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NOTES ON POLYPHASE EQUIPMENTS OF SOME EUROPEAN HIGH SPEED ELECTRIC RAILWAYS.

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The operation of railways systems by electric power is a subject of special interest to countries like Canada, possessing such remarkable natural resources in the way of water power.

The application of alternating current induction motors to electric railroading has not made much headway in this country and in the United States, continuous current motors having almost absolute sway. In Europe, however, much work has been done, and at the suggestion of our President, I will endeavor to point out very briefly the characteristics of two high tension three phase R.R. systems, viz: The Valtellina R.R., in the north of Italy and the Berlin-Zossen Road in Germany.

The Valtellina three phase 3,000 volt R.R. system has been equipped by Ganz & Co. of Budapest. The length of this road is slightly over 66 miles and the maximum grade 2%.

The power is derived from a waterfall on the Adda River, near the town Morbegno. The station consists of three 1,500 K.W., 3 phase, 20,000 volt, 15 cycles generators, direct connected to three 2,000 H.P. Francis turbines working under 100 foot head. Three phase current is sent on an overhead line to twelve sub-stations.

where it is transformed to 3,000 volts and supplies twelve independent sections of the R.R. system.

These sub-stations each contain one three core three phase air blast transformer, of 300 K.W. normal rating, but capable of working for short periods up to 900 K.W. The cooling apparatus, a fan, is driven by a small induction motor. The sub-stations are about 6¼ miles apart.

Passenger and freight traffic are operated independently, passenger traffic by motor driven cars, freight trains by electric locomotives.

The passenger cars weigh 53 tons and are capable of hauling, beside their own weights, 5 trailers of 10 tons each on a 2% grade at a speed of 40 miles an hour.

These cars are mounted on two four-wheel trucks. Fig. 1 gives a general idea of the construction of a truck. Two motors of 150 H.P. each, are provided for each truck, giving four motors per car. These motors are gearless, the rotor axle is hollow and permits the car axle to pass through it. The rotor shaft or sleeves is connected to the car axle by a flexible coupling, a modified form of a drag link. Jar and vibration are thus prevented. Control of the motors is made from both ends of the car, a controller being provided to each platform, to which the passengers have no access. These controllers are mechanically interconnected and have only three positions.

Each motor car is fitted with two primary and two secondary motors. The primary motors have six poles and are rated to develop 150 B.H.P. at 300 revs. per min. under 3,000 volts, 15 cycles. The diameter of the car wheels being 3.84 feet, the maximum speed of the car is close to forty miles an hour. The maximum torque these motors can develop is from four to five times their normal torque. There is practically no difference in weight and design between the primary and secondary motors, which are also rated at 150 H.P. under 300 volts and 15 cycles.

Fig. 2 gives a diagram of connections of one of these cars. In starting the two motors M_1 and M'_1 on a truck, are connected in concatenation or cascade. The stator winding of motors M_1 and M_2, the primary motors, are connected to the 3,000 volt line A through the high tension switch D. The rotor of these motors (ratio 10 to 1), thus giving 300 volts, are connected through the controller C to the stator windings of the secondary motors M'_1 M'_2. The rotor of these motors (ratio 1 to 1), are each connected to a three phase liquid rheostat R, containing an alkaline solution, the

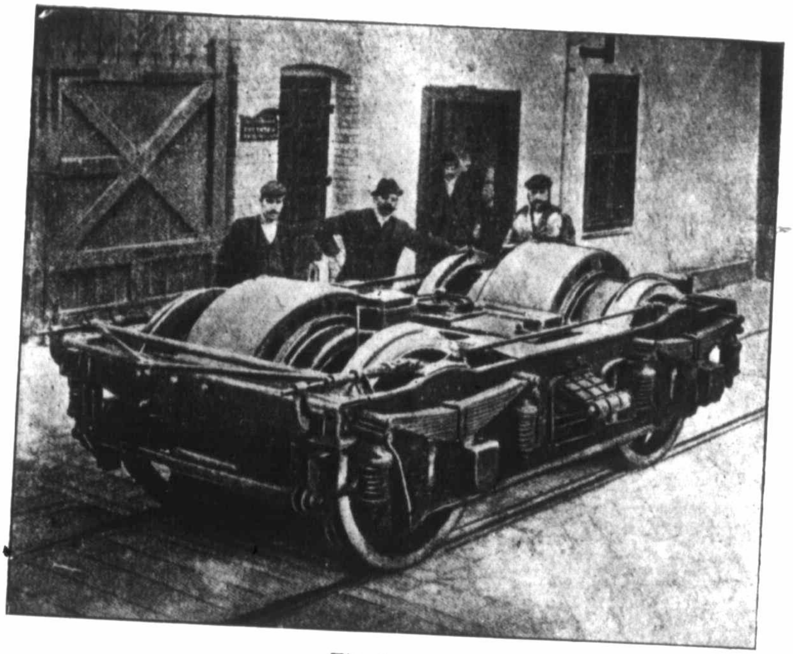


Fig. 1.

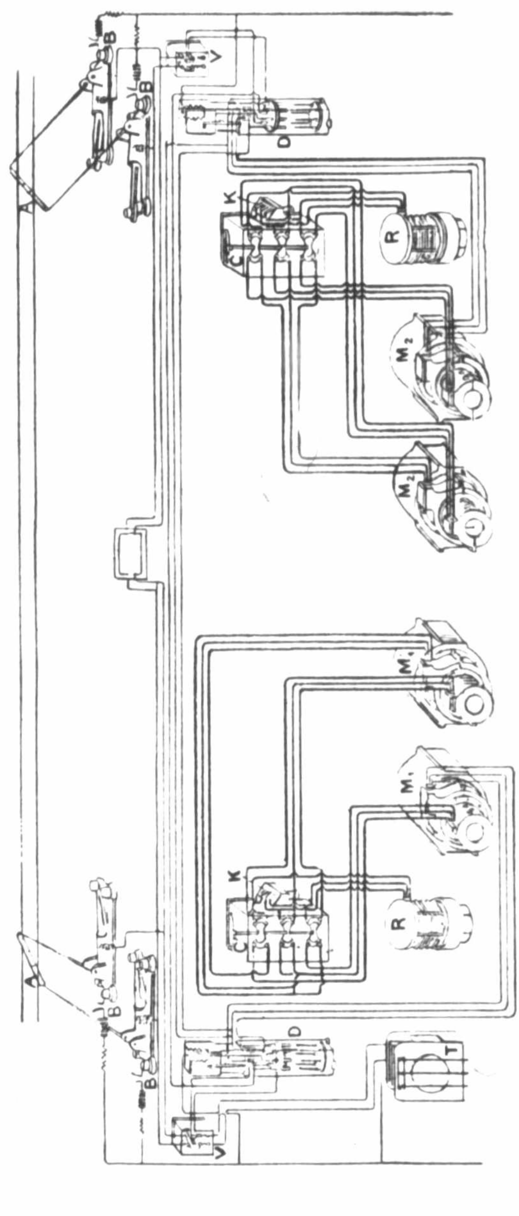


Fig. 2.

resistance of this rheostat, depends on the quantity of liquid which is forced and regulated into it by compressed air. When the liquid has reached a certain height an automatic arrangement short circuits the rotor windings. With the motors in concatenation the speed is approximately twenty miles an hour. It is well to mention here that before a start is made the controller is placed in position with the motors in concatenation before the primary switch D is made, throwing the 3,000 volt on the primary motors stator windings.

To obtain full speed, that is forty miles an hour, the primary switch D is opened, the controller is placed on third notch, cutting the low tension motors out of circuit and connecting the liquid rheostat to the rotor of the primary motors, the high tension switch is then closed, the primary motors are then alone in circuit. This method of control is very similar to the ordinary series-parallel control.

Fig. 3 gives a general idea of the construction of the 300 volt reversing switch. It consists of six copper plungers, which, when lowered, fit into an equal number of copper cylinders, by rotating the switch through sixty degrees the connections of the phases are changed, thus reversing the direction of rotation of the motors. This switch is operated from the end platforms by compressed air or if this fails, by hand.

The controller shown in Fig. 4 has only three points.

First point : Rotor of primary motors open circuited.

Second point : Concatenation control.

Third point : Secondary motors out of circuit and the liquid rheostat connected to the rotor of the primary motors.

This controller is operated by hand as the voltage on it does not exceed 300 volts. Freight trains are hauled by electric locomotives.

Fig. 5 gives a general view of these. They weigh 40 tons and are capable of hauling a 250 ton train on a 2% grade at a speed of 20 miles an hour. The body of these locomotives is mounted upon two four-wheel trucks and upon each of the four axles a motor is directly mounted, no gearing being used. Concatenation control is not used in these, the four motors are high tension motors and rheostatic control in the rotor circuit is employed.

Great difficulty was at first experienced in working an overhead trolley circuit with two wires under 3,000 volt pressure between wires, the third phase wire being the track. The trolley wire in size is equivalent to our No. O. B. & S.; these wires are placed 2′ 9″

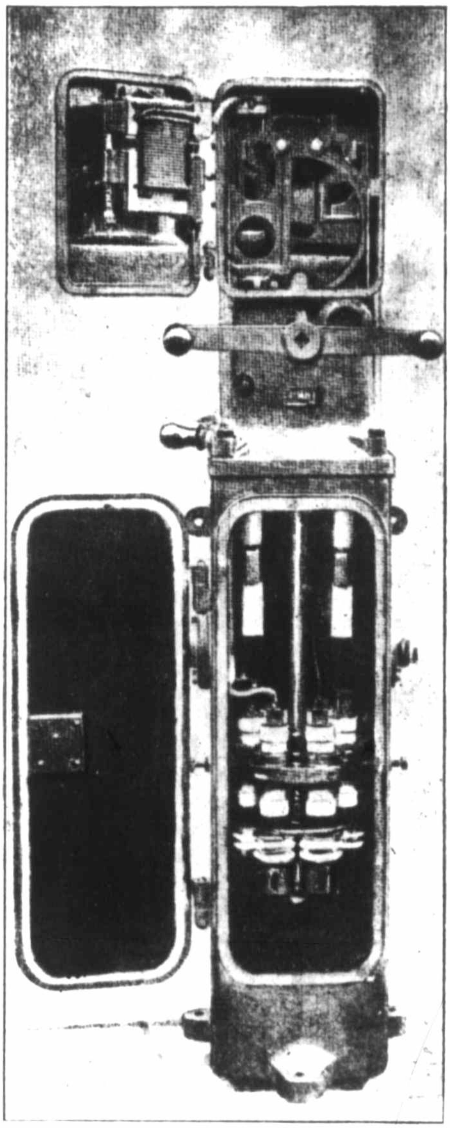


Fig. 3.

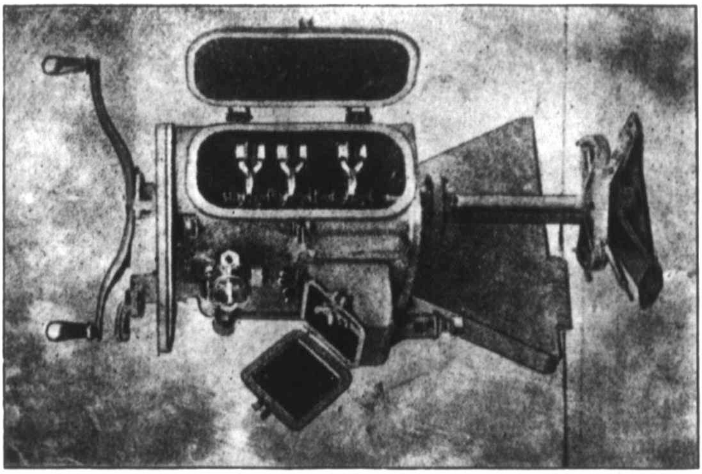


Fig. 4.

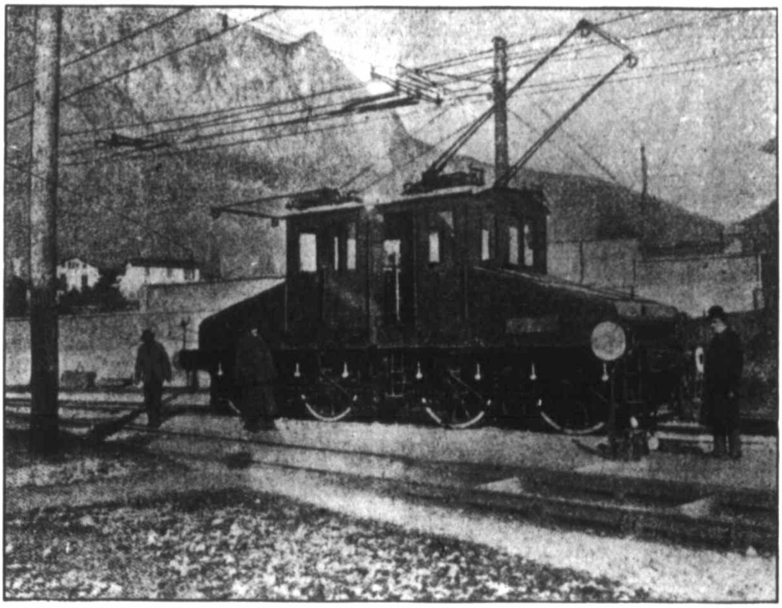


Fig. 5.

apart. According to circumstances they are supported by brackets or span wire, flexible suspension being employed throughout. The insulators are of a special type, with long insulating bolts, and the wires are held by very short mechanical clips which pivot from the insulating bolt. The method of supporting the high tension feeders and the trolley wires, the type of insulators used and the trolley insulators are shown in Figs. 9, 10 and 11.

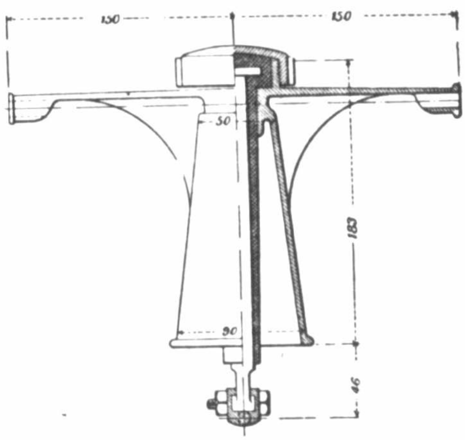
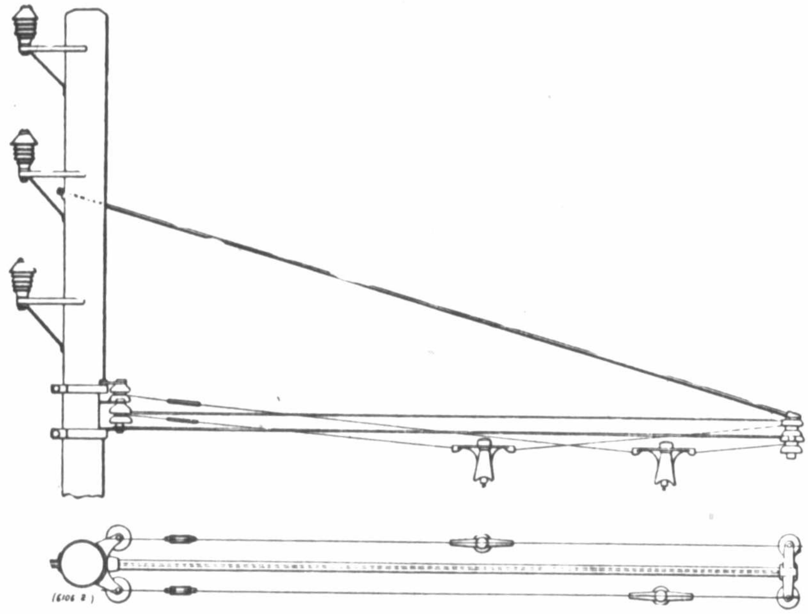


Fig. 9.

The 3,000 volt current is taken from the trolley lines by a sort of bow trolley made up of two copper rollers 16 inches long and 3¼ inches diameter. These rollers which are mounted in the same axial line revolve upon steel ball bearings and are separated by 5 inches of hard wood saturated in parafine under pressure. The current is transmitted by the rollers to highly insulated wires through carbon brushes held against the copper rollers. The current in this way is not allowed to pass through the steel bearings. The trolley wires are held 18 feet above the track.

An arrangement inside the cab permits the lowering, by compressed air, of the trolley arms to disconnect the car from the overhead circuit. The high tension wires on the cars are all protected by grounded metallic tubing.

This road has been in operation only since the 15th of October, 1902, and little data as to power consumption is yet available. I



Insulators and Trolley Lines

Fig. 10.

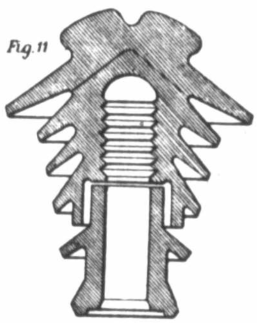


Fig. 11.

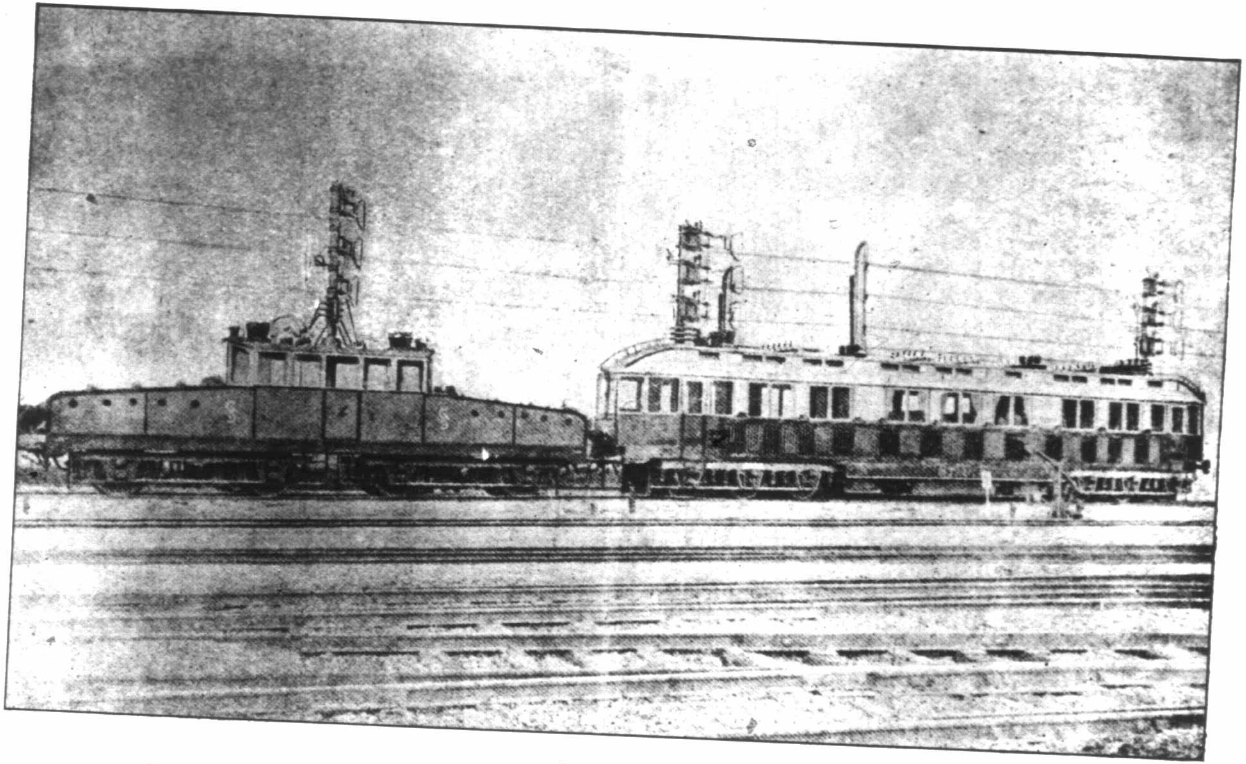


Fig 6

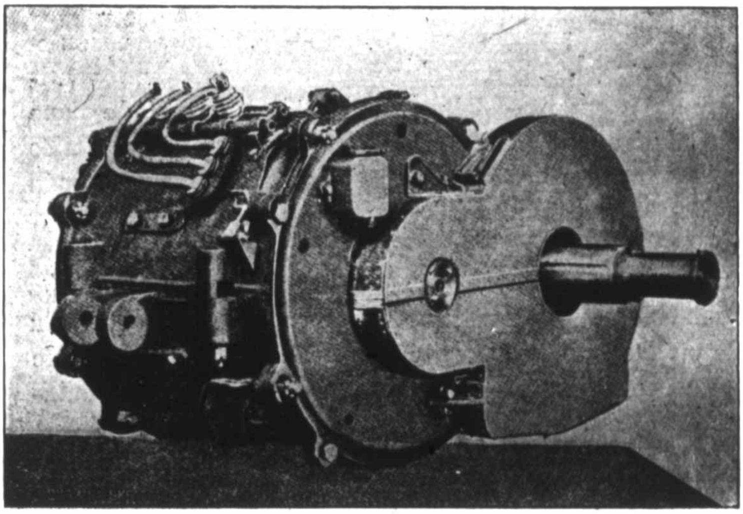


Fig. 7.

am indebted to "L'Industrie Electrique" for much of the above data and for the following :—

To start a motor car with five trailers, a total weight of ninety tons, seventy to ninety amperes are required ; at 3,000 volts this is equivalent to 415 K.V.A. Power factor of primary and secondary motors at max., torque when concatenated 70%.

When running full speed, the secondary motors being out of circuit, the current varies between fifty-two and fifty-six amperes. The power factor 80%.

To start a train weighing 250 tons on a 1.1% grade 150 amperes are required, viz : 810 K.V.A. The maximum horizontal pull is 16,000 lbs. On 4.4 feet diameter driving wheels and 20 miles an hour the H.P. developed is close to 875 H.P.

There are at present ten motor cars and two locomotives in daily service, consuming an average of 9,000 K.W. hour per day. The station equipment for this work is equal to 6,000 H.P. showing a rather small load factor.

THE BERLIN-ZOSSEN LINE.

The trials of high speed traction taking place at the present day in Germany over the Berlin-Zossen road, where speeds of 130 miles per hour have been obtained, have attracted the interest of railroad engineers all over the world. These trials and experiments have now extended over a period of two years. The first trials at high speeds were made with an electric locomotive, as it was deemed advisable to perform experiments with it rather than with a motor car.

Fig. 6 shows a general view of this locomotive, together with the motor car used now. The line voltage is 10,000, three phase, 45-50 periods per second. The underframe of the locomotive is of the double truck construction of a pair of motors, being provided for each bogey. The motors are designed to work at 10,000 volts. The wheels have a diameter of 4′ 4″ and the motors are geared to the axles of the driving wheel with a gear ratio of 2.

Fig. 7 shows an external view of the motor and gear case. The speed at starting is regulated by varying a resistance in the rotor or secondary circuit. Speeds of ninety miles an hour were obtained with this locomotive. It was found, however, that it was not sufficient at these high speeds on account of the velocity of the teeth being exceptionally great to fill the gear box with oil or consistent grease, but that lubricants had to be forced by compressed air through nozzles directed above and below the toothed wheels.

The more recent tests have been made with a motor car shown in Fig. 6. This car rests on two six-wheel bogey trucks and the motors are two to each truck, one attached to the front and rear axle of each truck, the middle pair of wheels in each group running free. The four motors have a total of 1,100 H.P. normal and 3,000 H.P. maximum. The starting and regulating apparatus for an output of 3,000 H.P. could not be built on the lines of the ordinary car controllers and many costly experiments were necessary to test new types of apparatus designed for this purpose.

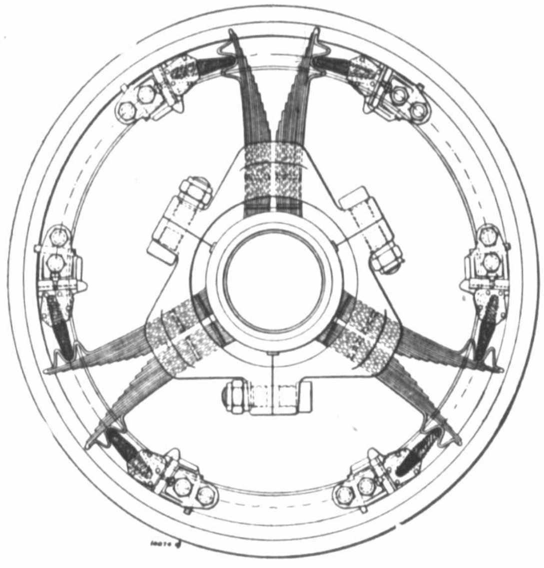


Fig. 8.

The motors are not geared, the rotor axle is hollow and permits the car axle to pass through it. The transmission from rotor axle to driving wheels is shown in Fig 8. A ring in three parts is placed at each end of the hollow shaft, in which are fitted three double arms in the shape of sets of springs, the ends of which bear against sliding pieces fixed on the wheels. The sliding and elastic movement thus obtained allows the regular working and play of the hollow sleeve on the axle. I understand that a slight modification of this tranmission has been made. The electrical equipment of each car is divided into two units, the control of these two separate circuits can be made from either end of the car, according to the direction of travel. Each contain :—

(a) Two motors with two sets of resistances and two starting devices.

(b) One large three core transformer with high and low tension switches.

(c) Air pumps with small transformers, safety cut outs and air receiver.

(d) One current collector.

(e) A driver's stand with air pressure mechanism for working the apparatus.

All apparatus, cables and safety appliances are placed in a room in the centre of the car. The motorman's platform contains no part under electric pressure, he controls the running of the car through mechanical connections with the apparatus in the central machine room. Some place had to be found for the transformers weighing twelve tons, reducing the 10,000 volts of the line at which voltage the current is supplied from the three overhead lines to 1,150 volts, the primary tension for which the motors are built. These are placed underneath the car body in the middle section. The cooling of these transformers is made through air currents passing through two air shafts, which run from the roof of the car to the transformers in such a manner that cool air is taken through one shaft, the hot air flowing out through the other.

Concatenation control is not used, and to bring the motors up to speed, starting resistances are inserted in the secondary current circuit in the usual way. On account of the space under the flooring of the car being already taken up by the transformers and connections, and to obtain as large a cooling surface as possible and as high a degree of efficiency for the weight as possible, the metallic resistances are carried against the sides of the car. A battery of 631 lbs. furnishes the current for lighting when the car is standing with the trolley off the lines. It is out of the scope of this paper to describe in detail the working of this equipment ; it does not, however, materially differ from the description of the previous one cited.

Each car is seventy-two feet long and weighs ninety tons. The track on which these high speeds have been obtained is a nearly level line throughout its length of eighteen miles and the track is in every particular up to the highest standard of modern railway construction. An article which appears in the November 7th issue of "The Electrical World and Engineer" states that when going at the rate of 130 miles an hour the steadiness of the car did not make the impression of so great a speed being obtained, but that persons or objects standing near the track presented blurred images as the car dashed past.

So far as the reports go they point to the satisfactory operation of the whole electrical equipment. The main results of these experiments will be to show under what conditions high speed electric railroading is practicable and what it will cost.

German engineers must be highly complimented on the work already done and on the enterprise they have shown.

The above notes are collected from numerous papers appearing in periodicals and journals amongst which may be cited "L'Industrie Electrique," "The Electrician," "Elektrotechnische Zeitschrift" and "Traction and Transmission."