all interlocking plants. The signal nearest the entrance to the interlocking is lettered "OUT," meaning that the train is passing from the block system into the interlocking limits. The first block signal past the interlocking is lettered "IN," conveying to the motorman that he is passing from the interlocking into the block system.

Besides its economical and effective operation, this system has other advantages. In case of trouble on the line, necessitating a shut-down at the power house, the trains would, of course, come to a standstill. Now if at the instant the power was turned on, all the trains, or even a greater part of them should start up at once, which usually happens in cases of this kind, none of them could get very far before the automatic

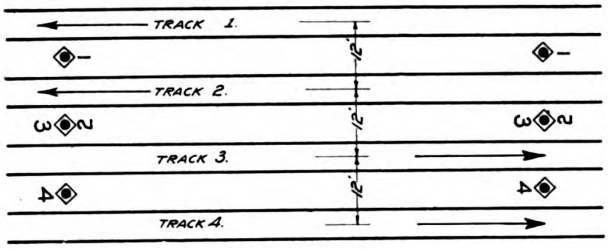


FIG. 3.

circuit breakers in the power house had again shut off the power. On this very road it has been necessary many times, when trouble causing the shutting off of power was remedied, to station men at certain intervals along the track to keep all the trains from starting at once. This condition, troublesome in itself, and productive of sometimes more delay than the actual breakdown, is done away with by the block signal system. It is evident that if a number of trains are standing one behind the other, each one will have to wait until the one ahead has passed the second block signal in front of it. After the first train has reached the end of the block and passed into the next block, the second train will start and when it in turn has cleared the signal for the third train, the latter will start, and so on. Thus no unusual demand for power will be made upon the station, and no additional delay will be caused in case of a temporary shut-down.

This very clever and ingenious block system is the invention of two officers of the road, Mr. M. J. Feron and Mr. B. J. Fallon, the former the superintendent and the latter the chief engineer. It is fully protected under the patent laws.

It is not within the scope of this article to present any arguments in favor of controlling the "human element" or in favor of banishing it as nearly as possible from the operation of trains, but it may not be a digression to state that the extreme effectiveness of this simple signal arrangement is due not so much to the signal and its position as it is to the assistance and co-operation of the "human element," the train men, who are themselves almost a part of the signal.

An inspection of the principle as shown in Figure 2 leads to the conclusion that this system can be used just as well on such roads as the Lake Street Elevated and the Northwestern Elevated, where motormen are on the inside of the track or on the left hand side of the cars. All that is necessary is to place the signals on the outside of the track. It would mean that each track would require a signal of its own, but the cost of the signals is so very little that even with a complete set of them for each track the total figures would still be ridiculously small. Also the possibility of using a system of this sort for service in tunnels and subways with lights instead of spot boards as the means of conveying indications is worth considering.

THE ELECTRO-PNEUMATIC SIGNAL AND INTERLOCKING SYSTEM AT THE NEW UNION STATION, WASHINGTON, D. C.

By FRED. W. BENDER

There has recently been completed in our national capital, Washington, D. C., a new union station, the simple grandeur of which is befitting the importance of its location. It is said to be the largest and most magnificent railroad station in the world, and is the result of the co-operation of the district government and the Pennsylvania and Baltimore & Ohio railroads in an effort to eliminate grade crossing and replace two passenger stations, thus centralizing all passenger traffic entering Washington. It is located four blocks north of the capitol, and faces south.

The property covers a ground area of over eighteen acres, and consists of the main station building, three signal towers, a complete power house, an express building housing three express companies, a complete locomotive and car repair shop, together with a coach yard of ample capacity. There are sixty miles of track in all. The concourse occupying the space between the station tracks and the main station has a floor area of 113,250 square feet, and is covered by an arched roof of 150 foot span, so that the floor space is entirely free from obstructions in the shape of supports for the roof. The terminal improvement is said to have cost upwards of $20,000,000.

The track arrangement entering from the north consists of three double track lines, two operated by the Baltimore & Ohio Railroad Company and one by the Philadelphia, Baltimore and Washington division of the Pennsylvania Railroad, converging at the New York avenue interlocking plant (which is the northerly end of the system) and diverging in this interlocking to ten parallel tracks which run through to the point where the tracks again diverge to thirty-three station tracks at the K street interlocking plant. Nine of the station tracks run in on a depressed level and merge under the station building at the Massachusetts avenue interlocking plant into a two track road leading south in a twin tunnel running under Capitol Hill for about 5,000 feet, joining the main line of the P. W. & B. R. R., thus connecting for southerly traffic over the long bridge across the Potomac to the R. F. & P. R. R.'s direct line to Richmond, Va.

The following railroads use the station: The Pennsylvania, the Baltimore & Ohio, the Seaboard Air Line,

the Atlantic Coast Line, the Richmond, Fredericksburg & Potomac, the Chesapeake & Ohio, and the Southern.

SIGNALING AND INTERLOCKING.

Owing to the distances involved in this terminal, the important class of traffic using it and the need for extremely safe and expeditious handling of trains, it was decided by those in charge of the specifications governing the signaling and interlocking requirements that the latest form of three-position speed signaling, involving the upper quadrant principle of operation with semi-automatic control of all interlocked signals, was necessary. The use of electric detector circuits for locking switch levers, in lieu of detector bars, was also decided upon.

With these conditions in mind, the advantages of the Union Switch and Signal Company's electro-pneumatic system of interlocking, because of its low voltages and extreme flexibility in electrical selection and simple adaptability for semi-automatic control of signals, three-position control, electric locking, etc., through the medium of its flexible spring combination, became apparent, and this company was awarded the contract for the three interlocking plants with intervening automatic signals, as shown on the layout plan. (See Figure 1, which is a supplement.)

The Union Company were manufacturing pioneers in the adoption of the upper quadrant principle, and prior to the award of this contract had already built three-position electro-pneumatic signals operating in the upper quadrant.

An installation of upper quadrant signals was made a year prior to this on the Middle Division of the Pennsylvania Railroad.

The principle of electric detector track circuit locking for switch levers in lieu of detector bars was also original with them, having been in use in electro-pneumatic plants for some years.

INTERLOCKING LAYOUTS.

The system of interlocking and signaling comprise three interlocking plants known as New York Avenue, "K" Street and Massachusetts Avenue.

The total number of lever spaces in the three frames is 291, of which 240 are active levers, leaving 51 spaces for future use. "K" Street, the largest machine, has a 191 lever frame, with 162 working levers. New York Avenue, the next in size, is 71 lever-frame, with 58 working levers. Massachusetts Avenue, the smallest, has a 29 lever-frame, with 20 working levers.

There are 108 working switch levers in all, operating 73 single switches, 5 derails, 86 ends of double slips and switches, and 43 pairs of movable point frogs. There are 106 working signal levers operating 251 three-position signals and 157 two-position signals, making a total of 408 working signals, besides which there are 164 fixed blades to carry out the speed signaling principle. Thirty of the working signals are light signals in the Massachusetts Avenue plant for tunnel operation. The use of the Electro-Pneumatic machines with the right and left signal lever operation, effected a saving of 90 signal levers over any other type of power interlocking machine. This permitted the towers to be built correspondingly smaller.

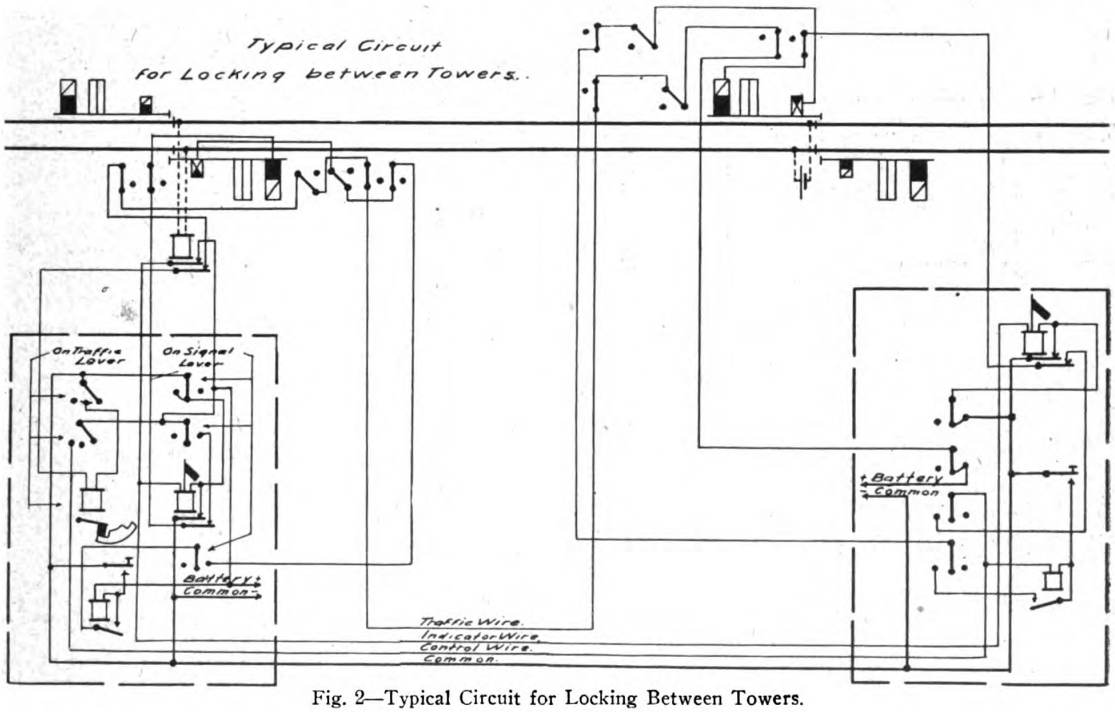
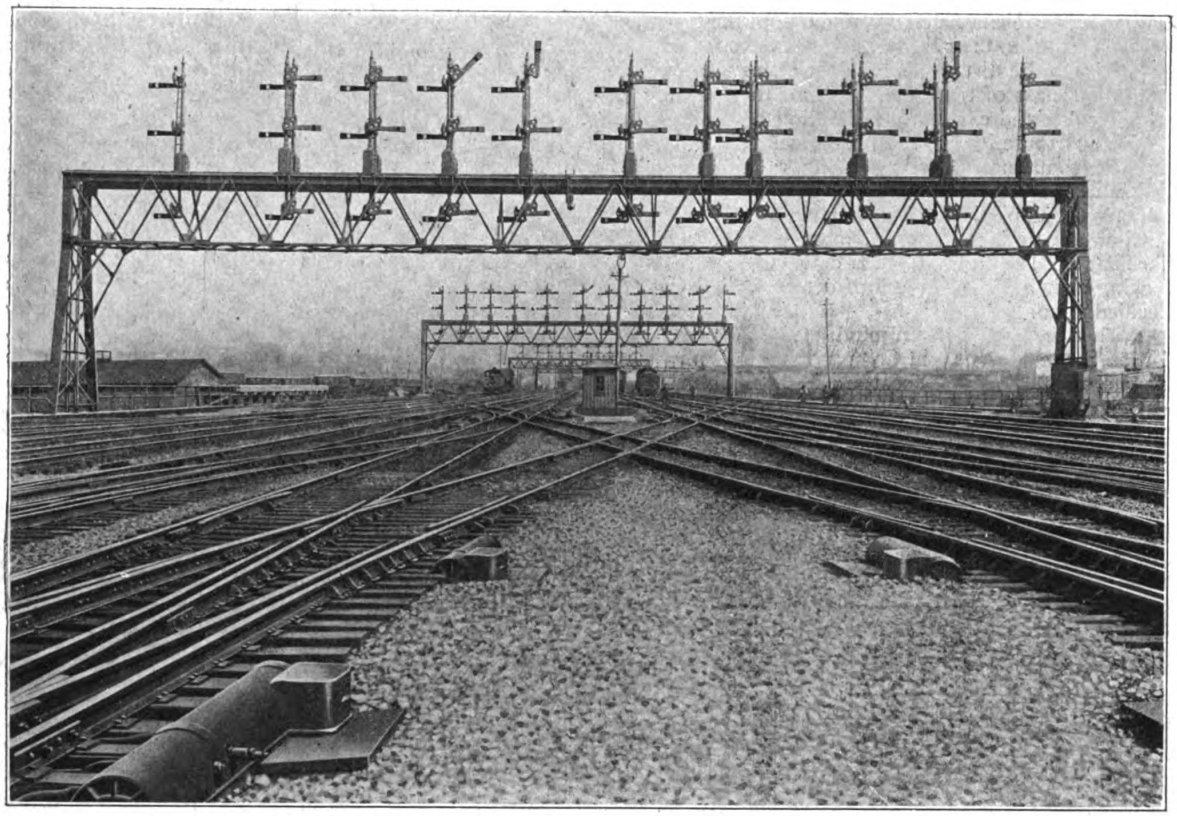


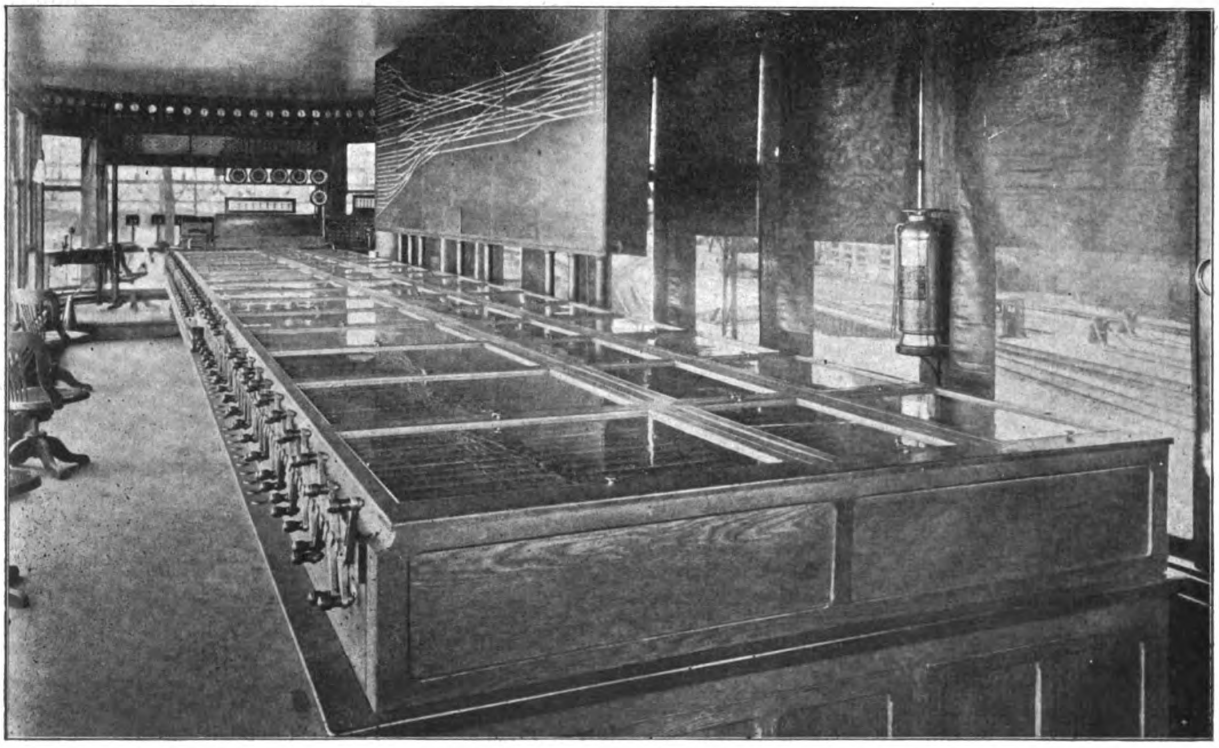
Fig. 2—Typical Circuit for Locking Between Towers.

TOWERS.

The towers are fireproof, being built entirely of steel frames and fireproof materials for the floors and walls, and (except in the case of Massachusetts Avenue tower) are three stories in height. The lower stories are used for offices and other similar purposes; the second story is used for switchboards, terminal boards and relays. In the "K" Street tower the spring combination plates and rollers of the interlocking machine, which are mounted vertically, are also located on this floor, on a specially built structural steel frame, it being found necessary to do this on account of the large amount of selecting that was necessary for control of the home signals and electric detector circuits, and more especially the selecting for the third position of the signals. In the third story are located the machines, illuminated track diagrams, track indicators and the indicator and push button cabinets used in the sys-



Bridge H—Looking North.

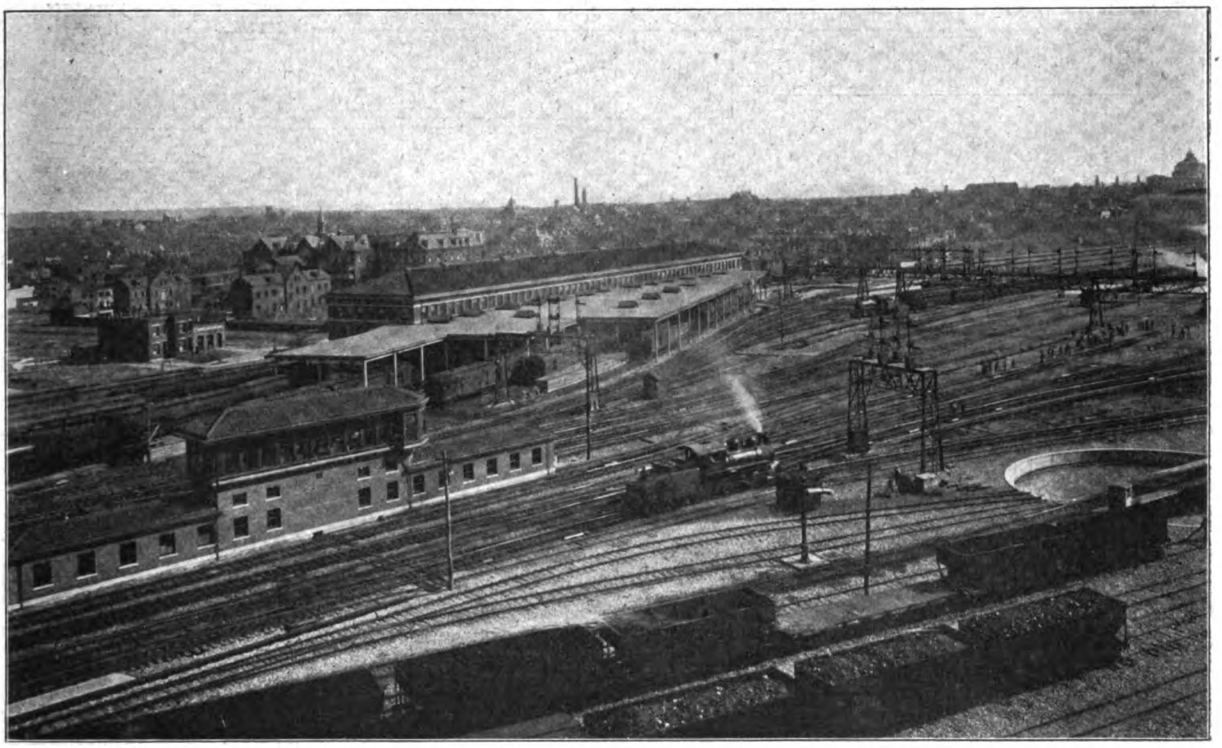


Interior View of K Street Tower—Showing Illuminated Track Model Over Machine.

tems of inter-communication and train starting. These towers were erected by the Terminal Company.

MACHINES.

The interlocking machines are of the standard electro-pneumatic type of the Union Switch & Signal Company and are arranged with standard equipment for electric detector circuits, by which the switch levers are prevented, through the medium of the regular electric indication locks, from being moved out of their position in case the relays of any of the track circuits affecting that particular switch are opened by the presence of a train on these track circuits. No additional special electric lock is, therefore, required for this important function. The track circuits were especially laid out with the end in view of obtaining the maximum protection, not only for the switch points themselves, but for all possible fouling movements; for this reason, the protection of all switches was carried by track circuit at least 100 feet ahead of every switch point, and in all cases back as far as the fouling point. In the ladder of double slips, the detector circuit protection was carried, with the slips reversed, to the track circuit on the next parallel track by means of selection on the lever rollers; this being done when sufficient fouling of facing point protection could not be otherwise obtained without locking the switches unnecessarily. The special selection required for this feature alone would have made this installation extremely complicated were it not for the use of spring combination, made possible by the adoption of electro-pneumatic apparatus.



Part of K Street Plant—K Street Tower in Foreground.

ILLUMINATED TRACK DIAGRAMS.

Instead of the usual form of mechanically actuated track model heretofore largely furnished with the electro-pneumatic machines, an illuminated track diagram being a reproduction in miniature of the entire tract layout controlled from a machine is located at the back of each machine. They are supported on iron pipe stanchions at the proper height above the machines for quick reading by the operators, and are made up of a riveted steel framework with casing, panels and partitions of aluminum, to insure lightness and imperviousness to temperature changes. The design embodying the use of steel and aluminum for this purpose is original with the Union Company, and these models are fine examples of good design and workmanship. The "K" Street model, being the largest ever built, is 19 ft. 6 in. long, by 5 ft. 4¾ in. high by 9 in. deep, containing 750 lamps and repeats 130 track sections. The fronts of these diagrams are glass, painted flat black, except for the long slots representing the tracks. These lamps are of 1 c. p. and are supplied by alternating current from a transformer which gives a secondary voltage of 14. The wires between the controlling relays on the second floor and lights in the model are carried through the iron pipe stanchions into the back of the model.

LOCKING BETWEEN TOWERS.

Between the three towers, and also between the Massachusetts Avenue interlocking and the outlying interlocking at Second and Virginia Avenues, and between New York Avenue interlocking and outlying interlocking tower at Rhode Island Avenue, a system of locking between towers is installed by which movements opposing the established direction of traffic on any track connecting these plants is absolutely prevented. (See typical circuit, Fig. 2.)

SYSTEM OF INTERCOMMUNICATION.

A very complete system of intercommunication is in operation between all the towers, by which the move-

ments of trains are announced through the medium of push-buttons and banks of semaphore indicators and train describers. Not only is the movement of trains announced, but various other information as to the class, destination and routing of trains is communicated with celerity, and directions are also given promptly through this system as to the disposal of trains when they have been announced. The instruments used in this scheme involve 272 semaphore indicators and 288 push buttons and 29 train describers.

The wiring used to operate this system is enclosed in one lead covered standard telephone cable run in underground terra cotta ducts. This cable has 160 wires of 19 B. & S. gauge.

SIGNAL BRIDGES.

There are eighteen signal bridges in this territory, ranging from 33 feet to 145 feet length of span. All the signal bridges were erected by the Terminal Company.

At Massachusetts Avenue, on account of the construction of umbrella sheds, and in order to obviate obstructions under these sheds, it was found desirable to mount signal bridges over the sheds supported by the shed posts, for the support of the south bound signals.

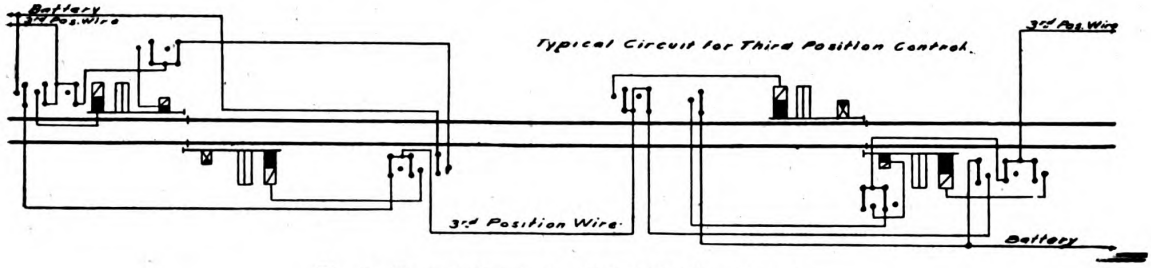


Fig. 3—Typical Circuit for Third Position Control.

SIGNAL FUNCTIONS AND CONTROL.

The three-position speed signaling system, upper quadrant aspect is used throughout, the upper arm of all signals controlling the highest speed routes only; the second arm or medium speed blade controls other route or routes where considerable speed, but not the maximum, may be maintained. The low speed arms, in all cases, lead to routes whose condition prevents them being used at any but low rate of speed. In addition to this function of the low speed arms, they may be cleared for high, medium or low speed routes which may be occupied (for example, drilling movements). This is done by a special circuit in which, by means of a push button, operated only by permission of the train director, a stick relay is thrown in series with the magnet of the low speed arm, at the same time cutting out all semi-automatic control, but permitting only the caution position of the slow speed arm. (See Fig. 5-a for sample of this circuit.) All signals automatically assume the clear 90° position from the next high speed signal ahead over the route set up, providing the signal in advance is in the caution 45° or clear 90° position. (See Figs. 3, 4, 5 and 5-a.)

To accomplish this, all the third-position circuits are selected over the switch rollers in the spring combination of the interlocking machines.

BATTERY ARRANGEMENT.

Eighty ampere hour storage batteries were used throughout the interlockings of the Electric Storage Battery Company's (of Philadelphia) chloride accumulator type, all track circuits, indicators, relays and electric locks being energized from them. Two charging circuits were used, one extending from the power house in each direction from the K street interlocking tower. All cells are in duplicate and arranged so that one-half the total number of cells are on discharge while the others can be charged without influencing the discharge side.

A special system of charging and discharging was designed so that the same size and type of cell could be used throughout. To accomplish this, the cells were arranged in groups and the discharge from that particular point calculated and enough cells were then located at each point to operate its various functions for a period of four days on each charge as a minimum. Special switches were designed to throw these batteries in parallel for discharging and in series for charging. For the 2 volt track batteries the cells all discharge in multiple, but in the interlocking batteries, where 12 to 14 volts are customarily used, the cells were shifted for discharge into one or more groups of seven cells each in series and a sufficient number of these groups arranged in parallel to last the required four days.

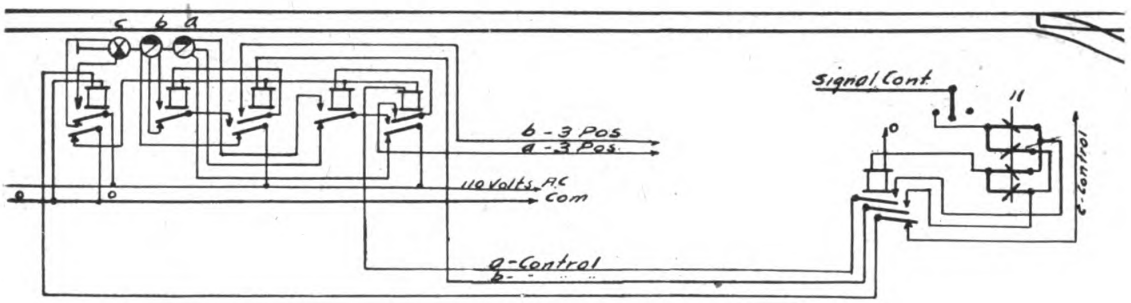


Fig. 4.

TRACK CIRCUITS.

All track circuits are fed from storage batteries at two volts, a special adjustable resistance coil being inserted in the positive track battery feed leading to each track circuit. There are 263 track circuits in the layout which would cover a distance of 18 miles of single track.

TRAIN STARTING SYSTEM.

The communication between conductors of outgoing trains, gatemen at the concourse entrance to station platforms and the tower directors at K street and Massachusetts avenue interlocking is of extremely novel design, and is the first installation of its character to be used. Intercommunication is established by means of light signals controlled by these employes. which each particular interlocking controls. This includes all of the thirty-three tracks for K street, and at Massachusetts avenue the nine through tracks are represented. In operation the train conductor about one minute before his train is due to leave operates the circuit controller in the platform light box in any of the shed posts by means of his key, lighting one of the three lights in the tower. The train director, when ready to start the train, pushes a button in the cabinet on his table, which extinguishes this light in the tower and at the same time lights a second light in his own cabinet and also one light in each of the five indicators in the platform and one of the lights at the platform gate. The gateman, after closing his gate and ascertaining that everything is ready for starting the train,

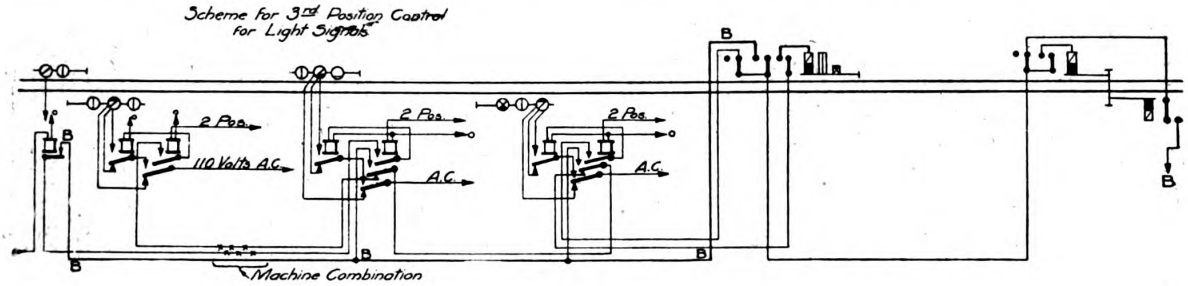
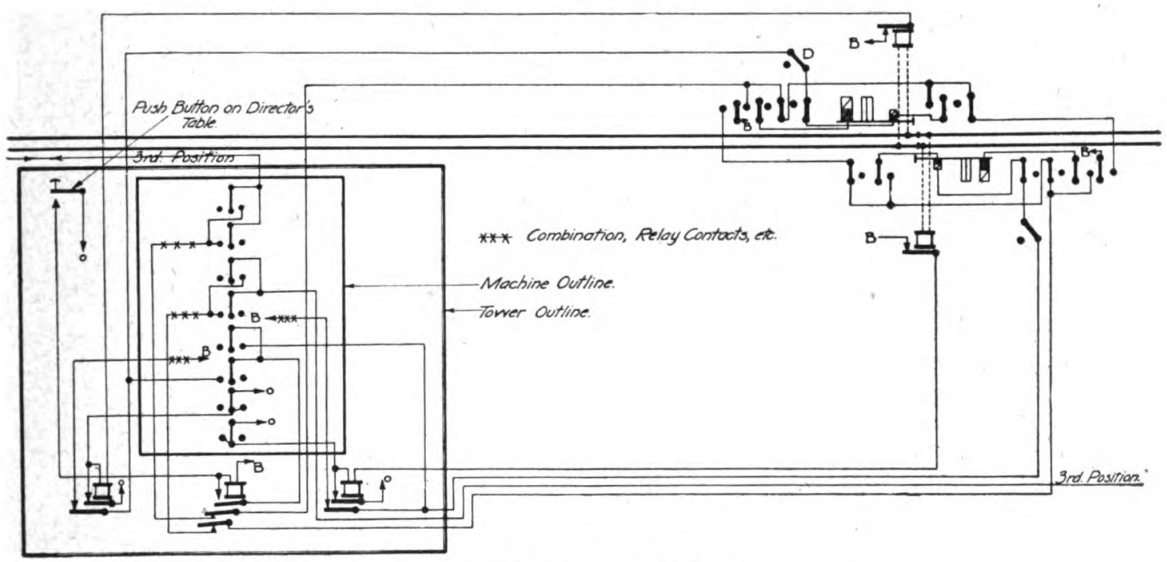


Fig. 5.



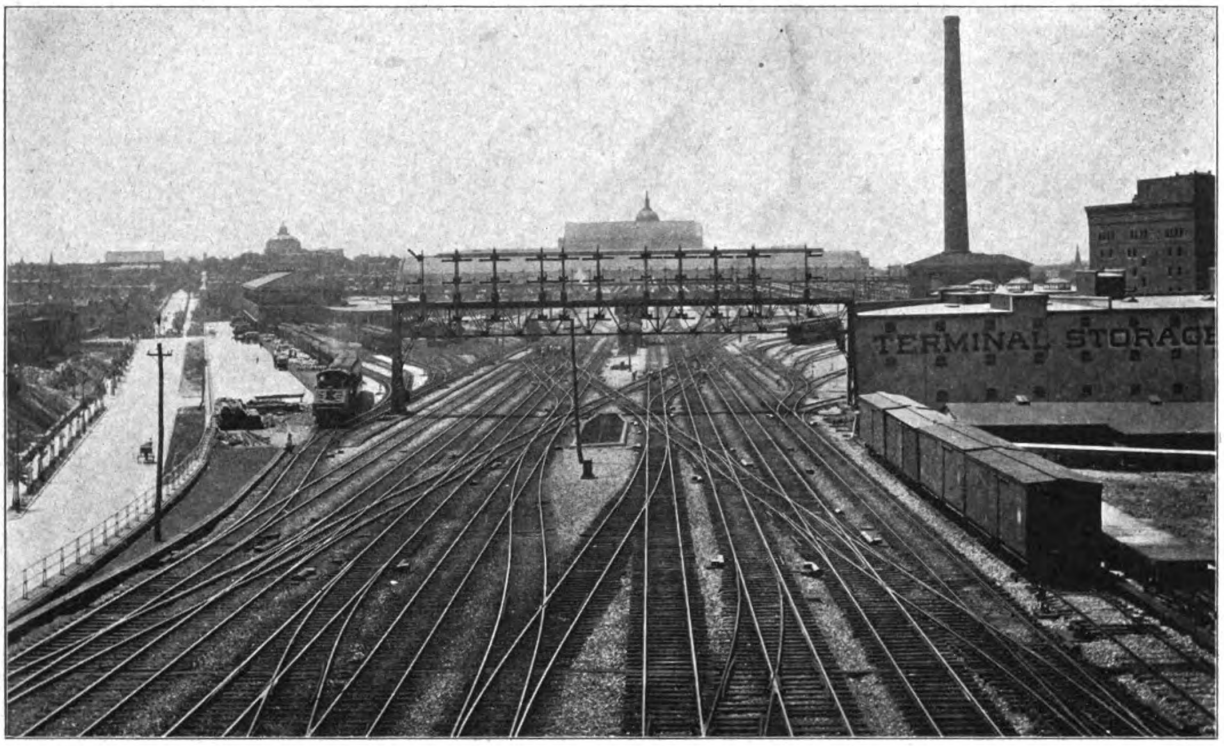
Typical Circuits for Push Button Control of Low Speed Signal for Switching Movements.

Fig. 5a.

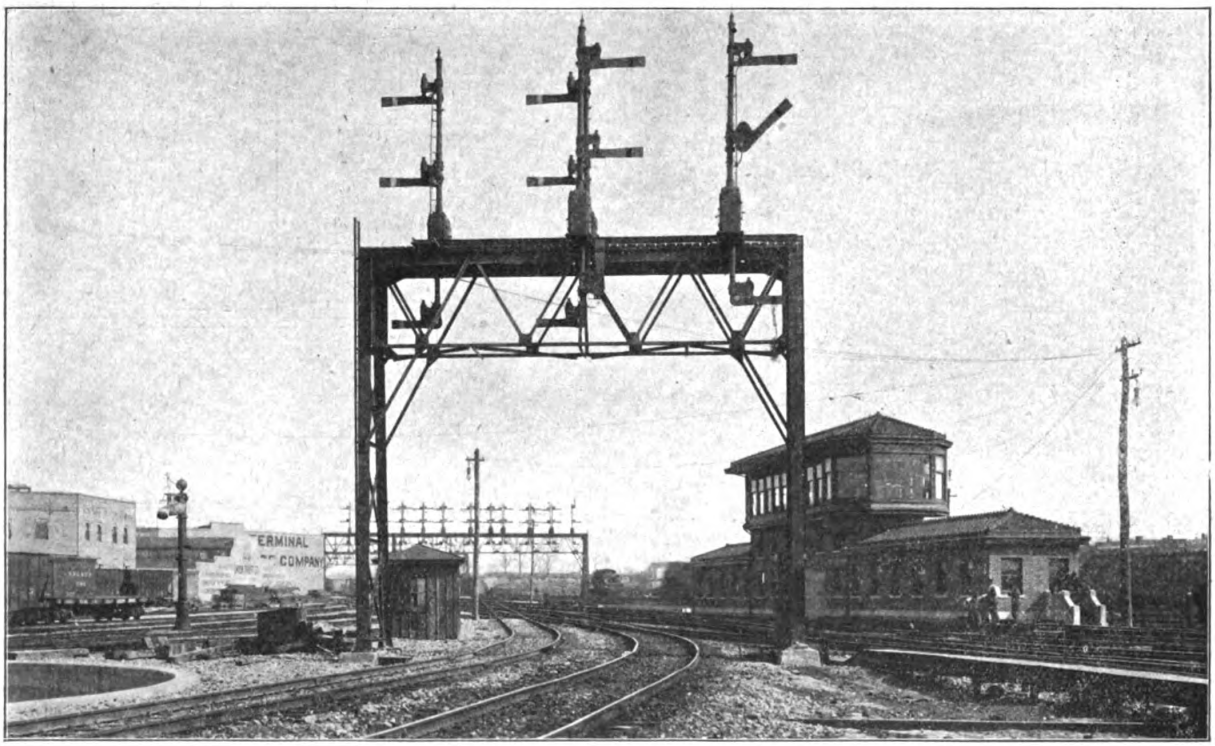
Over each platform gate are placed two electric lights normally dark. Inserted in five of the cast iron posts which support the umbrella shed are platform light boxes; these consist of two separate lenses, behind which are lights, also normally dark, and a circuit controller operated by a key similar to an ordinary latch key. (See Fig. 6.) Key operated circuit controllers were used instead of push button and other similar devices to prevent the manipulation of the system by other than the proper people. As part of this system there are located in K street and Massachusetts avenue interlocking towers, aluminum cabinets containing three normally dark lights for each station track over operates a key switch located at the gate, which lights the second light in the platform light boxes governing the train which it is desired to start, and the gate indicator and the third light of the tower. This gives permission to the conductor to move his train down to the interlocked signals, from which point the movement is governed by the signals in the usual way. All lights are extinguished after the train leaves the platform by the train director. (See Fig. 7.)

RELAYS.

All relays used in this interlocking are the Union Company's Universal Neutral type, those used on track circuits being wound to 12 ohms resistance.



Looking South Toward Terminal Station—Bridge H in Foreground (Dome of Capitol is Seen Over Station Roof—Congressional Library to the Left).



Bridge F at K Street Interlocking—Looking North.

There is a total of 734 of these relays in this entire system, 263 of which are track relays. All are suitably inclosed in relay cupboards and cases, those out on the ground being placed in cupboards built in the signal bridge legs. In the tower the relays are inclosed in a specially developed combined rack and terminal board suggested by the signal company, whereby all relays and the wires leading to them are conveniently accessible. The wires from the binding posts of all relays are of flexible electric light cord, so that the relays can be handled and inspected without disturbing the connections. These flexible leads are carried to binding posts on terminal boards which run the entire length of each shelf and just above the relays, leaving a space sufficient under this terminal board and above the shelves to reach from the front to the rear and vice versa. The wires are inclosed in boxing built vertically on upright posts and horizontally immediately back of each shelf. All of these intersections form junctions to run the wires in. The wires are run from the boxing through slots in the sides of the boxing to binding posts at each relay location.

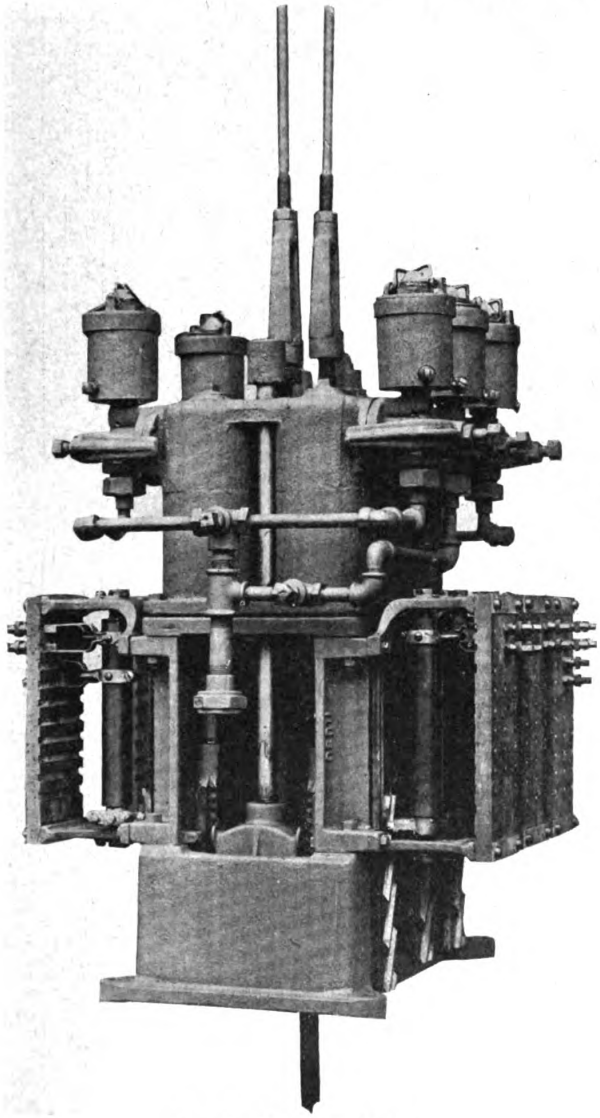


Fig. 8—Signal Mechanism.

ELECTRIC LIGHTING.

All signals are lighted by alternating current at 110 volts, the lights on each side of each interlocking being controlled through a fused knife switch on the switchboard in each tower, one 2 c. p. lamp being used for each signal. Electric lighting mains lead from these switchboards to the lights. At each signal bridge there is also a fused knife switch and the branch wires running up the signal poles are inclosed in loricated pipe, cast iron junction boxes inclosing binding posts mounted on slate bases being used at junctions of the loricated pipe.

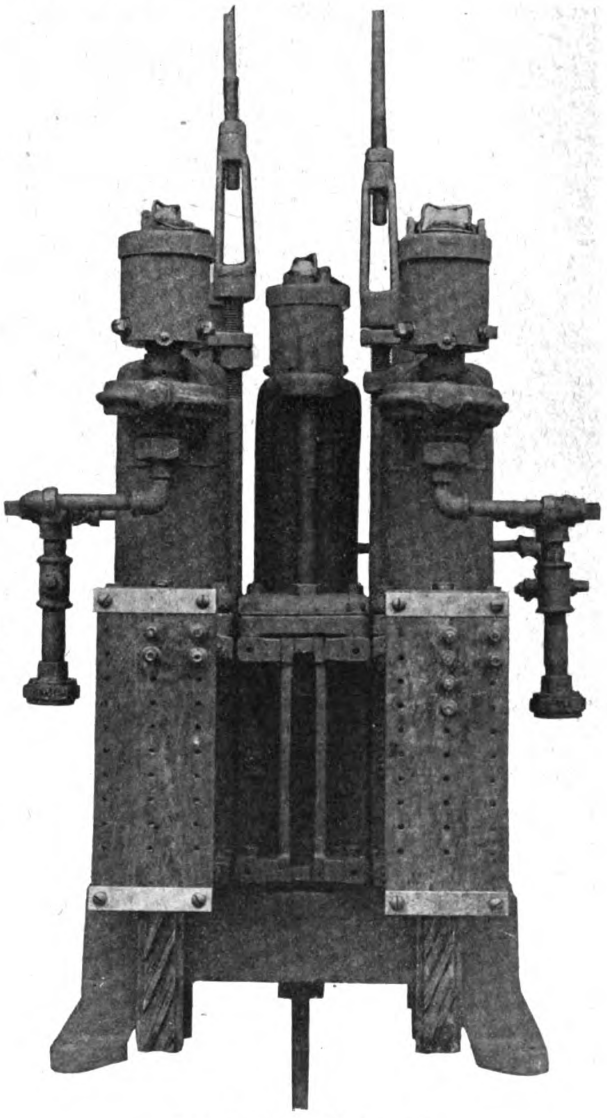


Fig. 9—Signal Mechanism.

SIGNAL MECHANISMS.

The mechanism of the three-position signals consists of two vertical cylinders, the compressed air being admitted to and released from them by means of the standard electro-pneumatic magnet and valve. Each cylinder operates a rack in a suitable guide, and the racks of the two cylinders face each other. Between the two racks is located a floating pinion, to which the rod operating the spectacle and blade is directly attached. (See Figs. 8 and 9.) This method of opera-

tion is a marked improvement in operating mechanisms for the control of three-position upper-quadrant signals, and was first applied in Washington.

POWER.

The compressed air, at a pressure of 80 to 90 pounds for the operation of all switches and signals throughout the entire system, is supplied from a duplicate set of steam driven air compressors located in the power house (these compressors also being used for furnishing air for all purposes needed in the Washington terminal) and is conveyed to the different functions through a duplicate system of 2-inch galvanized iron pipes, the air first passing through suitable manifold cooler. This system embraces two 2-inch pipes running from Bridge "N" at New York avenue to Massachusetts avenue tower on opposite sides of the yard, connections being made from each line up and across each signal bridge, which, with the complete system of valves used, makes it possible to get air to all functions at all times by the use of either main, leaving the other main accessible for repairs. Both mains are used except when repairs are necessary. All current for charging storage batteries and lighting signals is also supplied from the power house and is generated by Westinghouse generators direct connected to Westinghouse-Parsons steam driven turbines.

Three million feet of insulated copper wire (the equivalent of 568 miles of single conductor) was used in this installation; also 23,000 feet of 2-inch main air pipe.

The method of signaling adopted at the Washington terminal was the result of the combined opinions of the Baltimore & Ohio and the Pennsylvania railroad signal departments, Mr. F. P. Patentall, signal engineer, representing the B. & O. R. R., and Mr. A. H. Rudd, signal engineer, the Pennsylvania Railroad. The standards followed in the installation of these plants were those in use on both roads, the principles carried out in Washington embodying a combination of what was thought to be the best of each.

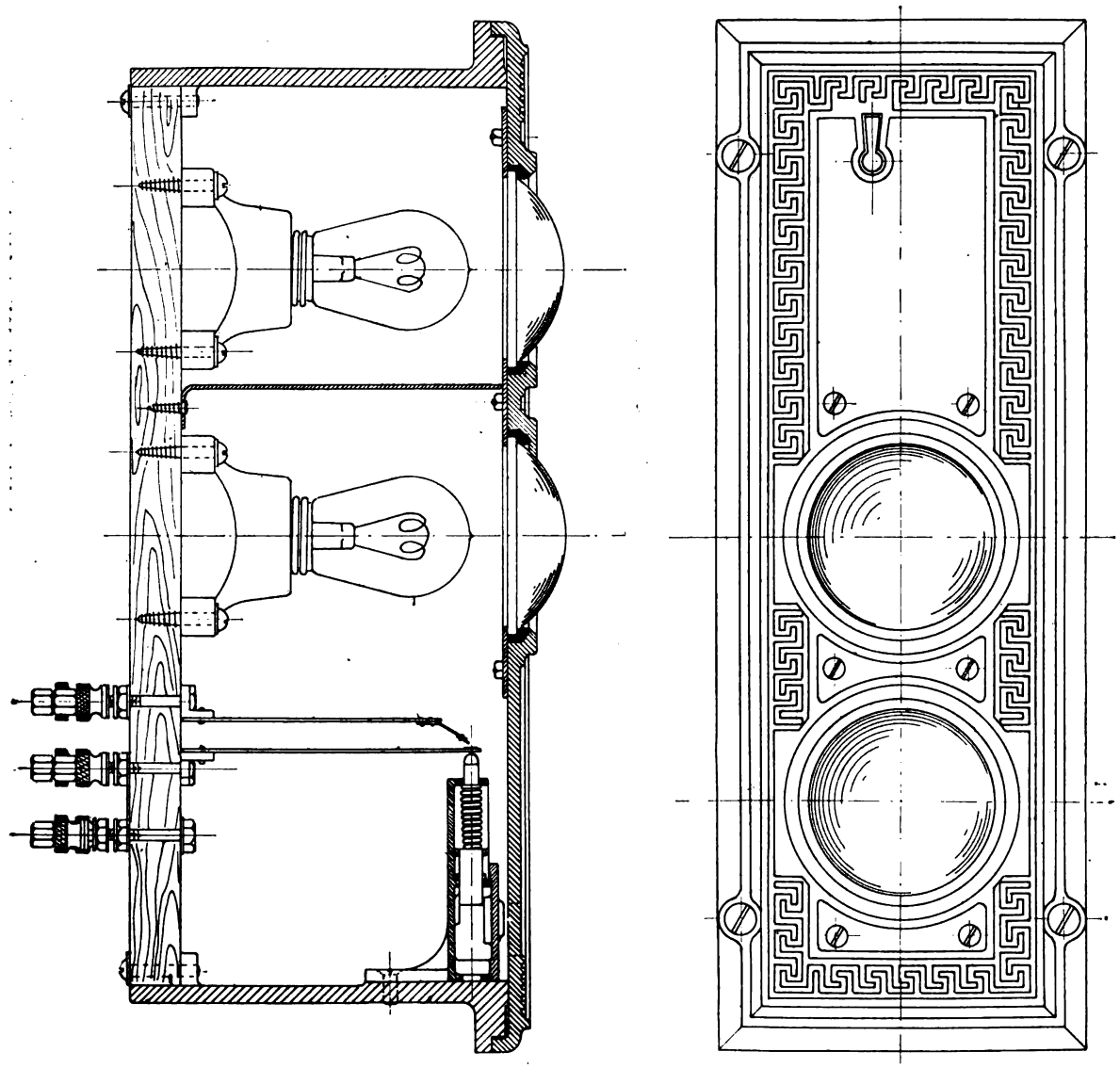
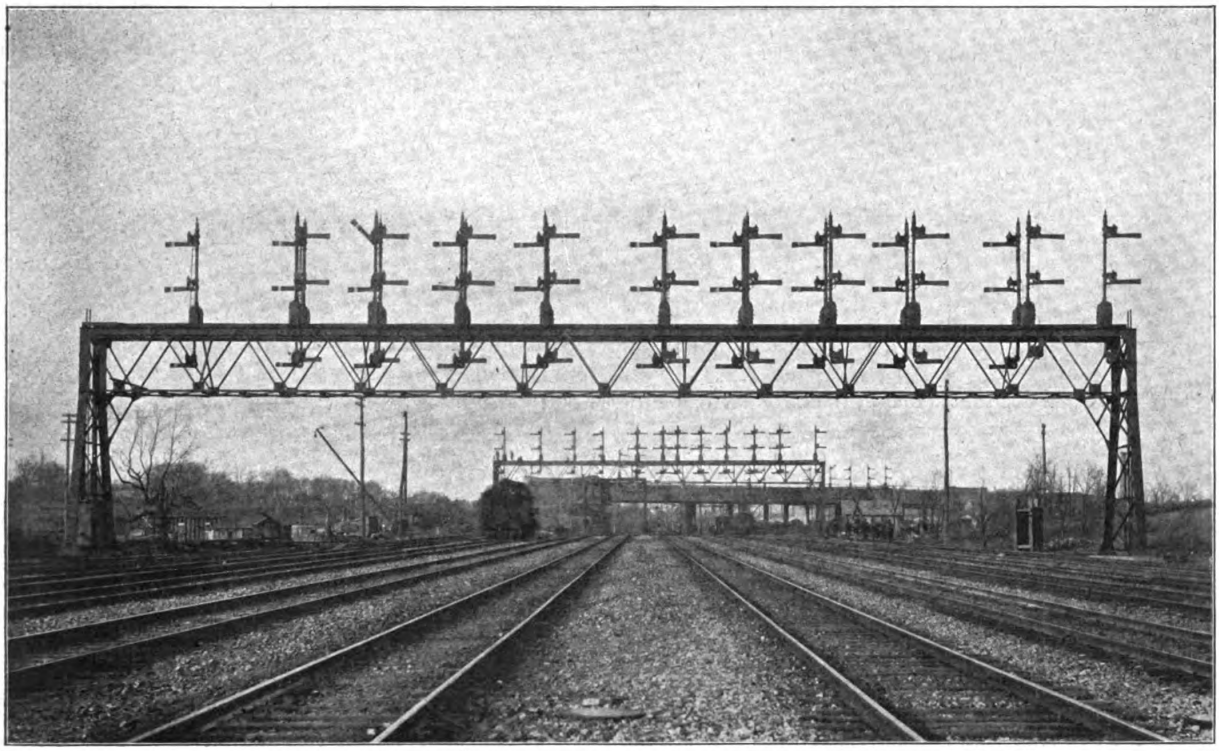


Fig. 6—Platform Light Box.

The entire terminal improvement was carried out under the direction of Mr. D. D. Carothers, chief engineer of the Baltimore & Ohio Railroad, and Mr. A. C. Shand, chief engineer of the Pennsylvania Railroad, Mr. W. F. Strouse being the engineer in direct charge of general construction. The actual work of installation was done under the direct supervision of the signal department of the Baltimore & Ohio Railroad, representing the Washington Terminal Company. The methods of construction followed were under the immediate direction of Messrs. Rudd and Patenall. All the labor and material customarily provided by signal companies in contracts of this nature was furnished by the Union Switch and Signal Company of Swissvale, Pa., the work being carried out by the signal company through its staff in the eastern district office at New York. The operation of this signaling comes under the jurisdiction of Mr. G. W. Martin, superintendent. Its maintenance is directly in charge of Mr. Charles McCauley, who was foreman in charge for the Union company when the work was installed.



Looking North Toward New York Avenue—Bridge K in Foreground.

General

The State Railroad Commission of Pennsylvania has fixed September 29 as the date for a hearing on the issuing of a recommendation to the street railway companies of the State relative to the occupancy of front platforms of open and closed cars by passengers, and also relative to the speed and signals to be observed at curves. All operating street railway companies in Pennsylvania have been invited to be represented at this hearing. Arrangements have also been made, through F. B. Musser, president of the Pennsylvania Street Railway Association, for the appearance at the hearing of the officers and executive committee of the association. A copy of the communication sent to all companies in the State, except those which are members of the Pennsylvania Street Railway Association, notice being given to the latter by officers of the association after correspondence with the commission, follows:

Sept. 19, 1908.

Dear Sir—By reason of disclosures resulting from an investigation of certain accidents which have recently occurred on street railways of the State, this commission is considering the advisability of making a general recommendation to operating companies relative to the carrying of passengers on the front platforms of cars and the speed and signals to be observed at curves.

The commission has fixed Tuesday, September 29, at 11 a. m., at this office, for hearing on this matter.

Arrangements have been made with the Pennsylvania Street Railway Association to have in attendance at that time the officers and executive committee of