ELECTRIFICATION ON THE CHICAGO, MILWAUKEE, AND ST. PAUL RAILWAY.

No. II.*

The Montana Company's transmission lines which provide the energy for working the electrified line between Harlowton and Avery, are carried in some cases on steel towers and in others on wood poles. The standard transmission poles are from 45ft. to 50ft. long. They are provided with two cross arms for carrying the 100,000-volt transmission line on suspension type insulators, and also an uninsulated ground wire. The overhead construction for the permanent way is of the modified flexible catenary type, designed by the General Electric Company, of New York, and was installed under the direction of the Railway Company. It consists of two 0000 copper wires—American B. and S. gauge 0.460in. diameter—flexibly suspended side by side from one steel catenary wire by independent hangers alternately connected to each wire. Bracket construction is used wherever the track alignment will permit, and where it will not, cross span construction is employed. The latter form of suspension is used in shunting yards as well. The wires are carried on 40ft. wood poles. A copper feeder is installed for the whole length of the electrified portion of the line. It is 500,000 circular mils, or, say, .39 square inches in cross-section. It is reinforced by a supplementary feeder on heavy gradients. The feeder, which is carried on insulators on the cross arms on the poles which carry the brackets for the overhead conductor wires, is tapped on to the latter at every seventh pole, or approximately every 1000ft. On the top of the pole is carried a supplementary 0000 negative feeder, which is tapped to the middle point of every second reactance bond. These bonds are used for insulating the 60 cycle signal circuits and are installed at points averaging from 5000ft. to 6000ft.

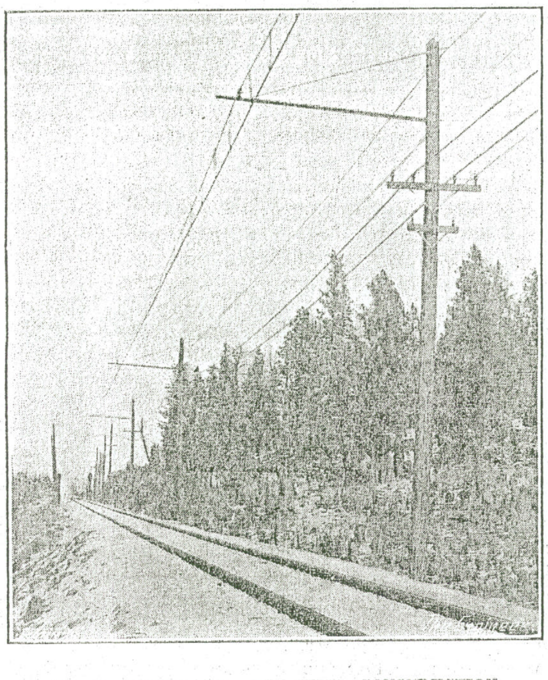

Fig. 15—STANDARD BRACKET CONSTRUCTION

apart. Each rail is bonded with a 250,000 cm.—say, 0.196 square inches—bond at each joint, and is double bonded on the heavier gradients.

It is said that the heaviest currents are collected from the overhead wire without any sparking. Now, the quantity of current ordinarily collected may be gauged from the fact that the continuous rating horse-power of the locomotives is given as being 3000 horse-power. The current at this rating must, with 3000 volts, be as much as 746 ampères. At times it is, of course, considerably more. Various views showing the overhead construction are shown in Figs. 15 to 18 inclusive. Fig. 15, which represents the line near Grace, shows the standard bracket construction. It will be observed that the work is of the lightest nature. Fig. 16 shows a view taken on a curve on a 2 per cent. gradient. Fig. 17 shows a view taken at the western entrance of Silver Bow Canyon. The line at this point is on a 10 deg. curve. The feeder tappings will be observed. Fig. 18 represents the line in a tunnel and shows the collapsible hanger used for tunnel work.

The service on the line consists of (*a*) two all-steel transcontinental passenger trains in each direction daily; (*b*) a local passenger train in each direction daily between Deer Lodge and Harlowton; and (*c*) from four to six freight trains daily in each direction. The transcontinental trains are elaborately equipped, and are known as the "Olympian" and "Columbian." They are described by the company in somewhat bombastic terms as being "the most sumptuously appointed trains in the American railway service, which means that there are none finer in the world." They comprise, continues the description, "observation-library cars, drawing room, compartment standard sleeping cars, tourist sleeping cars, dining cars, coaches, baggage, mail and express cars—all steel. Each train is the other's counterpart, and it seems impossible to improve on what this provides in the way of utility, comfort and pleasure." The goods, or "freight" traffic as our American cousins prefer to call it, consists, in the electrified portion, for the most part of *through* traffic. The trains are made up of numbers of different kinds of cars, belonging to numerous railway companies.

* No. I. appeared August 18th.

The electric locomotives which are employed on the line each have a weight of 564,000 lb., or, say, 252 long tons. Of this weight 448,000 lb.—or, say, 200 long tons—are on the driving wheels. There are eight driving axles, so that the axle load is 25 tons. As a matter of fact, each locomotive consists of two identical units connected together by a flexible coupling, and each has a four-wheel bogie at the end, remote from the connection. These bogies each

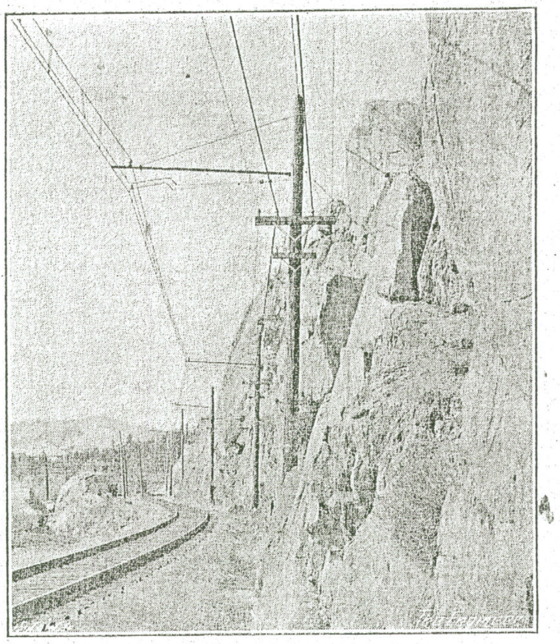

Fig. 16—VIEW ON CURVE ON 2 PER CENT. GRADIENT

take 25 tons, so that their axle load is $12\frac{1}{2}$ tons. The driving axles of each unit of the locomotive are arranged in two sets of four in independent bogies. The result is that although each locomotive has an overall length of 112ft. and a total wheel base of 102ft. 8in., the rigid wheel base in no case exceeds 10ft. 6in. The diameters of the driving wheels and bogie wheels are 52in. and 36in. respectively. Each of these enormous locomotives is fitted with eight motors, each of which is of 375 horse-power at continuous rating, and which at one hour's rating can work up to 430 horse-power. The locomotive as a whole, therefore, can develop 3000 horse-power continuously, or 3440 horse-power for one hour. At continuous rating the tractive effort is 71,000 lb., or nearly $31\frac{3}{4}$ tons. The tractive coefficient is 15.83

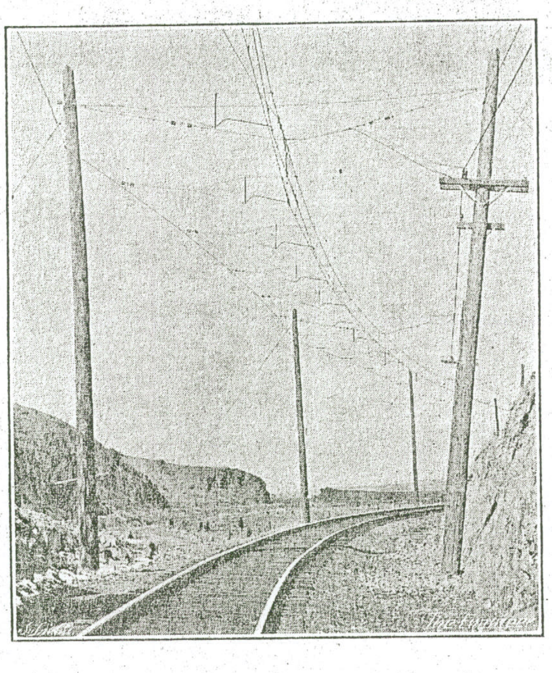

Fig. 17—OVERHEAD CONSTRUCTION ON 10 DEGREE CURVE

and the speed at this tractive effort at 3000 volts is 15.75 miles per hour. At one hour rating the tractive effort is 85,000 lb.—nearly 38 tons—the tractive coefficient 19, and the speed at this tractive effort 15.25 miles per hour. The tractive effort available for starting is 136,000 lb.—just over 60 tons. These figures differ slightly from those given in our article describing the locomotives, which appeared in our issue of August 13th of last year, but they are the latest figures supplied by the railway company, and are presumably to be taken as accurate, though the figures from which the article just referred to was prepared were obtained from a reliable source, and after one, at any rate, of the locomotives had been made and tried. The principal differences are in the weights. The figure for total weight of engine given is about 44,000 lb. more than that given in last year, while the weight on the drivers is 48,000 lb. more. There are two types of main line locomotives—those for freight and those for passenger traffic—and they are identical, saving for differences in gearing, and that the passenger locomotives carry two oil-fired boilers for heating the coaches. One of these boilers is carried in each half of the locomotive. The two boilers together are capable of evaporating 4000 lb. of water per hour, and this equipment, with tanks for oil and water, bring the weight of the locomotives up to approximately 600,000 lb. The two types of locomotives being the same in all except the gearing, has made it possible to arrange for the interchangeability of all the other mechanical parts and of the whole of the electrical arrangements—a matter of great importance from the standpoints of operation and maintenance.

The "Mallet" type engines, which are being superseded by these locomotives, had, as was pointed out in the first article, a total weight of 555,700 lb., of which 324,500 lb. was on the drivers. The rated tractive effort was 76,200 lb., and the rated tonnage on a 1 per cent. gradient was 1800. The electric freight locomotives are to haul a load of 2500 tons up a 1 per cent. gradient, and not only that, but it is expected with them to effect a considerable reduction in running time. Thus, it has been found that on the 21 mile 2 per cent. gradient between Piedmont and Donald, the electric locomotive can reduce the running time of passenger trains from an hour and five minutes to approximately 40 minutes. Again, on the run from Deer Lodge to Butte, which under the steam locomotive schedule required an hour and twenty minutes, a saving of approximately thirty minutes can be made.

In the freight service it has been found that on the first division on which steam locomotives required 10 to 12 hours to run 115 miles, the electric loco-

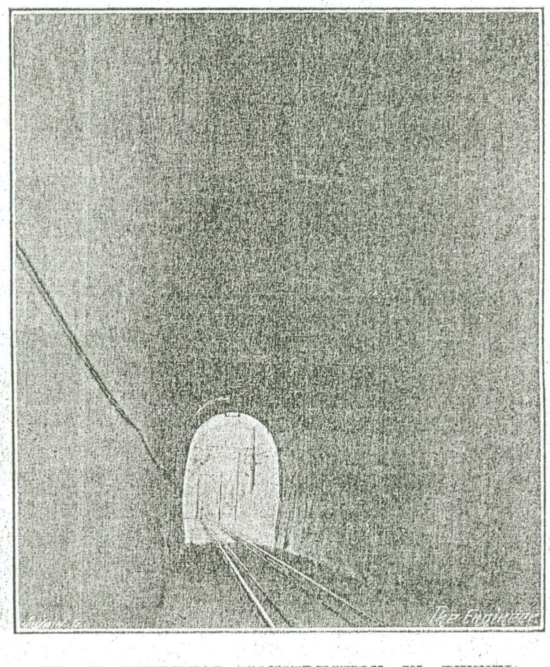

Fig. 18—OVERHEAD CONSTRUCTION IN TUNNEL

motives can accomplish the same distance in from 7 to 8 hours. Moreover, the heavy gradients and frequent curves at certain points offer serious obstacles to steam locomotive operation even in summer time, and with winter temperatures, with as much as 40 deg. Fah. of frost and heavy snowfalls, serious delays used to be experienced because of engine failures and inability to make steam. The electric locomotives will not be subjected to the same disabilities, but it will be interesting to note how the overhead work stands the snowfalls and heavy winds of winter.

So far, apparently, the capabilities of the electric locomotives do not appear to have been in any way impaired by the cold weather. During initial operations in the Rocky Mountain Division they were thoroughly tested. Trains of 3000 tons trailing have been hauled east and trains of 2800 tons have been hauled west, a helping engine being added on the heavier gradients. From the operating data obtained on the first division, it became evident that much heavier trains could be hauled by the electric locomotives than by the Mallet engines, and, consequently, all passing places are being lengthened to accommodate longer trains, for the line, as will be gathered from the accompanying illustrations, is single. On some of the runs, where the gradients are less than one in a hundred, trains comprising as many as 130 cars and wagons, and weighing as much as 4000 tons, have been hauled by a single locomotive. The four through passenger trains designated the "Olympian" and "Columbian," are taken across the mountain ranges by a single passenger locomotive. These trains at present consist of eight full vestibuled coaches and weigh, approximately, 650 tons. Instead of changing locomotives at Three Forks—see Fig. 3, *ante*—as had been customary under steam operations, the same locomotive is now run through the 220 miles from Deer Lodge to Harlowton, the crews being changed midway. When complete working has been brought about, passengers will be able to travel over the entire electrified division in approximately 15 hours, including all stops, which will represent an inclusive speed of nearly 29½ miles per hour. The local passenger train which operates between Deer Lodge and Harlowton is hauled by a half-unit locomotive weighing about 150 tons. The passenger locomotives, it may be remarked, have a gear ratio which permits of the working of 800 ton trailing trains at speeds of approximately 60 miles per hour on the level. The average passenger train weighs from 650 to 700 tons and is hauled over the two per cent. gradient without a helper. The freight locomotives are designed to haul a trailing load of 2500 tons at approximately 16 miles per hour on all gradients, up to and including one in a hundred. On two per cent. gradients it was proposed to limit the trailing load to 1250 tons, but in actual operation this load has been exceeded.

It so happens that the Butte, Anaconda and Pacific Railway runs through some of the country traversed by the Chicago, Milwaukee and St. Paul Railway, and Fig. 19 shows a point where it crosses over it. The view is interesting, as it depicts two long trains, one on each line, and because both lines are electrically worked. The long ore train passing over the bridge is an ore train hauled on the Butte-Anaconda line by two 80-ton 2400-volt direct-current locomotives. The goods train on the line below the bridge is hauled by one of the Chicago-Milwaukee 3000-volt direct-current locomotives. It is significant that in these two instances high tension direct current is employed, and that it is direct current which is the first to be employed on a long stretch of trans-continental main line.

Each of the passenger and goods locomotives is equipped with eight G E-253-A 1500-volt motors, of the control equipment, and, on the passenger locomotives, for the oil-fired steam boilers used for heating.

We may add that there are at present in operation 42 of these locomotives and that each one has cost approximately £25,000. An interesting series of views is given on page 168. Fig. 20, shows a goods train of 82 cars, weighing 2680 tons, west bound in Silver Bow Canyon. In Fig. 21 is seen an eight-car passenger train coupled to a high-speed locomotive standing in Deer Lodge station. Fig. 22 represents a heavy goods train descending a two per cent. gradient on the eastern slope of the Rockies, while Fig. 23 shows a passenger train traversing a viaduct on the same gradient.

For shunting purposes electric locomotives of the swivel truck type, and weighing 70 short tons each, are employed. The following are the leading particulars of these engines :—

Length inside knuckles of couplers	40ft.
Height over cab	13ft. 10in.
,, trolley down	16ft. 8in.
Width over all	10ft.
Total wheel base	29ft. 4in.
Rigid ,, ,, ...	8ft.
Diameter of wheels	40in.
Weight locomotive complete	140,000 lb.
,, per driving axle	35,000 lb.
One hour rating	542 h.p.
Tractive effort at one hour rating	18,400 lb.
Speed at this rating	12 m.p.h.
Continuous tractive effort	13,480 lb.
Speed at continuous rating	13.2 m.p.h.
Tractive effort (30 per cent.)..	42,000 lb.

A single pantograph, of a construction similar to that used on the main line locomotives, is mounted on the cab, and in other ways the locomotives represent the standard construction commonly used with the steeple cab type of shunting engines. The motors,

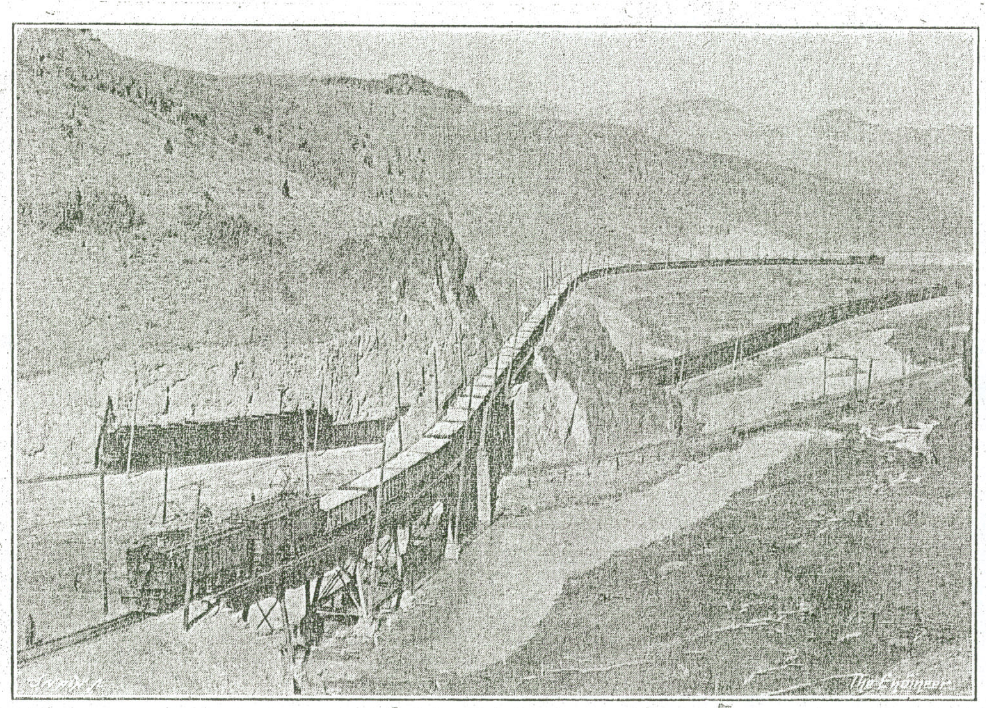

Fig. 19—TWO LONG ELECTRICALLY HAULED TRAINS

insulated for a pressure of 3000 volts to earth and each is twin geared to its driving axle in the same manner as on the Butte, Anaconda and Pacific Railway, the Detroit River Tunnel and the Baltimore and Ohio locomotives, a pinion being mounted on each end of the armature shaft. Additional flexibility is obtained by the use of a spring gear and a spring nose suspension, so that the effect of shocks is minimised and the wear of the gears is reduced to a minimum. The motors are of the commutating-pole type and are constructed with longitudinal ventilating ducts in the armatures for forced ventilation from a blower in the cab.

The control equipment is of the Sprague General Electric Type M arranged for multiple unit operation. The main control switches are mounted in steel compartments inside the cab, with aisles for inspection and repairs. A motor generator set in each half of the locomotive furnishes low pressure current for the control circuits, headlights, cab lighting and for charging the storage batteries on the passenger coaches. The blower for ventilating the traction motors is also connected directly to one end of this set. Under steam operation on the portion of the line not yet electrified the charging current for these batteries is furnished by a steam turbo-generator carried on the locomotive.

The pantograph collectors, one of which is mounted on each half of the locomotive, are of the double pan type with a working range of from 17ft. to 25ft. above the tops of the rails. The contact elements are of the same metal as the overhead conductor wires, so that the current passes from copper to copper. The air brake equipment is practically the same as that used on the steam locomotives, except that motor driven compressors are used to furnish the compressed air. In addition to being employed for working the brakes compressed air is also used for signals, whistles, bell-ringing, sanding, flange oiling, the pantographs, part which are called by the makers G E-255, are of the box-frame, commutating-pole type, designed for 1500 volts with an insulation of 3000 to earth. Many of the parts are interchangeable with those used on main line locomotives—for example, the air compressors, small switches, headlights, cab heaters, &c.

THE INTERIM REPORT OF THE AIR INQUIRY COMMITTEE.

No one who had followed the accounts of the Air Inquiry Committee's proceedings published in the daily Press could have had much doubt as to the line that would be followed in its Report, which was issued as a White Paper last week. This particular document is, however, only an Interim Report, and is solely confined to dealing with the charge of criminal negligence made by Mr. Pemberton Billing in a recent speech in the House of Commons against the administration and higher command of the Royal Flying Corps. The terms of reference with regard to which the Committee was enjoined to inquire relate solely to this branch of the Air Service, and did not include any investigation into the affairs of the Royal Naval Air Service. This is perhaps a very good thing, because, although the R.N.A.S. as it was constituted and directed in the earliest stages of the war was undoubtedly deserving of very severe criticism from the point of view of the arrangements made for design and construction of machines, charges such as were flung broadcast by Mr. Pemberton Billing need to be based on far more definite information and evidence than that over which he succeeded in wasting the time of some very eminent legal and technical authorities. The Interim Report of the Committee states bluntly that in no case has any direct evidence been given in support of any allegation of negligence. No one who reads it will fail to miss the higher sarcasm evinced in the second paragraph of the Report, wherein the Committee states that "its final report must be delayed owing to the mass of evidence it had before it, evidence," it is added, "given for the most part in a spirit of informed and genuine criticism . . . ." Mr. Billing's charges, as he admitted, were based largely on mess-room gossip, and while he made other criticisms and suggestions deserving of careful consideration, his charges of criminal negligence or murder are stated—perhaps rather mildly—by the Committee to be "an abuse of language, and entirely unjustifiable."

Luckily, however, more interesting matters emerge from the Report than the anticipated complete refutation of absurd and vague charges. The Committee states very distinctly that flying, even at home, is at present attended with considerable danger. On a perfectly calm clear day in warm weather with a good machine—and we unhesitatingly include the B.E. 2 C type in this category—flying over pretty country when the engine is running really well is quite a pleasant amusement, but in cold wet weather with a questionable machine and a doubtful engine it is as risky and as unpleasant a pastime as any in which one could very well indulge. Those who have experienced both would unhesitatingly choose a torpedo-boat destroyer in a heavy gale to the latter as a form of recreation. That it has become a wonderfully safe method of progression in the course of the last three years compared with what it was in 1911 and 1912 is very certain, but it is none the less risky except under favourable conditions.

A considerable portion of the criticisms put forward by Mr. Billing related to the structural design of the machines which were involved in the accidents he quoted as being due to "criminal negligence." The Committee's reply to such charges may be expected to be more detailed in its final report, but it cannot be much more clearly expressed than by the statement issued to the effect that "the question of negligence in the use of a particular type of machine must always be determined with reference to the types of machines and engines available at the date when a given accident occurred. It might be quite proper to use in the early stages of the war an aeroplane whose use to-day would be wholly wrong." Thus we find in the instances quoted by Mr. Billing a number of accusations of structural defects or of defective design, most of which are in the light of this finding of the Committee entirely disproved. Case (*a*), the B.E. 2.8 type of machine —which in this case came to grief in August, 1914—was abandoned because it was "somewhat under-engined and was apt to lose speed quickly in the air. It was not fast, nor sufficiently better than other machines then in use to justify its continuance at the front."

Case (*b*) was a particularly unfortunate one, involving as it did the death of Mr. E. T. Busk in a B.E. 2 type machine, which caught fire in the air over Farnborough in November, 1914. Mr. Busk's death was a great loss to the aeronautical world, as he possessed an exceptional knowledge of both actual flying and of the design of machines. The case as quoted by Mr. Billing, however, could not conceivably be construed as one involving any element of negligence on the part of the administration of the Royal Flying Corps.

Cases (*c*) and (*d*) relate to Bleriot machines, both of which were in process of being discarded when the accidents occurred—curiously enough both on the same day, December 30th, 1914—on account of their being too slow in climbing with a full military load. Case (*c*) was apparently one of an insolubly mysterious disappearance. The machine vanished into the unknown on its way back from France much as did that of the late Gustav Hamel. How this accident happened can only be surmised, and yet Mr. Billing thought fit to quote it as evidence of somebody's incapacity. Case (*d*) was one of considerable interest to designers. Had the experiment of diving with the engine full-out at the target on which it was desired to drop bombs and then of flattening out when only about 300ft. away from the object to be attacked been carried out on a modern machine, it is unlikely that a collapse would have taken place owing to the extra stresses which are thrown on to the spars under such circumstances compared with those experienced in flying normally. There was, however, a double object in this experiment. A machine flying level at a high speed must necessarily, in order to hit a given target, release its bombs a long distance away from the intended object of attack, and this distance varies with the height and speed of the machines. For instance, in the case of an aeroplane flying at an altitude of 5000ft. to 6000ft. and at a speed of 80 miles per hour, it would be necessary to drop a bomb about a quarter of a mile before passing over the target, as the bomb would leave the machine with a forward velocity of nearly 120ft. per second and would fall in an approximately parabolic curve. Quite apart from the increased difficulty in the way of anti-aircraft guns hitting a machine diving at its object owing to the much more rapid rate of change of range, the greater accuracy of target-hitting obtainable by driving the aeroplane at the target instead of over it is undeniable. The early machines,

ELECTRIFICATION OF THE HARLOWTON-AVERY SECTION OF THE CHICAGO, MILWAUKEE, AND ST. PAUL RAILWAY

(For description see page 159)

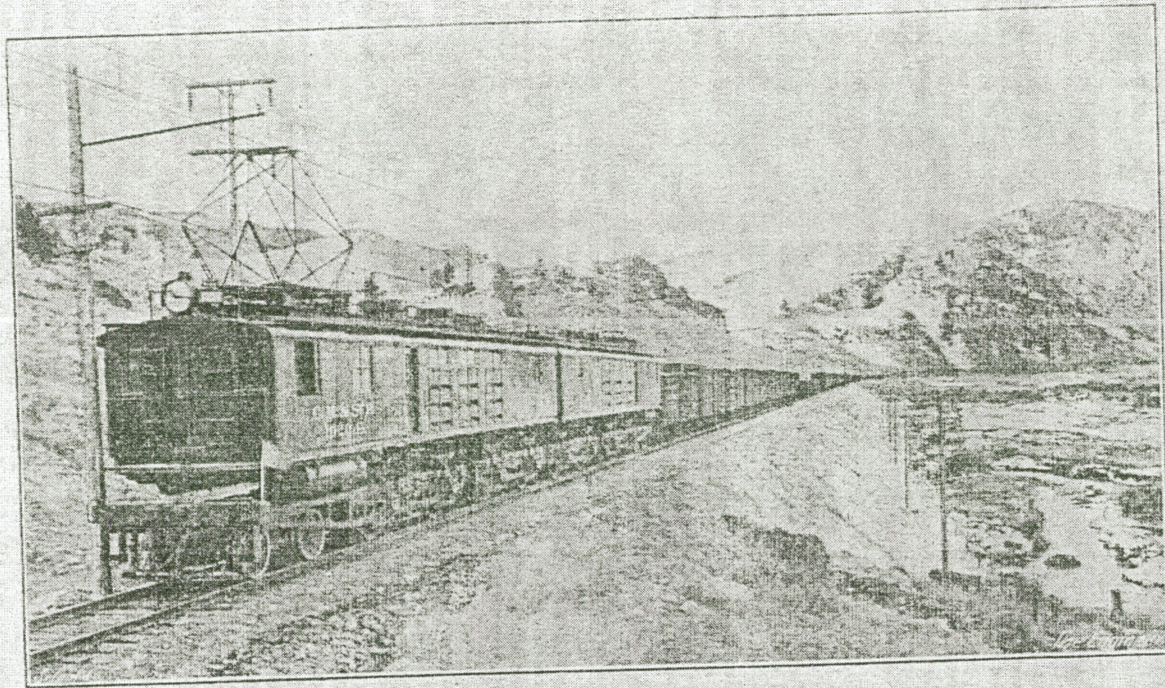

Fig. 20—52-CAR TRAIN WEIGHING 2680 TONS

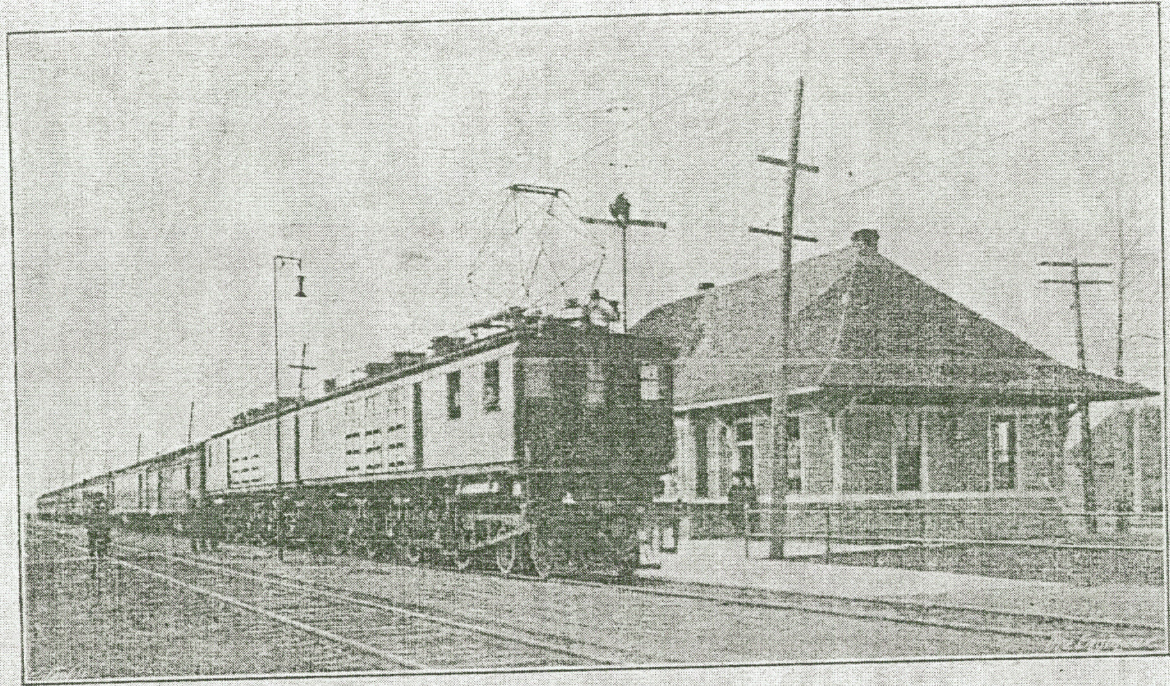

Fig. 21—ELECTRIC LOCOMOTIVE AND EIGHT-CAR PASSENGER TRAIN AT DEER LODGE STATION

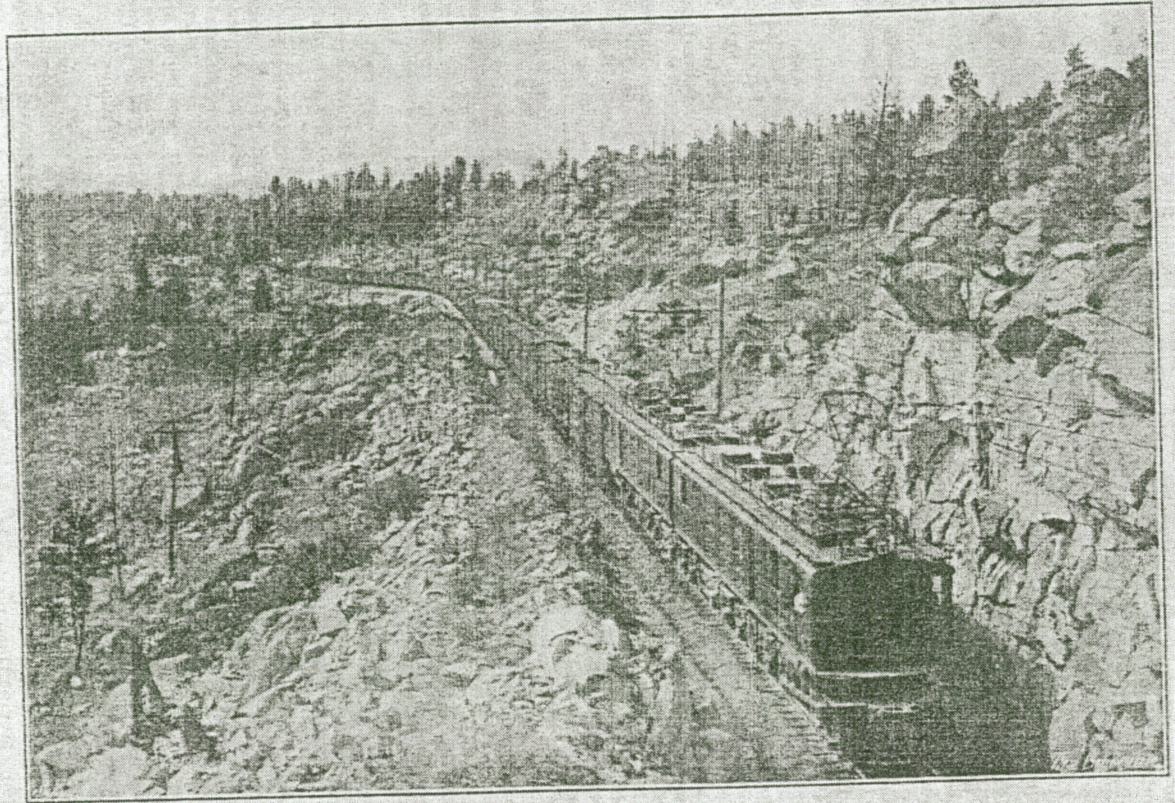

Fig. 22—GOODS TRAIN DESCENDING 2 PER CENT. GRADIENT

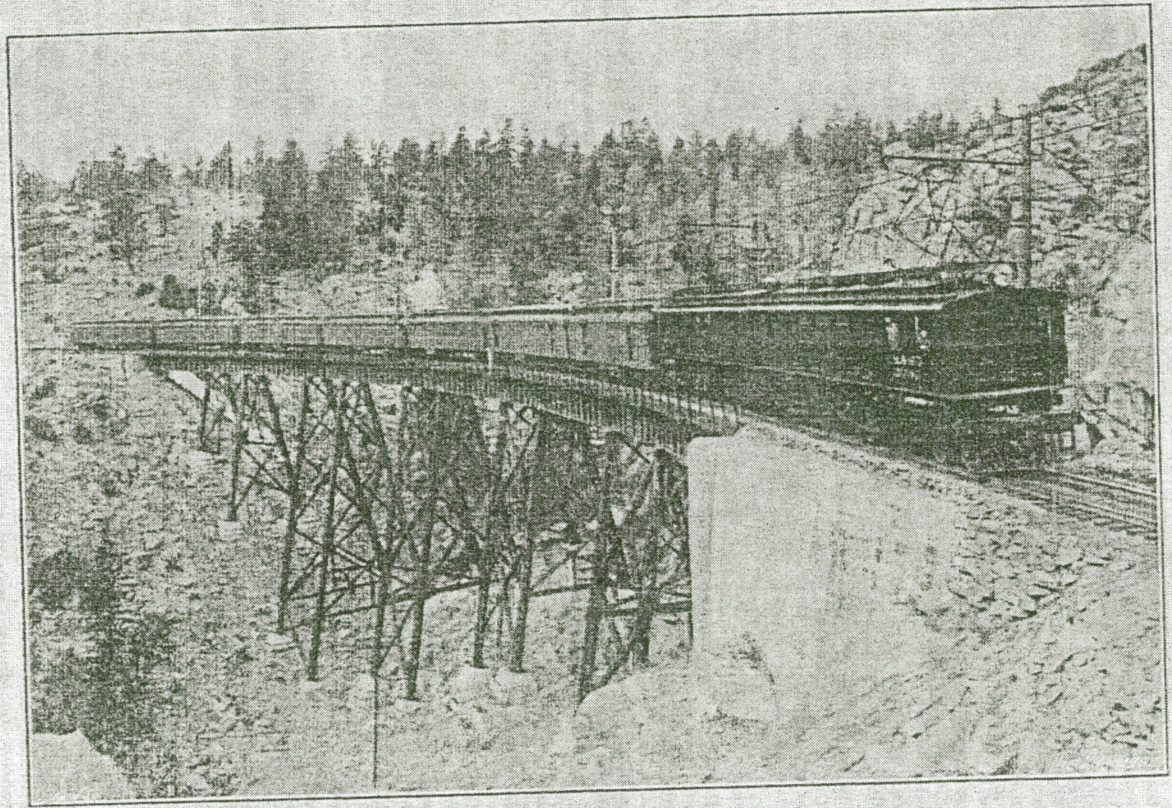

Fig. 23—PASSENGER TRAIN CROSSING VIADUCT ON 2 PER CENT. GRADIENT