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100,000 LB. CAPACITY DYNAMOMETER CAR.

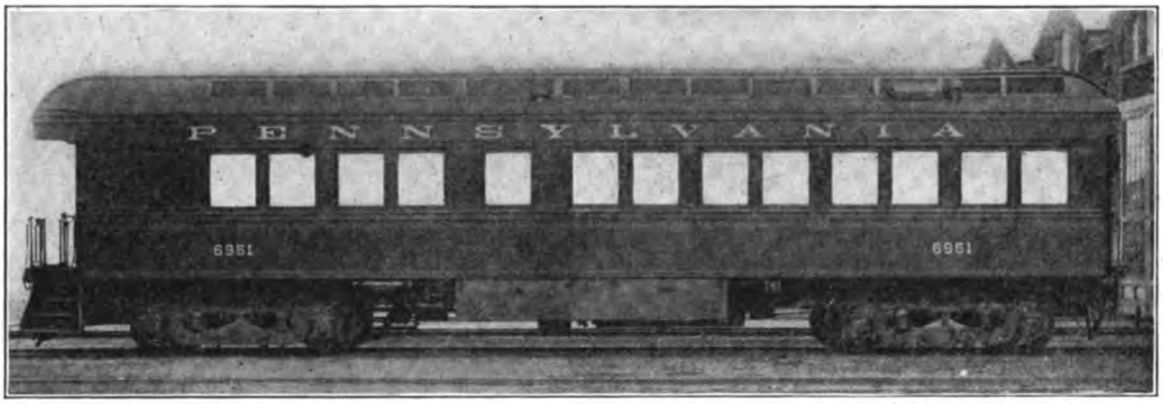
PENNSYLVANIA RAILROAD.

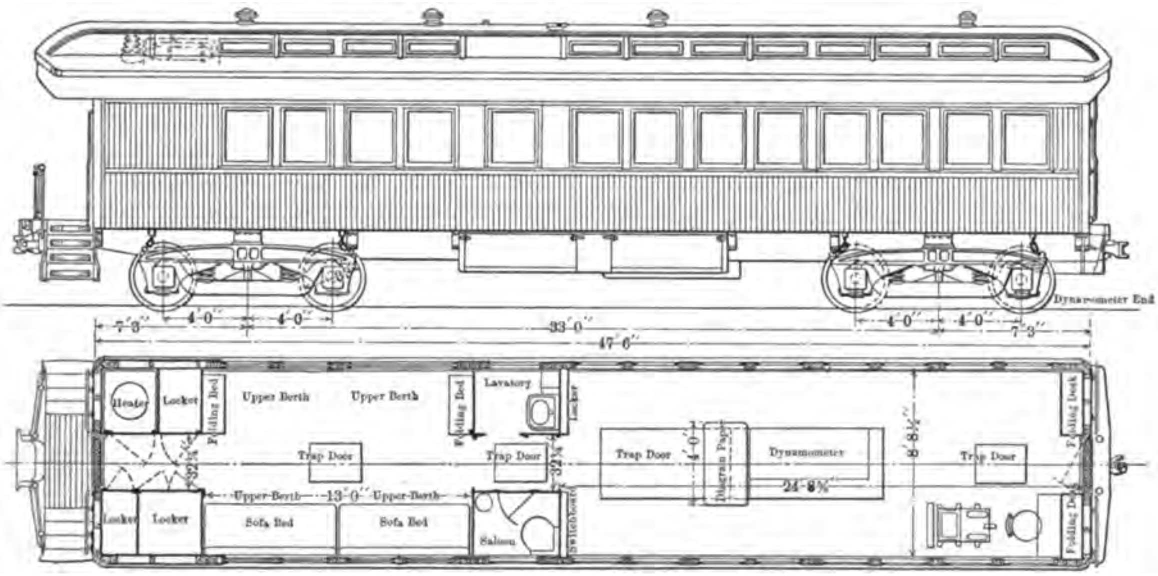
The Pennsylvania Railroad has recently completed a new dynamometer car which, in its construction and working, embodies the result of many years of tests and experiment, and is undoubtedly the best car of its type that has ever been built in this country.

This makes the fifth dynamometer car which the Pennsylvania Railroad has constructed, the earlier three of which were simple and crude affairs compared to the later cars. The fourth car, built in 1885, had a capacity of 28,000 lbs., and has been the means of obtaining a vast amount of very valuable information during its 22 years service. It, however, is altogether too light for modern trains, and the later car has been given a capacity of 100,000 lbs.

The dynamometer complete, with all its attachments, was designed, built and will be patented by Mr. A. H. Emery, of Stamford, Conn., who also constructed the dynamometer used in the former car. The car body complete, as well as the paper driving mechanism and other recording apparatus outside of the dynamometer, was designed and built at Altoona. The specifications for the dynamometer called for a maximum capacity of 100,000 lbs. and a maximum movement of the recording pen of 10 in., the motion to be in the same direction from the base line for either push or pull, and the apparatus to be adjustable so that the value of one inch of motion of the pen could be made to be either 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000 or 10,000 lbs.

After considering several different systems for the dynamometer it was finally decided to use the hydraulic principle in which all of the load on the drawbar should be transmitted directly to the piston of a large hydraulic cylinder secured to the frame of the car. The pressure exerted by this piston on the fluid in the cylinder to be carried to the piston of a small recording cylinder, the movement of which is restricted by a number of carefully calibrated helical springs. The strength of each set of springs will determine the amount of movement of the recording pen secured to the end of the piston rod of the small cylinder, for any pressure exerted on the large hydraulic cylinder or main press. Thus by knowing the relative areas of the two pistons and the amount that the springs will compress under a certain load, the load on the drawbar corresponding to the movement of the recording pen can easily be determined.





100,000-POUND DYNAMOMETER CAR—PENNSYLVANIA RAILROAD.

Taking up first the general construction of the car body. Reference to the illustrations will show its general exterior and interior appearance. It is built with a platform at one end, the opposite end, which carries the drawbar connected to the dynamometer, being built blind. The superstructure is much the same as an ordinary wooden passenger coach.

The underframe is made up entirely of steel. The side sills are formed of five inch 17.9 pounds "Z" bars attached to the center sills by means of cantilevers. The center sill is built up in the form of a box girder 38¾ in. wide inside, 20 in. deep, and extending the entire length of the car. This sill consists of two

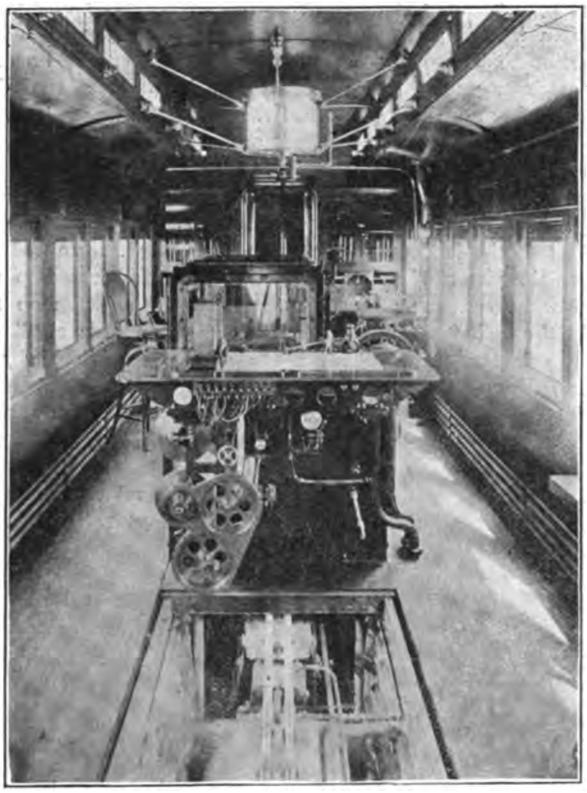


FIG. 3.—INTERIOR OF THE WORKROOM.

20 x ¾ in. plates with ½ in. cover plates top and bottom, the corners being reinforced by 3½ x 3½ x ⅝ in. angles. Within this girder is placed the housing of the main press, which is built up of 1⅜ in. plates securely riveted to the sides of the ¾ in. plates besides being reinforced by three steel castings. This section of the sill has to act as a foundation for all the delicate apparatus in the car, as well as to carry the heavy strains transferred to it by means of the piston rod which passes through the cylinder to the forward end of the car at which place it is attached to the draft gear by means of a heavy cast-steel housing, the details of which are shown in Fig. 8.

The trucks are of special and heavy construction, having an 8 ft. 0 in. wheel base and of a style somewhat like a locomotive truck. The journal boxes are fitted with equalizers, upon which rests double sets of elliptic and helical springs. The truck bolster is pressed steel connected at the ends by means of a transom to the cast steel side frames, to which are also bolted the pedestal jaws. The journal boxes are of a special design, being fitted up with oil trays, which not only carry the oil but support a special lubricating pad held up against the journal by means of two helical springs. The lid is never removed for ordinary oiling, as provisions have been made by an additional opening covered by a small lid, so as to insure a good seal. The axles are fitted with thirty-three inch steel tired wheels, having spoke centers, journals being 5½ x 10 in.

The forward wheels of the rear truck, figuring the dynamometer end as the front end of the car, are of special design, and are not equipped with brake rigging. These wheels drive the paper mechanism, and for that reason they have been very carefully and accurately turned with a straight tread. When it is considered that a slight change in the diameter of these wheels

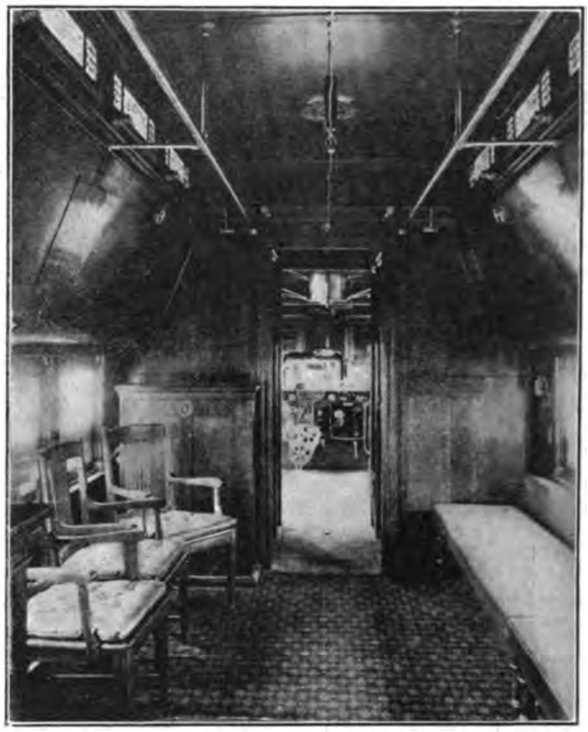


FIG. 4.—INTERIOR OF THE LIVING ROOM.

will make a very large difference in the number of revolutions they make in a 10-mile distance, and hence in the movement of the paper below the recording pen, it is easily understood why special care should be given at this point, and why the tread is made straight instead of coned.

The interior of the car is divided into two main compartments, the larger of which, at the forward end, is known as the workroom and the other, which is directly back of it, being separated by the lavatories, is known as the living room. Back of the latter is a short aisle on one side of which is a heater and a large closet for supplies, and on the other a compartment for coal, oil, etc., ahead of which is a space for a case in which the recording springs of the dynamometer are kept immersed in oil when not in use. The living room, which is 13 ft. 0 in. long, contains four upper berths, two sofa beds, and two cabinet beds, also several chairs and a table, which can be taken apart and stored underneath a berth. It is in this room that the results of the runs can be worked up or the room can be used as a dining-room, there being electric cooking utensils provided in the car. It also can, of course, be used as sleeping quarters, the accommodations being suitable for a crew of eight men. In the workroom, which is 24 ft. 8 in. long, is contained the weighing and recording apparatus, located in the center of the room; a direct con-

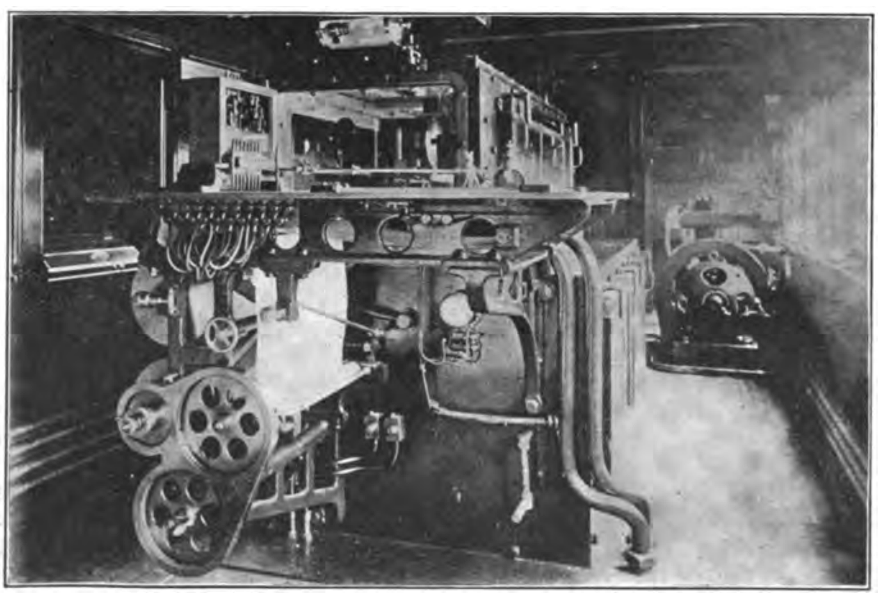


FIG. 5.—VIEW OF RECORDING TABLE AND PAPER DRIVING ROLL.

nected 2½ h.p. oil engine generator set; two folding desks, switchboard and tool cabinets, etc. The photographic illustrations will show the appearance of these different rooms.

The car is lighted by electricity, a storage battery of 32 cells located beneath the car being provided for this purpose. This battery can be charged from the direct connected set on the car when other means are not available. All of the small closets in the car are provided with electric lights, which are turned on by the opening of the doors. A number of plugs are also provided for portable lights. The Thrumveller heating system has been installed and provision is also made for connection to steam from the locomotive or from steam lines in the yard. No provision is made for a cupola or elevated lookout window, such as is usually provided in cars of this type, and the exterior observations are made through a glass shield which can be fitted to any of the side windows, and permits the observer to have a clear view ahead.

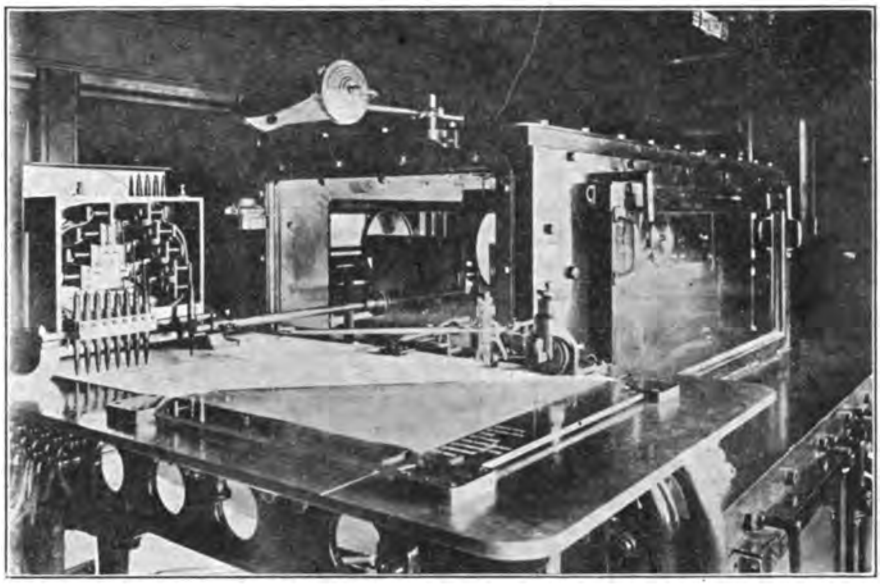


FIG. 7.—VIEW OF TABLE SHOWING RECORDING PENS.

The car measures 47 ft. 6 in. over end sills and weighs about 62 tons complete in working order. The interior finishing and furniture are specially noticeable for their richness and simplicity.

Paper Driving Mechanism.—The paper mechanism is driven, as mentioned above, from the forward axle of the rear truck. This axle was specially made and contains at its center a spiral gear which is integral with it. This gear meshes with a similar spiral gear keyed to a horizontal shaft, which runs forward a distance of about 21 ft., where it ends in a bevel gear. Here the motion is carried to a vertical shaft projecting up into the case beneath the case containing the recording apparatus. On the upper end of this vertical shaft is another bevel gear, which meshes with two gears running freely on a horizontal shaft, which will be seen in Fig. 5 projecting through the end of the case and geared to the paper driving roll. On this shaft and splined to it between the two bevel gears is a collar provided with teeth which can mesh with corresponding teeth in the hub

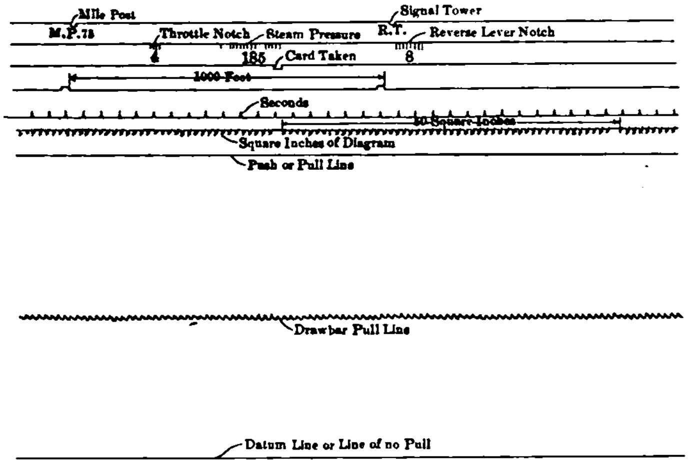


FIG. 6.—SAMPLE RECORD FROM DYNAMOMETER.

of either gear. The movement of this collar is controlled by a handle under the recording table. The adjustment is such that both gears can run free on the shaft or the splined sleeve can be meshed with either so as to drive the paper only in one direction no matter which way the car is running. The paper is carried in large rolls, the supply roll being the upper one in Fig. 5. From this the paper goes up through a slit in the table over the top and below the recording pens, and then down through a second slit in the far end, under a guide roll back underneath the table and then down vertically through the driving roll and to the receiving roll, which is friction driven and always moves fast enough to keep the paper tight. The driving roll is of bronze, with its surface slightly roughened, and has its diameter so proportioned to the diameter of the car wheels that the paper moves across the record table at the exact rate of 1 in. per 100 ft. travel of the car. A rubber roll presses the paper firmly against the driving roll, so that no slip can occur.

Fig. 6 gives a sample record which is reversed in position from the location of the paper as shown in the view of the recording table, Fig. 7. The lower, or datum, line, is made by a small wheel with its circumference in contact with an inking pad, which revolves in the opposite direction of the motion of the paper, as the paper passes beneath it. Above this is the record of the drawbar pull made by the pen on the end of the piston rod from the recording cylinder. This will be seen projecting out through the front of the glass case. Above this is the record of a pen which automatically shows whether the load on the drawbar is a push or a pull. Since the dynamometer is arranged to register on the same side of the datum line for both it is impossible to tell from the record line whether the load is forward or backward. The next record is from the mechanical integrator, the arm of which is connected to the recording pen. An electrical connection is made to the integrator wheel on the table, so that every notch in the record has a value of 1 sq. in. of area between the dynamometer record and the base line. Every fiftieth notch is skipped, so that the numbers can be quickly summed up. Since the integrator wheel usually stands at an angle to the motion of the paper it has a tendency to cause the paper to slip sidewise. To correct this an instrument, shown at the right of the integrator wheel in Fig. 7, is provided. This consists of a rubber wheel rolling on the paper, which can be set at any desired angle to counteract the influence of the integrator wheel. Beneath this rubber wheel and set in the face of the table is another wheel, the diameter of which is very carefully made so that it will have one revolution for every 10-in. motion of the paper, and by electrical connection makes a record showing the 1,000 ft. distance traveled by the car, which record is the fourth from the top in Fig. 6. The record directly below this is made by a connection to the chronometer and indicates the distance passed over by the paper at five second intervals. There are three other pens, the records of which are shown in Fig. 6. The third from the top is operated by an observer on the locomotive and records the time of taking indicator cards. The second is also operated from the locomotive and records the steam pressure and the position of the throttle and reverse levers. The upper one is operated by the observer at the lookout window, and is used to record locations of permanent objects, such as mile posts, signal towers, curves, etc. An extra or reserve pen is also provided for use in emergencies.

One corner of the paper is covered by a triangular sheet of glass, on which the operator can rest his arm while making notes without any danger of impeding the motion of the paper.

The Dynamometer.—As mentioned above, the load from the

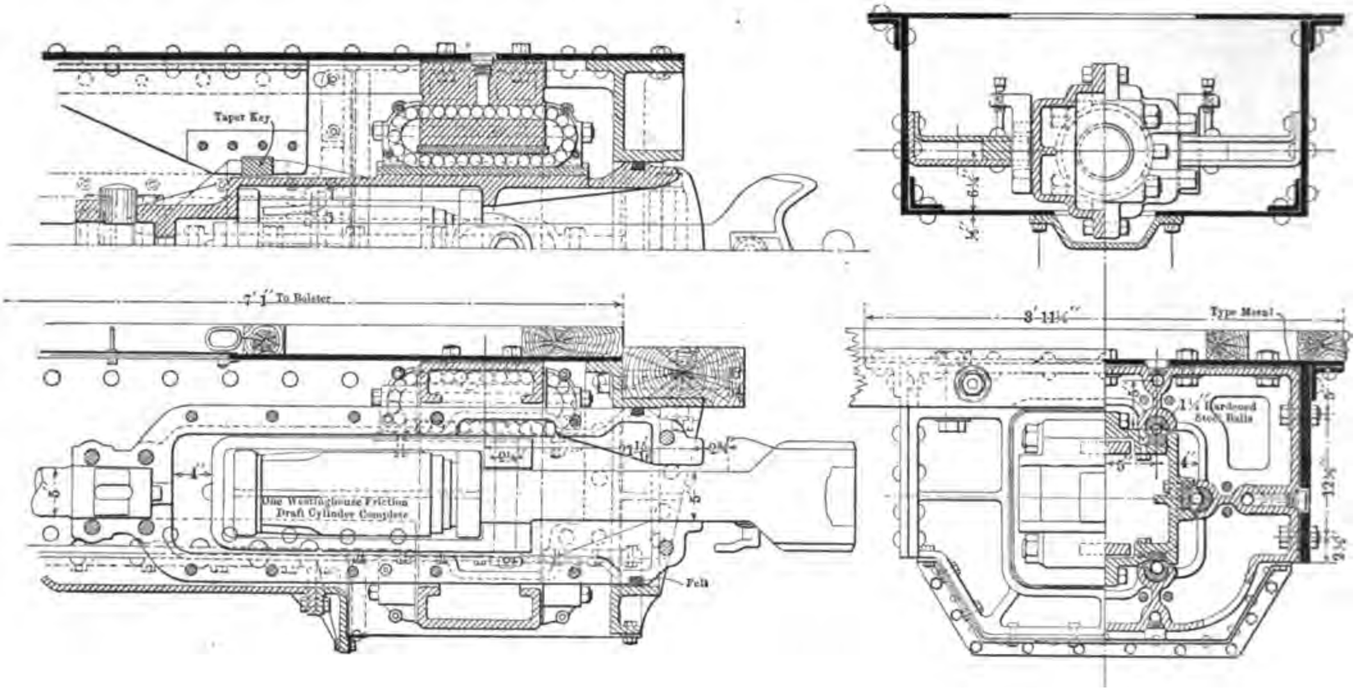


FIG. 8.—DRAFT GEAR HOUSING AND END OF CENTER SILL—PENNSYLVANIA R. R. DYNAMOMETER CAR.

drawbar is transmitted directly to the piston of the main press, and since it is desirable to get a very accurate measurement of the exact load on the drawbar, it is necessary to use all possible care in eliminating friction between the coupler and the piston. This has been done by the liberal use of a ball and roller bearing at all points of support, and in addition special arrangement has been made to keep all dust and dirt from getting access to the interior of the box girder center sills wherein the connections lie.

The coupler head is connected to a Westinghouse friction draft gear by the usual yoke. This draft gear is secured within a heavy cast steel housing, the details of which are shown in Fig. 8. This housing is carried in a frame which forms part of the center sill construction, and is supported and guided in it by a set of six circuitous ball bearings, each containing 32 hardened steel balls 1¼ in. in diameter. The bearings, or ball races, are so arranged as to have 10 of these balls constantly in contact with the housing, thus holding it in rigid alignment and practically without friction. The space between the outer end of the housing and its frame is fitted with a felt bushing. To relieve the dynamometer mechanism from all load when it is not in use provision is made for the inserting of tapered keys between lugs on the housing and its frame, so that they are rigidly held together and the load is carried directly to the sills in the usual manner.

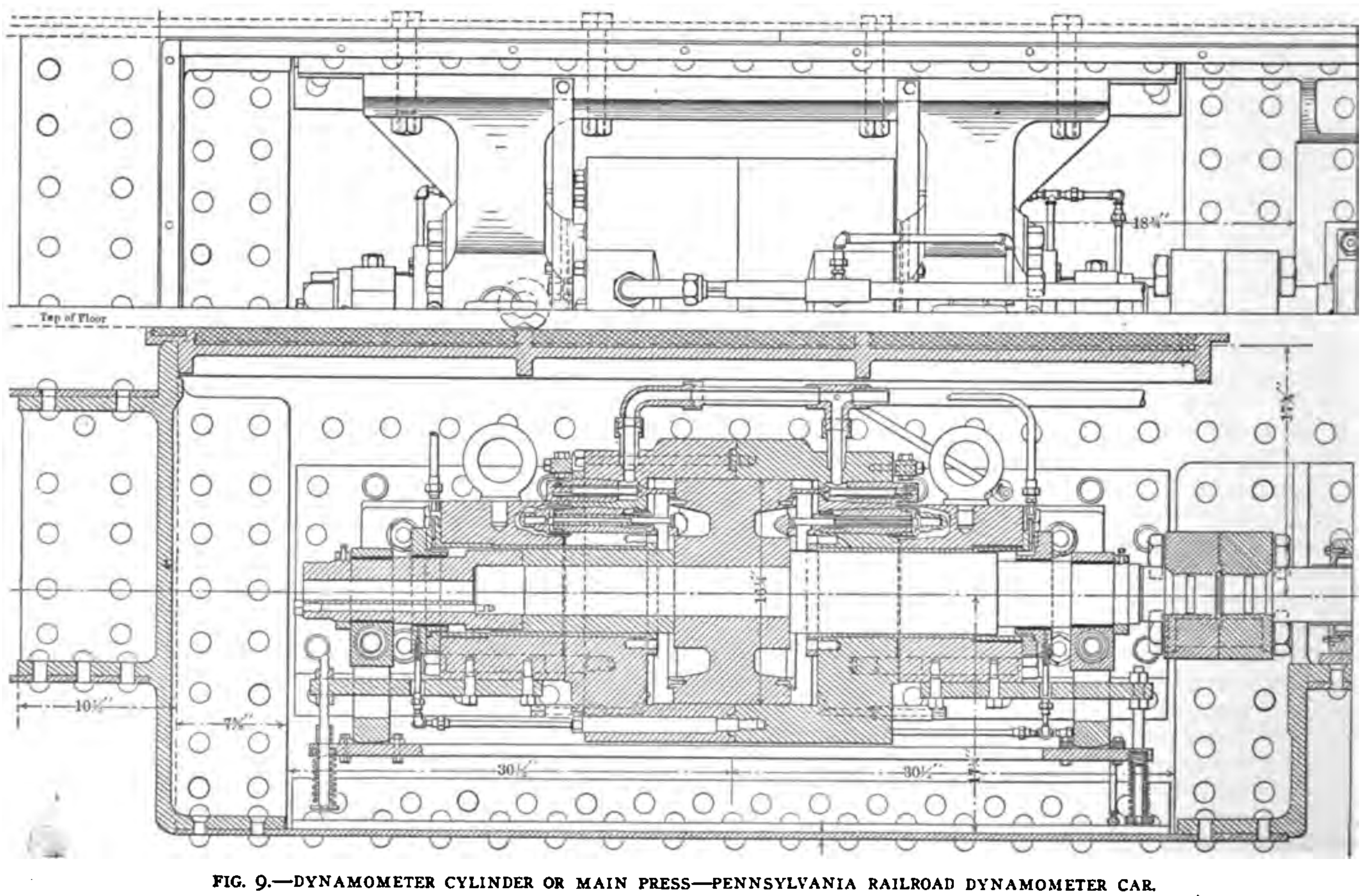


FIG. 9.—DYNAMOMETER CYLINDER OR MAIN PRESS—PENNSYLVANIA RAILROAD DYNAMOMETER CAR.

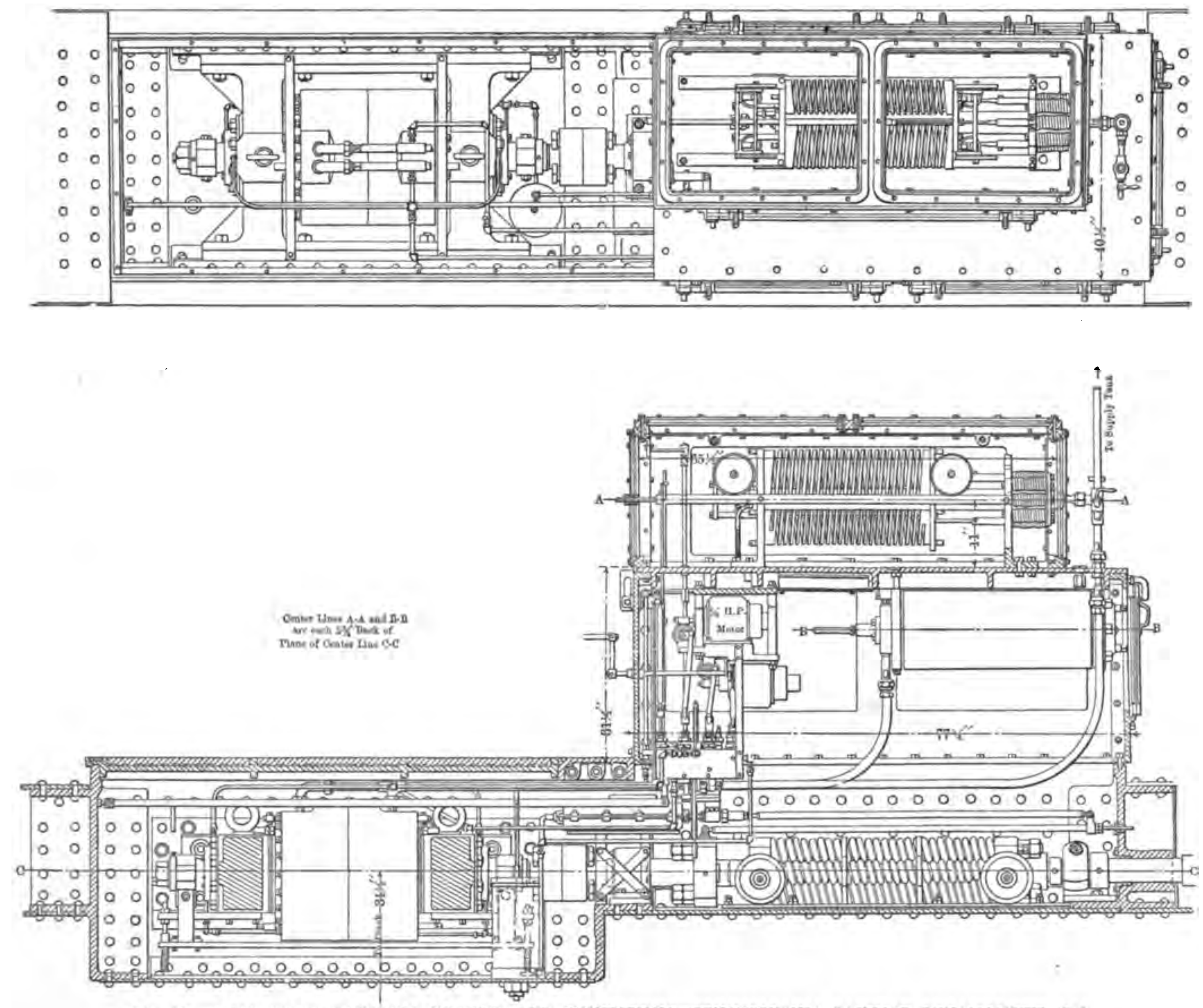


FIG. 10.—MAIN PRESS, RECORDING CYLINDER AND CONNECTIONS—PENNSYLVANIA RAILROAD DYNAMOMETER CAR.

The rear end of the housing is connected to a shaft or drawbar which about 6 ft. back passes through a cast-steel partition in which is placed a special form of stuffing box that is practically frictionless, and beyond which it connects to a spring buffer. This spring buffer is designed to take all loads above 100,000 lbs., the capacity of the apparatus. It consists of three cross heads, one being permanently fixed to the extension of the piston rod from the main press of the dynamometer, while the other two crossheads fit around the drawbar shaft and are held in place by nuts on the outer side of each. Four long bolts pass through all three crossheads and are secured in the one from the main press and are movable in the other two. There are distance or spacing thimbles around the bolts between the first and second crosshead at the left. Coil springs are fitted around the bolts between the two crossheads at the right, and by means of nuts on the ends of the bolts these springs are set with a compression of 100,000 lbs. The whole apparatus is carried on a small carriage fitted with four wheels, as is shown in the illustration. Since the springs are under compression of 100,000 lbs. all loads up to that limit will be transmitted directly through the buffer the same as if it were a solid bar. If the load increases above this, one crosshead will move away from the thimbles and the springs will compress until they have shut 1⅛" less whatever the piston has moved from the central position, when a stop on the drawbar shaft will strike against the partition just to the right of the buffer and then any load over that necessary to compress the springs this much will be transmitted directly to the frame of the car. The same action takes place for either pulling or buffing strains.

To minimize the friction, the weight of the draft gear and its connecting rod to the piston of the main press cylinder, is carried on frictionless bearings either in the form of rockers which rotate on ball bearings or else it is carried on ball bearings with straight race-ways. That part of the box girder which contains the main press is made absolutely dust proof. Provisions have also been made to keep this compartment at as nearly a uniform temperature as possible, both winter and summer, so that a minimum variation in the viscosity of the oil will be obtained.

Fig. 9 shows the details of the main press and Fig. 10 illustrates its connections to the recording cylinder. The construction will be seen to be very heavy and since it is necessary to eliminate friction as far as possible and as the leakage allowance is very small, it is necessary to make some provision for carrying the weight of the piston and its rod so as to prevent wear of the bushings in the end of the cylinder and allow a close fit without friction. This has been done by means of a support at either end outside of the cylinder, consisting of rocker arms bearing on a flat support which is carried by four springs from the main cylinder housing. The rocker arms at their upper ends carry a cross shaft fitted with roller bearings on which the piston rod rests. By adjustment of the springs supporting the carrying plate it is possible to just relieve the weight of the piston from the bushings.

The piston itself is 16¼ in. in diameter and is 8 in. long. It is carefully fitted to the cylinder and is grooved with a spiral groove on its periphery to secure lubrication and avoid the use of packing. The cylinder itself is made of gun iron in two parts fitted together as shown in the illustration.

Since it is necessary for the dynamometer to register in either

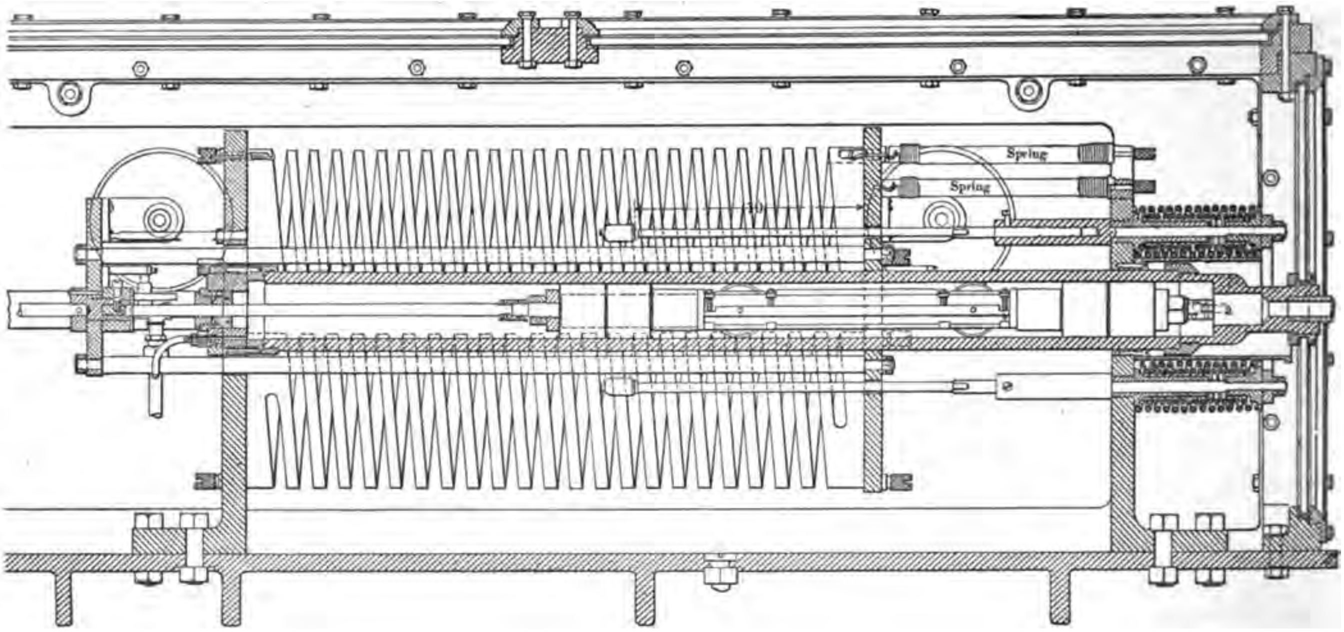


FIG. 11.—DETAILS OF RECORDING CYLINDER—PENNSYLVANIA RAILROAD DYNAMOMETER CAR.

direction, automatic valves have been arranged so that when the piston is in the exact center the valves leading to the recording cylinder and the supply tank are both slightly open and the whole apparatus is in equilibrium. A slight movement in either direction, however, will close the valve to the supply tank on the side toward which the piston moves and open the valve leading to the recording cylinder, while on the opposite side the reverse takes place, thus while either side of the piston is compressing the liquid into the recording cylinder the other is always open to the pressure from the supply tank.

Fig. 11 shows a cross section of the recording cylinder and Fig. 12 is a view of this cylinder with the springs in place, and also shows the recording piston with its rod and carriage on the table in the foreground. The recording cylinder, which is connected by an oil pipe at the back end through the cooling cylinder directly to the main press, is 40 in. long and 2 17/32 in. in diameter. It has a piston area equal to about 1/36 of that of the main press. Since it is even more necessary to eliminate friction at this point than in the main press extreme care has been taken in the design of the piston and cylinders so as to allow perfectly free movement and to prevent all possible wear while at the same time making the leakage so small as to be negligible. For this purpose four pistons are provided in pairs, each pair being fastened to the end of a long arbor. This arbor is provided with a pair of rollers whose axles are carried in two side bars, thus forming a small truck which carries the arbor and piston. Eight springs which are interposed between the wheels and the truck can be accurately adjusted so as to just support the weight of the moving parts. The ends of the recording cylinder are supported by plates, which also carry two rectangular bars, forming a track for a four-wheel truck. Extending from the arbor carrying the piston is a small piston rod, which connects to a crosshead forming the forward end of the truck just mentioned. The rear end of this truck is formed by another crosshead, the connection between the two being made by four rods, which pass freely through openings in the forward stanchion supporting the recording cylinder. The recording springs are placed between the rear crosshead of the truck and this front stanchion. The piston rod is carried on beyond the crosshead and through the glass case which encloses all of this apparatus and on its end carries the pen for making the record. The recording springs are fastened in place by thumb screws and are of special construction, which will be mentioned later.

In order to prevent any possibility of accident to the recording springs in case too light springs are in place for the load on the main press, a spring buffing arrangement is attached back of the rear stanchion, and so connected as to come into action when the carriage has made a movement of 10 in., the limit of travel of the pen. Springs are used for this purpose in place of solid stops, because of the possibility of the throttling device between the main press and the recording cylinder being left open when light springs were in place and a sudden load which might come upon the machine would then force the piston out very rapidly and make it inadvisable to bring it against a solid stop. The construction of this apparatus is clearly shown in the illustration.

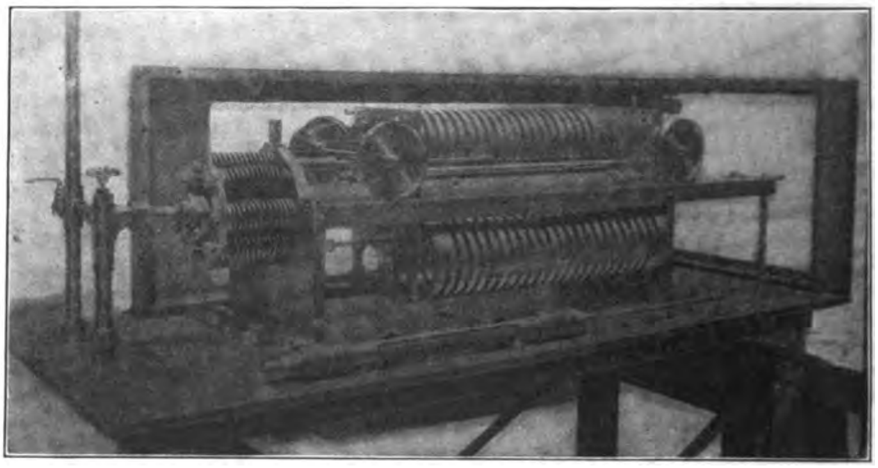


FIG. 12.—VIEW OF RECORDING CYLINDER, SPRINGS AND SPRING BUFFER.

The manufacture of the springs to resist the movement of the recording piston, which must be capable of giving exactly the same movement per increment of load for any point during a compression of 10 in., required a large amount of study and experimentation. After several failures and much tedious labor, the problem was solved by making the springs in the following manner: A drum of nickel steel was rough turned to the desired outside and inside diameter and cut off to the proper length, and was then hardened in an oil bath. After being hardened it was turned and bored to the exact size, carefully fitted to a mandrel and a spiral groove was cut through the drum, starting near one end and stopping near the other, leaving a spring of square section with solid ends. This was then carefully tested and ground on the outside until it would give exactly the same movement under the same increase of load at any point in a compression of 10 in. for any number of applications. In fact, so accurate was this work that its probable error in 10 in. is only about 1/1000th of an inch. The difficulty attending this work will be understood when it is stated that after the drum was hardened it, in some cases, took two days to drill a 7/16 in. hole ⅝ of an inch deep in the drum. The threading of one drum took 27 working days to finish. There was but one kind of tool steel which was found capable of doing this work and that would only operate when given special heat treatment and required constant sharpening. The springs are 27 in. long and vary from 5.6 to 7.3 in. outside diameter. They weigh from 29.4 to 58.6 lbs. each. The smaller ones, of course, being the ones used for the larger movement of the pen under lighter loads.

For supplying oil to the cylinders and to take care of all leakage past the piston a complete system of tanks, piping and pumps has been provided. The large supply tank, shown near the roof

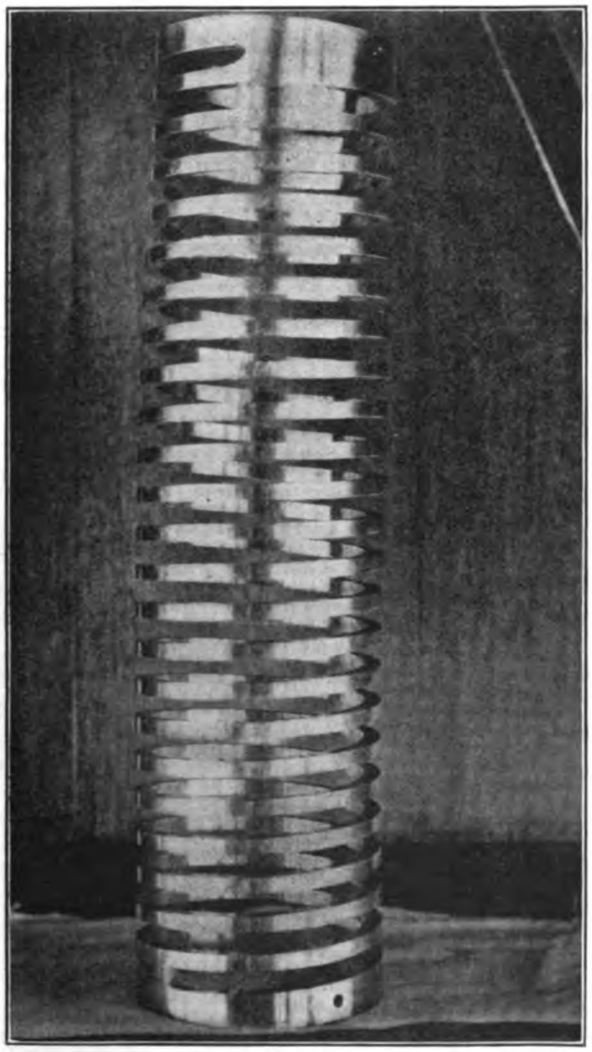


FIG. 13.—ONE OF THE SPRINGS.

of the car in Fig. 4, is connected directly to the valves in the main press. Interposed between the main press and the recording cylinder is a cooling cylinder on the end of which is a needle valve which can be controlled from the operating table and is used to throttle the passage of the oil to the recording cylinder. If necessary, this valve can be closed, thus cutting off the recording mechanism altogether.

The leakage past the piston of the recording cylinder, as well as that through the piston rod glands of the main press, is conducted through a system of pipes to the leakage tank, which is fitted with a float valve, and upon the oil reaching a predetermined level this closes the circuit and starts a motor driven pump which returns the excess leakage to the supply tank. If on account of leakage past the main piston or for any other reason this piston leaves the center line of the cylinder more than ⅝ of an inch another electrically driven pump is started, which will force the piston back to within ⅝" of mid-position, being capable of working against the maximum pressure exerted by the main press. Both of the electrical pumps are supplemented by hand pumps, and there is an electrical alarm which sounds when anything goes wrong with the electrical pump.

Average Load in Box Cars.—It is a question whether railroads exercise their best judgment in building their equipment upon the single basis of carrying capacity instead of on the double basis of cars and carrying capacity. Too many high-capacity cars have been built in recent years, as shown by the small average load; and in view of the fact that there have been relatively few changes in classification. In order to demonstrate the truthfulness of this as relates to box cars, some figures were prepared covering the business of the busiest months of the Erie Railway, and it was found that, exclusive of merchandise, the average load placed in a 60,000-lb. car was 15 tons; in a 70,000-lb. car, 21 tons; in an 80,000-lb. car, 21½ tons.

It will be noted that the average load would utilize less than half of the carrying capacity of the 40-ton box car, and about two-thirds carrying capacity of the 30-ton box car. During the last fiscal year, the Erie Railway handled 1,120,000 loaded box cars. Of this number 470,000 were loaded with merchandise, which averaged 12,000 lbs. a car, and 650,000 were loaded with freight other than merchandise, which averaged 41,000 lbs. If the Erie Railway could have had its choice of 30-ton cars or 40-ton cars, in which to handle all freight requiring box cars, during the last fiscal year, a saving of $312,000 would have been effected in the cost of operation by the use of the smaller car, the lesser weight of the smaller car making this possible. Heavy capacity cars are operated economically when used for handling specified commodities of great specific gravity, such as tidewater coal and ore.—*Mr. C. C. Riley before the New York Traffic Club.*

Power Factor in Railroad Shops.—The percentage of generator capacity to the sum of the rated motor horse-powers is somewhat uncertain, but it is lower perhaps than generally imagined. At the 1903 convention of the Master Mechanics' Association a committee reporting on electrically driven shops stated that 40 per cent. of the aggregate horse-power of the tools could be taken, and to this added the constant and average lighting load in order to determine the capacity of the generators required, without including in the list of such motors those required for cranes, transfer tables or turntables, but that the question of a spare unit should always receive consideration. The Master Mechanics' proceedings for 1900 stated that at the Baldwin Locomotive Works, the switchboard load averaged only about 27 per cent. of the total motor rating, in this case the crane motors being included. At the Topeka shops a switchboard load equal to 38 per cent. of the various motors, exclusive of those on the cranes, was found to obtain. At the McKee's Rocks shop the power consumption was about 30 per cent. of the motor rating. The actual installation of some large and modern shops is very interesting. At Collinwood the total generator capacity (after deducting requirements for lights) was 50 per cent. of the sum of the motor ratings, not counting those upon the cranes. At McKee's Rocks shop it was 47 per cent. on the same basis; at the Angus shop, Montreal, 37 per cent. The new Parsons shop of the M. K. & T. Ry. has a generator capacity of about 75 per cent. of the total rated motor capacity. Of course the question of the size of generators and also spare units affects this to a certain extent, and the best way to study the question is to lay out a hypothetical load diagram and determine from this the most economical size of units.—*Mr. G. R. Henderson at the New England Railroad Club.*