schnectady, New York.

A CATALOGUE DE LUXE.

The Crouse-Hinds Company of Syracuse, N. Y. has just issued Catalog No. 1000 on Condulets, which sets what is believed to be the highest standard ever reached in a trade publication. This 200 page, cloth bound volume, 9 by 12 in., is magnificently printed in four colors on heavily coated stock. A complete illustrated description of every kind of device manufactured by the company is conveniently shown in its natural colors, brass screws, copper contacts and aluminum covers being as distinct as cast iron bases.

This text opens with a three-way pictorial index, its 18 pages giving a complete display of the line. The index is arranged alphabetically as to types, numerically as to families and pictorially as to uses. The catalogue constitutes a liberal education for any electrical contractor or supply man. Its merits and novelties are so numerous that only a few can be mentioned here.

In addition to the standard lines of condulets have been added a full line of covers and fittings which will take any number of switches or receptacles. A new type of service entrance condulets provided with protective fuses and a padlock is shown for the first time. Two pages are devoted to a complete list of makes of fittings which can be used with condulets. Much space is devoted to bodies with "obround" and elliptical openings as well as to condulets which can be used under water and in places where destructive vapors abound. Among the thousands of new lines listed are a complete line of housings for railway work, both steam and electric. Fixtures complying with the U. S. postal requirements are fully illustrated together with a complete line to care for police, wire and marine requirement, as well as portable telephone systems for railway dispatching. Other valuable features are the house numbering fixtures and a pilot light for electric ironing circuits.

The description in each case gives shipping weight, size of standard package and list price, together with information as to installation. This monumental work has only to be seen to be appreciated.

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