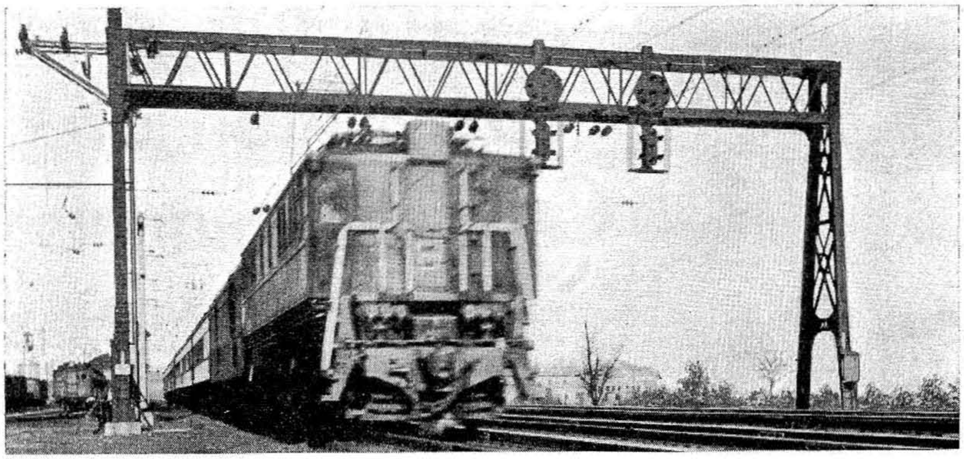
Signaling on the Pennsylvania's



Electric locomotive passing interlocking home signals on bridge

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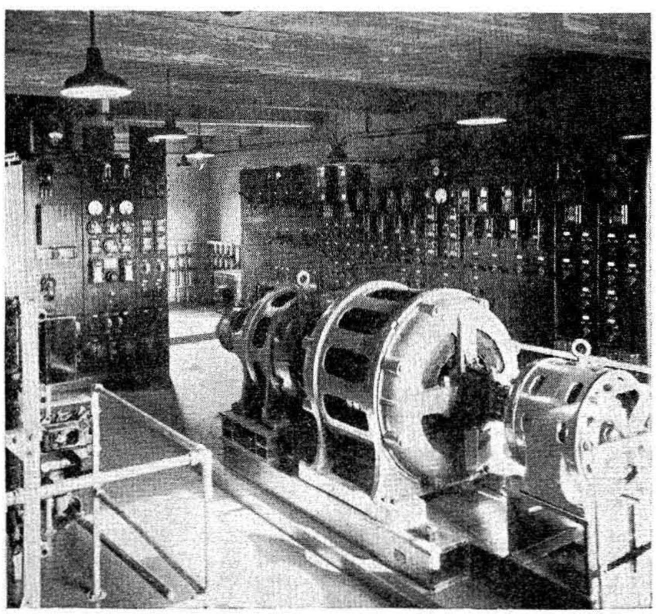
ON January 16, the Pennsylvania Railroad inaugurated, for passenger service, its new 25-cycle electrification between New York, N. Y., and Trenton, N. J., and on February 1, replaced steam operation of passenger trains between Manhattan Transfer (New York) and Philadelphia. The electrification just completed, together with that previously in service, not only connects these two great centers of population, but includes all the suburban service on this road in the vicinity of New York and Philadelphia. It extends electric operation of main-line trains southward to Wilmington, Del., and westward to Paoli, Pa. It includes also a major portion of the Long Island suburban lines; and, over the New York Connecting Railroad, provides a connection with the New York, New Haven & Hartford to New Haven, Conn. Including the Long Island lines, a total of 1,450 miles of Pennsylvania track is now under electric operation. Passenger trains on the New York-Philadelphia-Wilmington-Paoli lines are now operated electrically.



Interior of substation control building showing signal and power switch control panels and motor-generator set for signal power supply

The electrification program now authorized also includes the line from Wilmington, south to Washington, D. C. The New York-Washington line is 230 miles in length; consists of stretches of two, four and six tracks; and serves New York, N. Y., Philadelphia, Pa., Baltimore, Md., and Washington, D. C., as well as many other large and important cities and towns lying between them. It is anticipated that over this piece of railroad there will be a daily electrified train movement in normal times of 60 freight trains and 830 passenger trains included in which will be 492 multiple-unit trains. This movement represents a freight trailing gross ton-mileage of 10,030,000,000 a passenger car-mileage of 133,575,000 and an electric locomotive mileage of 17,787,000. In addition to this movement, there will be a daily movement of 130 interdivisional freight trains over some portions of the electrified zone, which movement will be electrified as the electrification is extended westward.

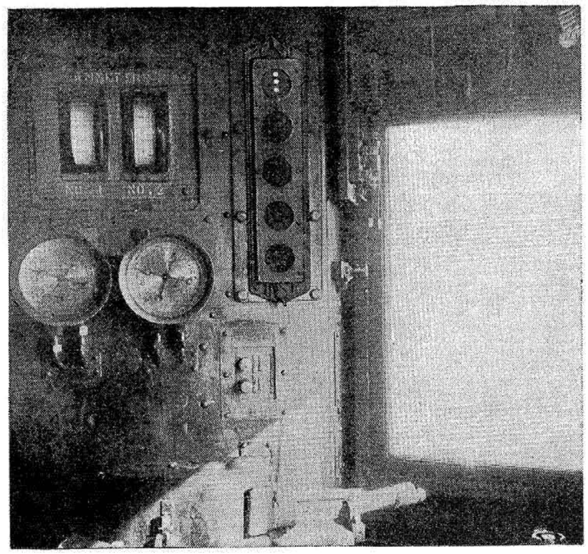
The section placed in service on January 16, extends from Manhattan Transfer, N. J. to Trenton, and from Manhattan Transfer through the tunnels under the Hudson river to the Pennsylvania Terminal in New York and on through the tunnels under the East river to Sunnyside yards on Long Island, as well as the section from Manhattan Transfer to Jersey City. This territory involves 68 road miles embracing 6 miles of six-track, 44 miles of four-track, and 12.8 miles of double-track, main line, as well as 2.5 miles of double-track tunnel under the Hudson river, 2.5 miles of four-track tunnel under the East river, a 21-track terminal at New York and a 12-track terminal at Jersey City. The a-c. operation is superimposed on d-c. operation between Sunnyside and Manhattan Transfer, as well as between Jersey City and Manhattan Transfer. Direct-current operation is required for Long Island trains between Sunnyside and Manhattan Transfer, and for Hudson & Manhattan trains between Jersey City, Manhattan Transfer and Park Place, Newark.

Changes in Signaling

The change-over from steam to electric propulsion necessitated a complete reconstruction of the signaling system. West of Newark the wayside signals of the

Electrified Line

Position-light signals replace semaphores—Automatic signals re-spaced for train speed of 70 m. p. h. Coded cab signaling system installed on wayside and in locomotives—Twenty-six plants rebuilt



Position-light cab-signal in cab of electric locomotive

semaphore type on signal bridges were replaced with position-light signals which, except at interlockings, are mounted on new bridges which form a part of the "H" catenary structure. At interlockings the signals are mounted on heavy anchor-type bridges which act as anchors for the trolley system. West of Newark the signals were relocated to afford proper spacing for train speeds of 75 m. p. h. with two-block indication, while

List of Interlockings in New York-Trenton Section

Interlocking Station	*Location*	*Type of Machine*	*Workin Levers*
"H"	Sunnyside	Electro-pneumatic	33
"Q"	Sunnyside	Electro-pneumatic	65
"R"	Sunnyside	Electro-pneumatic	59
"F"	Sunnyside	Electro-pneumatic	36
"C"	Penna. Station	Electro-pneumatic	32
"JO"	Penna. Station	Electro-pneumatic	51
"KN"	Penna. Station	Electro-pneumatic	34
"A"	Penna. Station	Electro-pneumatic	144
"W"	Meadows High Line	Electro-pneumatic	10
"Z"	Jersey City	Electro-pneumatic	37
"SC"	Journal Square	Electro-pneumatic	37
"WR"	Journal Square	Electro-pneumatic	46
Hack	Hackensack River Draw	Electro-pneumatic	18
"GY"	Waverly & Passaic Jct.	Electro-pneumatic	23
"N"	Manhattan Transfer	Electro-pneumatic	66
"S"	Manhattan Transfer	Electro-pneumatic	63
"CK"	Newark, N. J.	Electro-pneumatic	32
"RD"	West Newark Junction	Mechanical	41
"NK"	Neck Lane	Electro-mechanical	*12-5
Elmora	South Elizabeth	Electro-pneumatic	19
"DK"	Rahway	Electric	42
"HU"	Metuchen	Electro-mechanical	*2-23
"CN"	Millstone Junction	Mechanical	28
"MK"	Monmouth Junction	Electro-mechanical	*22-13
"CD"	Princeton Junction	Electro-mechanical	*5-24
"MO"	Millham Junction	Mechanical	31

NOTE—*Miniature Levers.

train speeds up to 90 m. p. h. can be accommodated merely by changing to three-block indication.

In the tunnels under the East river and the Hudson river, as well as in the Pennsylvania terminal, the color-light signals formerly in service were retained. Both of the two main tracks from the Pennsylvania terminal through the Hudson river tunnels and over the Meadows High Line to Manhattan Transfer are signaled for train operation in either direction. Reverse running with lock and block protection is provided for the tracks in the Pennsylvania terminal and through the East river tunnels.

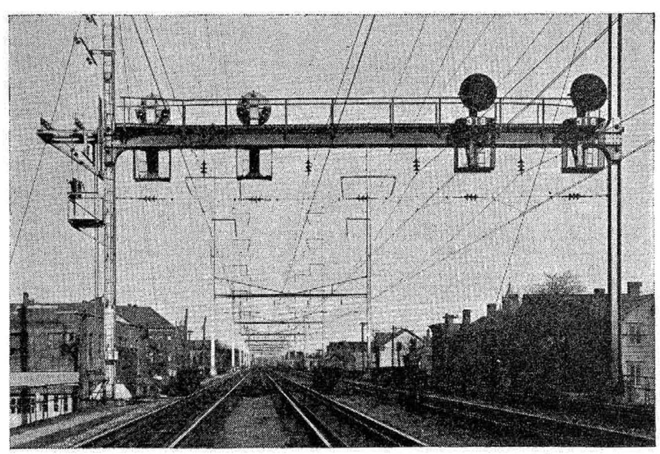
As a part of the new signaling system, continuous coded cab-signaling was installed in all the electrified territory with the exception of the tracks in the terminals at New York and Jersey City. Locomotives and multiple-unit cars are equipped with cab signaling, including whistle and acknowledger. The cab signal indications are, caution-slow speed, approach, approach-restricting, and clear.

The automatic train stop system of the tripper type formerly used in the tunnels at New York will be retained for the control of the Long Island equipment. These tripper stops are controlled by track circuits with a full block overlap, and, when in the stop position, effect an emergency application of the brakes.

Interlocking Reconstruction

The respacing of the signals and the introduction of the 100-cycle track circuits and the coder cab signaling, necessitated numerous changes at the 26 interlockings in this territory. Of these plants, 18 are electro-pneumatic, 4 electro-mechanical, 3 mechanical and 1 all-electric; a total of 1,053 working levers being involved.

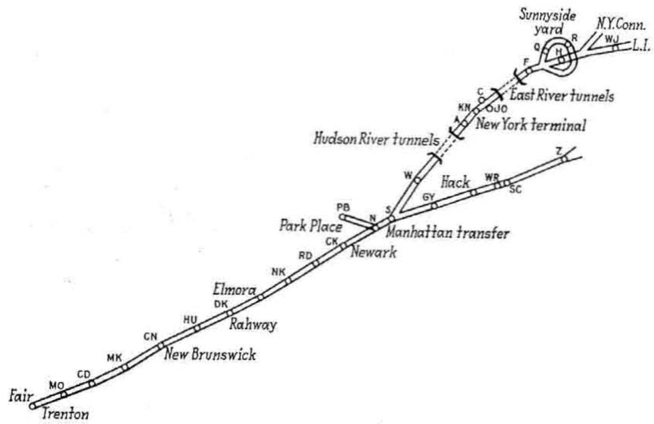
The a.c. electrification necessitated the installation of trolley wires at three draw spans in the New York area; two of these plants are of the swing-span type and one the lift-span type. At each of these bridges the inter-



Beam-type signal bridge—An anchor type of signal bridge combined with catenary support locking circuits are arranged to insure that the trolley will not interfere with the opening of the bridge, and that the trolley is in place and rails are locked before the signals can be cleared.

100-Cycle for the Signaling

As the propulsion current is 25-cycle, it was necessary to use a different frequency for the signal track circuits to prevent any interference. Therefore, 100-cycle current was adopted for the track circuits which, of course necessitated an entire new 100-cycle power system for the signaling, separate and apart from the propulsion power system.

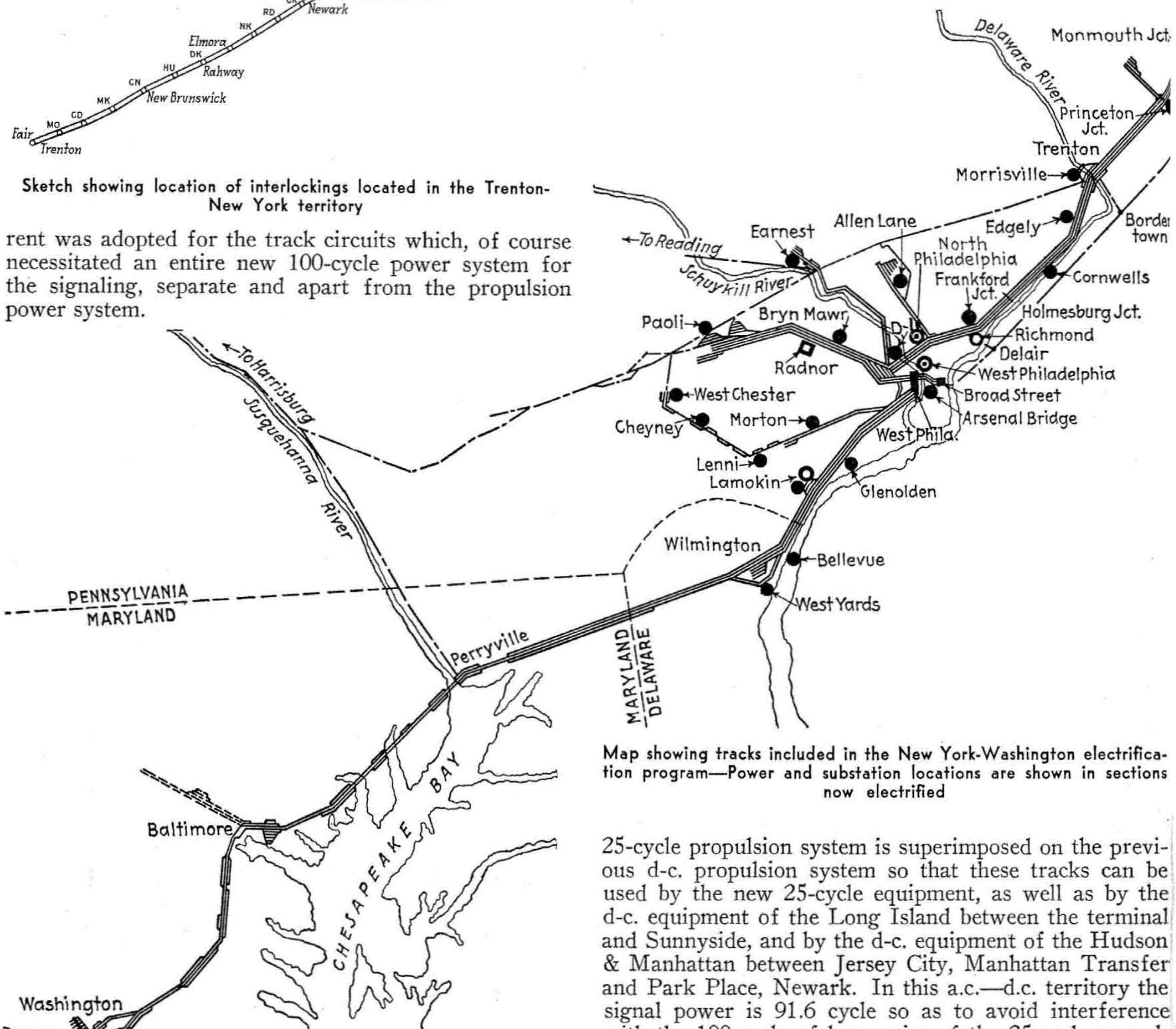


Sketch showing location of interlockings located in the Trenton-New York territory

Centrifugal frequency relays are used on all track circuits with the exception of the short ones at interlockings or on sidings, where single-element frequency vane-type relays are used. An important feature of the signaling was the installation of impedance bonds, the function of which is to terminate the 100-cycle track circuit at each signal location, but to continue on to the next block the rail circuit for the 25-cycle traction current.

On the territory from Newark west through Philadelphia to Wilmington and Paoli, only 25-cycle propulsion current is used, the signaling power system being 100-cycle and all track circuits are of the double-rail end-feed type, using impedance bonds of 200 amp. per rail capacity, with a 4-ohm bond at the feed end and a 1-ohm bond at the relay end.

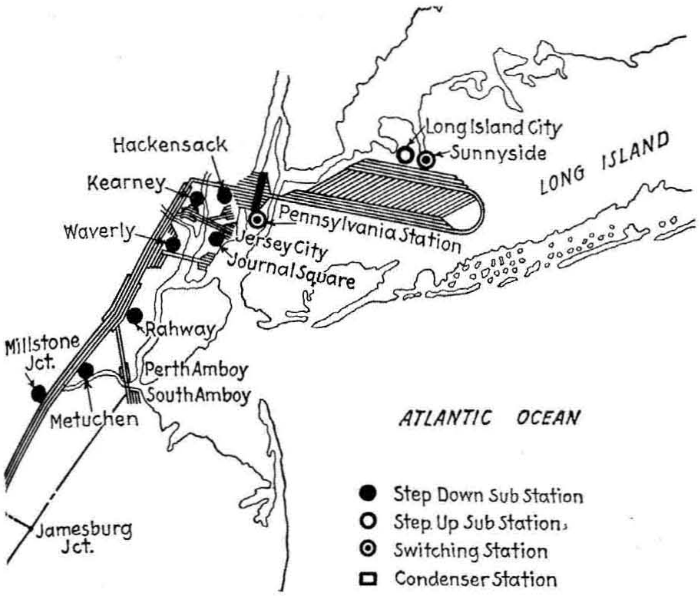
On the territory between Manhattan Transfer and Sunnyside yard, including the New York terminal, as well as between Jersey City and Manhattan Transfer, the



Map showing tracks included in the New York-Washington electrification program—Power and substation locations are shown in sections now electrified

25-cycle propulsion system is superimposed on the previous d-c. propulsion system so that these tracks can be used by the new 25-cycle equipment, as well as by the d-c. equipment of the Long Island between the terminal and Sunnyside, and by the d-c. equipment of the Hudson & Manhattan between Jersey City, Manhattan Transfer and Park Place, Newark. In this a.c.—d.c. territory the signal power is 91.6 cycle so as to avoid interference with the 100-cycle of harmonics of the 25-cycle propulsion current, resulting from the dual, a.c.—d.c. operation in this section. The cab signaling equipment is arranged to operate efficiently on either 91.6 cycles or 100 cycles

In the Pennsylvania terminal area most of the track circuits are single rail. Departure test loops automatically give the required cycle of cab signal indications before trains leave for their destination. Similar test loops will



be used at Sunnyside yard, Jersey City terminal, Henderson street, Park Place, Journal Square, Manhattan Transfer, Millstone and Trenton. In the a.c.—d.c. territory the impedance bonds are rated at 1,500 and 2,500 amp. per rail to take care of the heavy d-c. loads. These bonds have an impedance at 100 cycles of approximately 0.5 ohm.

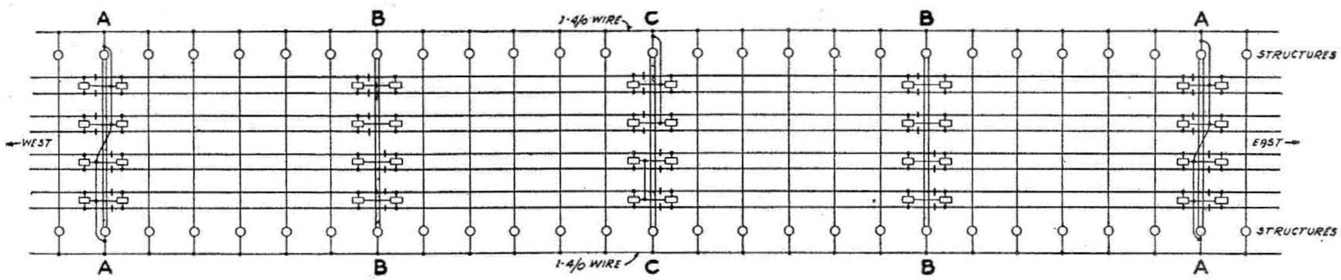
To provide the maximum power rail return with the least reduction of broken-rail track circuit protection,

consisting of seven .064-in. diameter strands surrounded by an outer layer consisting of three .077-in. tinned copper, and seven .077-in. galvanized steel strands. The rails are drilled with a 3/8-in. drill and the tapered bond pins are driven in with a hammer. The bonds have a safe carrying capacity of 400 amp. at 25 cycles without undue heating.

This simple form of bonding has been found satisfactory. The steel strands prevent mechanical failure and the composite structure also reduces the possibility of theft, since the salvage of the copper is impracticable. The bonds are maintained by the signal maintainers and eliminate the need of any special maintenance facilities. It has been determined by experience and calculations that the somewhat increased resistance losses incurred by this type of bond are of little consequence as compared with the savings effected by low first cost and reduced maintenance.

The connections from the rails extending to the track transformers and relays are in No. 6 stranded parkway cable buried in the ballast, no conduit being used. At the rail the parkway conductor is connected to the pin-type track wires by connectors, this connection being placed in the bootleg riser.

The low-voltage control circuits between automatic signals are in lead-covered cable run underground in duct. As a rule this cable is 30-conductor No. 14 with two No. 4 core wires. Parkway cable was used from the nearest manhole to the instrument case on each signal bridge. At interlockings the lead-covered cable is 61-conductors in most cases. Where new construction was not



Arrangement of power bonding and structure grounding

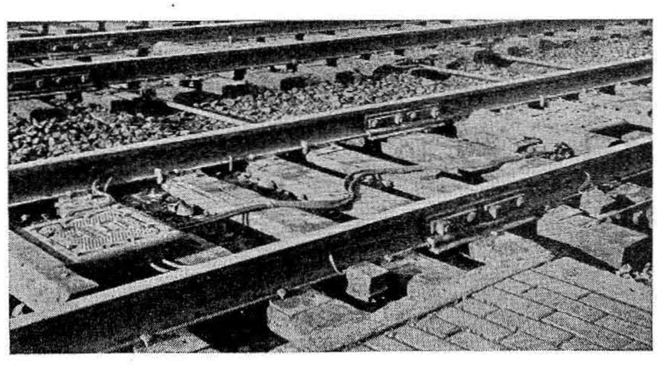
a careful layout of cross-bonding was required. To insure maximum broken rail protection of coded track circuits in automatic signal territory, the circuits are so arranged that when a train enters the block and a "V" relay is de-energized by the shunting of the track relay the track voltage and local track relay voltages are automatically reduced by an auto-transformer from 110 volts to 85 volts for the primary side of the track transformer, and from 110 volts to 52.5 volts for the local element of the track relay. It is a characteristic of the centrifugal relay that it will operate on low track voltage provided the local voltage also is lowered. The higher values are required, however, to insure the proper braking effect needed for quick release of the instrument when shunted. The scheme permits correct track circuit values for both relay and coded circuits.

Bonding

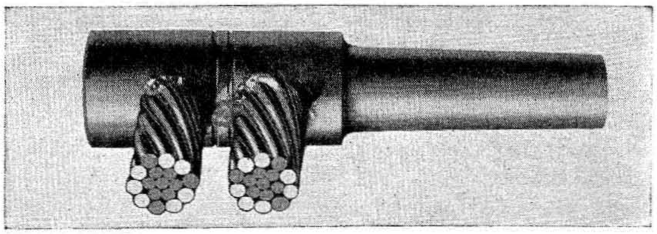
The bonds on the rail joints are, of course, used jointly by the propulsion and the track-circuit currents. The rail bonds are modified signal-type pin bonds. They consist of tapered pins connected by two conductors. Each conductor is made up of a stranded copper center

involved, the cables were run in existing wooden conduit, but otherwise the lead cables were run in fibre conduit to terminal locations, from which point parkway cable extends to various switch and signal units. The fibre duct is buried 3 ft. below the surface of the ground and is incased in concrete.

In automatic territory, wooden instrument cases are mounted adjacent to the signal bridges on concrete foun-



The impedance bonds are located between the rails



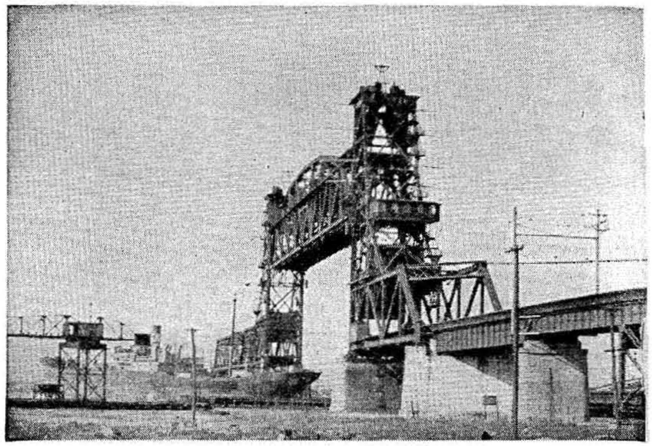
Hackensack lift bridge equipped with traveling trolley sections

dations, while at interlockings the cases are mounted on the signal bridges. The cases in the Hudson and East River tunnels are made of copper-bearing steel and Allegheny metal.

Duct Line Construction

On certain sections of the territory now electrified the telephone and signal circuits were previously carried on line wires. The pole line originally consisted, in some locations, of six 10-pin arms along one pole line and, in other locations, of three arms on each of two pole lines, one of which was on either side of the right-of-way. It was felt that these aerial wires would not only be a hazard, but would be subject to excessive interference from the normal induction to be expected incident to the electrification. The relatively large number of additional circuits required for electrification purposes, together with the telegraph circuits previously superimposed on telephone circuits which would operate satisfactorily only on the basis of full metallic operation, led to the selection of lead-covered cable as the only satisfactory method of economically obtaining the desired safety.

As an example of this construction, the following explanation applies to the 18 miles of six-duct conduit installed between Liddonfield and Trenton, which consists of 2 by 3 multiple tile laid three wide and two high on creosoted plank with the top and sides encased in



Hackensack lift bridge equipped with traveling trolley sections

concrete. The conduit was laid in this manner with the thought that ultimately 9 ducts in a 3 by 3 formation would be required; such an arrangement is now attainable merely by excavating and laying the additional three ducts on top of the present ones. The majority of the manholes were cast in place. The Pennsylvania over-

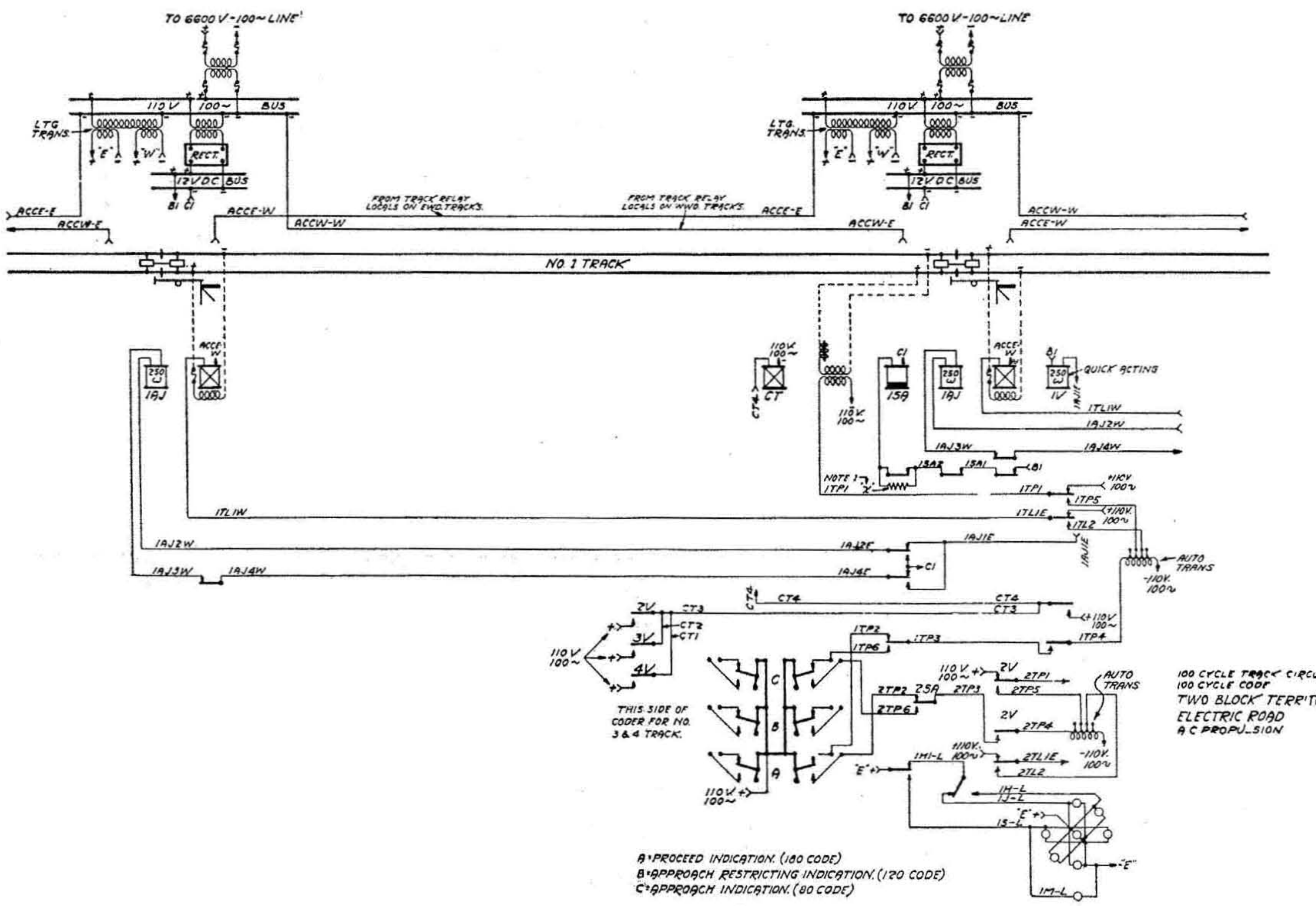
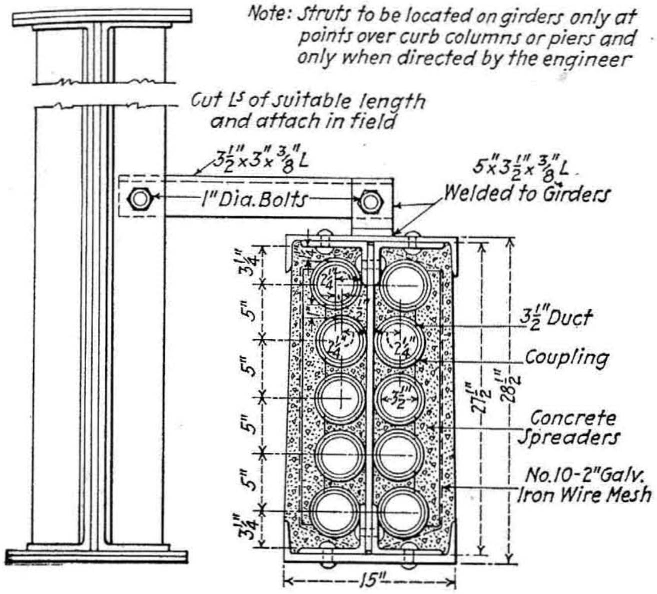


Diagram of coded track circuits for cab-signaling system in automatic signal territory hanging type of manhole frame and cover was used in all cases where surface traffic was not encountered.

The conduit was located so that the manholes were approximately in line with the catenary poles, this being done because there was less probability of future track installations blocking the manholes in this location. The maximum distance between manholes is 500 ft. so that a single 510-ft. length of cable will serve as a replacement length for the maximum section, thereby eliminating the necessity of maintaining a stock of odd lengths for replacement in the event of a cable failure.



Typical method of carrying multiple ducts over street and stream crossings

A special type of I-beam conduit was used to carry the duct across streets and streams where the clear span was less than 70 ft. This type of construction places a conduit in vertical formation on each side of the web and the entire formation is incased in concrete. This construction permits the duct to be supported only at the piers on either end and, because it is not connected to the bridge or track structure, the vibration is reduced to a minimum. In two or three instances messenger is used to support cables carried across streets where the clear span is in excess of 70 ft. The messenger and cable are protected against any falling wires by a shield made of galvanized-iron 2-in. mesh, supported by a frame.

Signal Power Supply

The 6,600-volt 100-cycle signal power line consists of two No. 0 seven-strand bare copper conductors strung on pin-type insulators mounted on single crossarms bolted to the catenary poles 10 ft. below the 132,000-volt 25-cycle power transmission line. The signal line is transposed every 3.5 miles. The 100-cycle signal power is supplied from 75-kva. motor-generator sets located at various points along the line. For example, between Newark and Trenton, one motor-generator is located at Morrisville, Princeton Junction, Millstone Junction, Rahway and Kearny. At the first three points mentioned, a single-phase induction motor is used, taking power from the 25-cycle propulsion power system. At the two other points, three-phase motors are used, the power being taken from a commercial supply or other Pennsylvania Railroad lines.

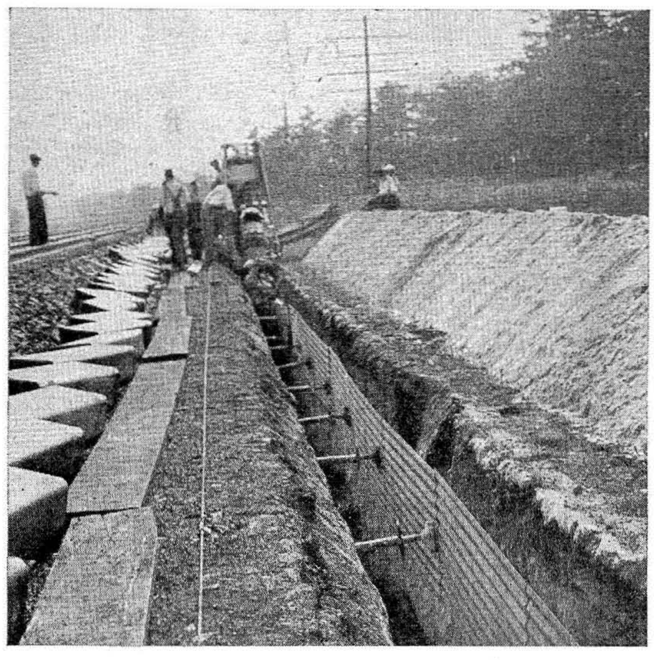
The 100-cycle current is generated at 440 volts, which is transformed up to 6,600 volts for the line transmission. This line voltage is transformed to 110 volts at the signal locations, a 3 kva. 6,600 110-volt transformer being used at each automatic signal bridge and a 5 kva. transformer at each home signal bridge at an interlocking. The 110-volt secondary circuits are so arranged that the load may be sectionalized from one transformer to the other, or each transformer segregated for certain portions of an interlocking.

Line Is Sectionalized

Manually-operated air-break switches at each signal bridge are used to sectionalize the 6,600-volt line when desired. The line transformers are protected with 7,000-9,000-volt lightning arresters and are fused at 3 amp. on the primary side. The secondary windings of the 3 kva. transformers are fused at 30 amp. and the 5 kva. transformers at 60 amp.

Automatic switching is provided to switch the line load between the different substations mentioned above. Power is supplied normally from Morrisville east to Princeton Junction; from Millstone west to Princeton Junction and east to Rahway; from Kearny west to Rahway.

If power should fail at Morrisville or Millstone, then Princeton Junction cuts through immediately and the machine at Princeton Junction automatically is started for standby service and will feed to Morrisville and Millstone in case the power fails at both Morrisville and Millstone. In case of power failure from Millstone east or Kearny west, the machine at Rahway cuts



Laying a section of the underground multiple-duct system between New York and Philadelphia

through at once and the machine at Rahway automatically is started for standby service and will feed to Kearny and Millstone in case of failure at both Millstone and Kearny. Each machine locks out in case of over current or under voltage and service must be restored by manual operation. The same general scheme of power supply for signaling employed in the Newark-Trenton section is also used for the other territories involved in the electrification project.