Signaling for Electrified Operation

Some of the engineering obstacles encountered, and how they were overcome, in signaling the Pennsylvania's newly electrified four-track line between Trenton and Philadelphia

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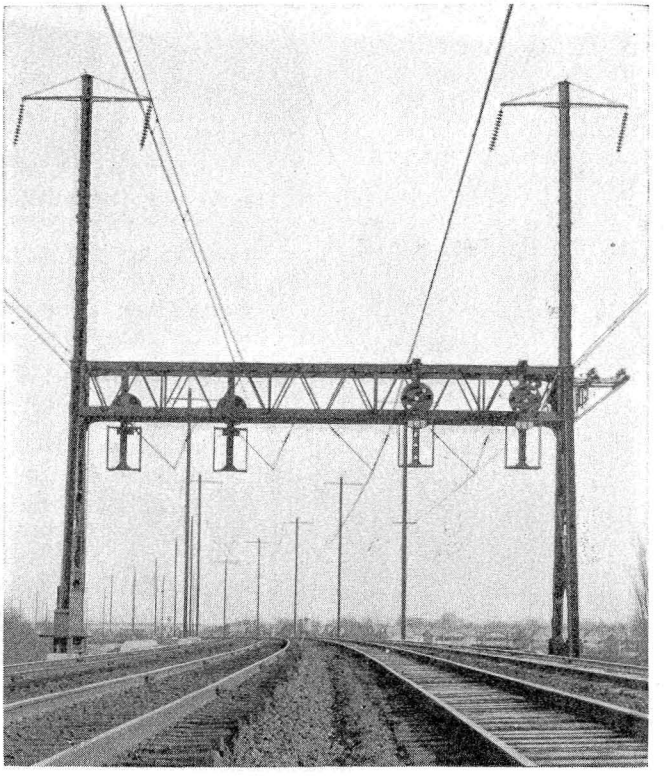
IN line with a general program of changing from steam to electric operation on the Pennsylvania Railroad, a-c. electrification was recently completed between Philadelphia, Pa., and Trenton, N. J., a distance of 33.4 miles, and multiple-unit service has been established between these points to take care of all local service.

Electrification Features

Standard catenary bridge construction was used, employing H-section columns whoch are set in concrete and guyed. Where it was impracticable to use guys, H-type cross beams were installed. The average span between catenary bridges is 260 ft. Anchor bridges, spaced about one mile apart, are used also for supporting the signals, instrument cases, signal-feeder sectionalizing switches, transformers and lightning arresters. The propulsion current is 11,000-volt, 25-cycle, single-phase.



Signal bridge at Bristol

The high-tension power line is carried in duplicate on each side of the tracks on suspension-type insulators which are suspended from crossarms attached to the 70-ft. vertical columns of the catenary bridges. The power line carries alternating current at 132,000 volts, 25-cycle, single-phase. The conductors are No. 4-0, 7-strand copper, strung with a minimum clearance of 4 ft. 6 in. from the conductor to the nearest steel structure and a minimum clearance of 9 ft. between transmission wires. A 4-0, 7-strand copper ground-return wire is carried at the top of the catenary bridges. In most cases the ground wire is not insulated from the steel structure. The catenary bridge structure is connected to the neutral connections of the track impedance bonds. Calculations indicate that this arrangement of bonding will not materially lessen broken-rail protection. At stations and at bridge structures, the ground wire is insulated and the structure is grounded directly to the rail in order to keep the rails and structures at the same potential.

Three substations are located on the New York division where the 132,000-volt power is transformed to 11,000 volts for the trolley. These substations are located at Cornwells Heights, Edgely and Morrisville, an average of approximately 5 miles apart. Power is supplied by the Philadelphia Electric Company.

Signal System

The four tracks are protected with position-light automatic wayside and cab signals, and four interlocking plants. The continuous cab signals give four indications: clear, approach - restricting, approach, and caution—slow speed. The interlocking plants are listed below:

"Fair," Trenton, N. J.—73-lever electro-pneumatic machine
- 26 levers for 51 signals
- 27 levers for 37 switches, 3 double-slips, 3 movable-point frogs and 3 derails
- 14 spare spaces
- 8 spare levers

"Morris," Morrisville, Pa.—24-lever mechanical machine and a 12-unit S-8 frame
- 3 mechanical levers for 7 signals
- 6 mechanical levers for 8 switches and 1 derail
- 5 mechanical levers for 9 facing-point locks
- 10 spare spaces
- 4 unit levers for 9 signals
- 5 Type S-8 unit levers for 10 switches
- 3 spare spaces

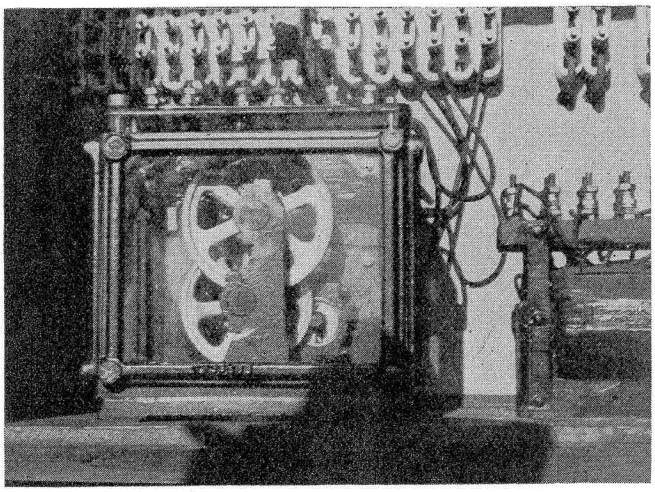
"Greene," Bristol, Pa.—23-lever electro-pneumatic machine
- 8 levers for 20 signals
- 10 levers for 20 switches
- 1 spare lever

4 spare spaces
"Wells," Cornwells, Pa.—32-lever mechanical machine
11 levers for 17 signals
8 levers for 16 switches
8 levers for -6 facing-point locks
5 spare spaces

Signal Power Supply

Three 75-kv.a. motor-generator sets, located approximately 15 miles apart—one at West Philadelphia, one at Cornwells, Pa., and one at Morrisville, Pa.—supply the 100-cycle a-c. signal power. The sets at West Philadelphia and Morrisville are operated from a 25-cycle traction bus with single-phase motors, while the one at Cornwells is operated from a 2,300-volt, 3-phase, 60-cycle line, current being furnished by the Philadelphia Suburban Electric & Gas Company. The 100-cycle current is generated at 440 volts and is stepped up to 6,600 volts for transmission.

Power is normally supplied from West Philadelphia east to Cornwells and from Morrisville west to Cornwells. In case of an interruption, the line is automatically cut through at Cornwells and the emergency set at this place is automatically started up prepared for stand-by service. If the circuit is interrupted after being cut through, the Cornwells set will automatically cut in and feed east to Morrisville and west to Philadelphia. Manual



Coder relay

operation is necessary to cut any of the sets back on the line after an automatic cut-out. Each set is of sufficient capacity to carry the entire load.

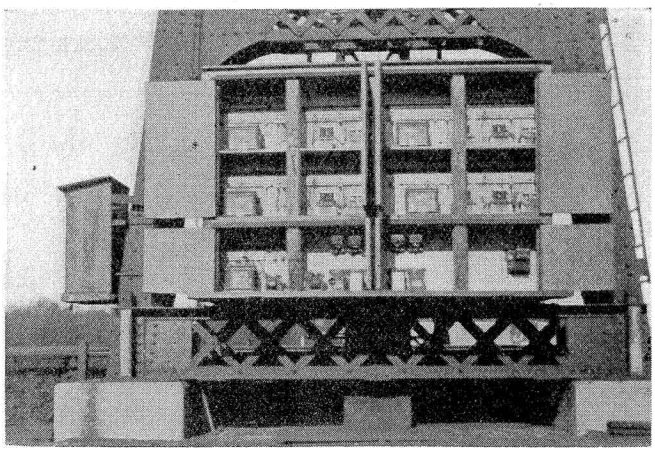
Signal Power Line

All of the a-c. interlocking, signal and track circuits are 100-cycle, fed from a 6,600-volt single-phase line. This 6,600-volt line is carried on pin-type insulators mounted on single crossarms bolted to the vertical catenary columns at a height of 33 ft. 6 in., maintaining a minimum clearance of 10 ft. below the 132,000-volt transmission line. The line consists of two No. 0 7-strand bare copper wires and it is transposed four times between Trenton and Philadelphia. Manually operated sectionalizing switches are provided at each signal bridge.

At each automatic-signal bridge 3-kv.a. 6,600 110-volt transformers are used and at the interlockings 5-kv.a. 6,600/110-volt transformers are in service. All transformers are protected with 7,000/9,000-volt lightning arresters. The primary sides of the transformers are fused with 5-amp. fused cut-outs enclosed in weatherproof porcelain boxes. The secondary circuits are fused at 20 amp.

Track Circuits

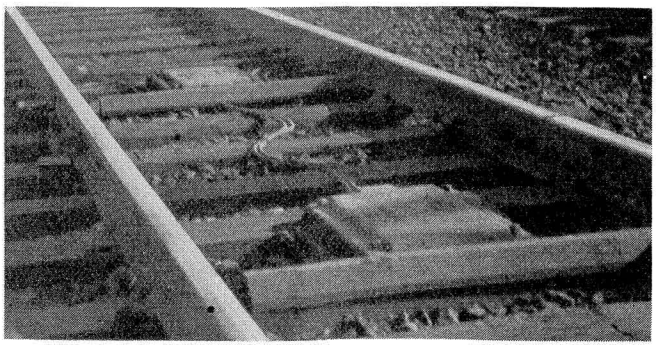
End-fed double-rail track circuits are used throughout with double impedance bonds at each signal location and at each cut section, this arrangement being required be-



Relay case at a signal bridge

cause of the track circuits being coded. Centrifugal relays are used on all main tracks and frequency-vane relays on sidings where track circuits are not over 500 ft. in length. Rail bonds are of 700-amp. capacity, a 4.2-ohm bond being placed at the feed end and a 1-ohm bond at the relay end of the circuit with the neutral connections tied together.

To provide the maximum power-rail return with the least reduction of broken-rail track-circuit protection, cross bonding has been installed. In order to insure maximum broken rail protection in connection with coded track circuits in automatic signal territory, the circuits are so arranged that when a train enters the block and the relay is energized by the shunting of the track relay, the track voltage and the local voltage are automatically lowered, by means of a reactance transformer, from 110 to 85 volts for the primary side of the track transformer, and from 110 to 52.5 volts for the local element of the track relay, it being characteristic of the centrifugal relay that it will operate on a lower track voltage provided that the local voltage, also, is lowered. The



Impedance bonds

higher values are required, however, to insure the proper braking effect needed for a quick release of the instrument. This scheme results in the relay normally working under correct track and local voltages—which are higher

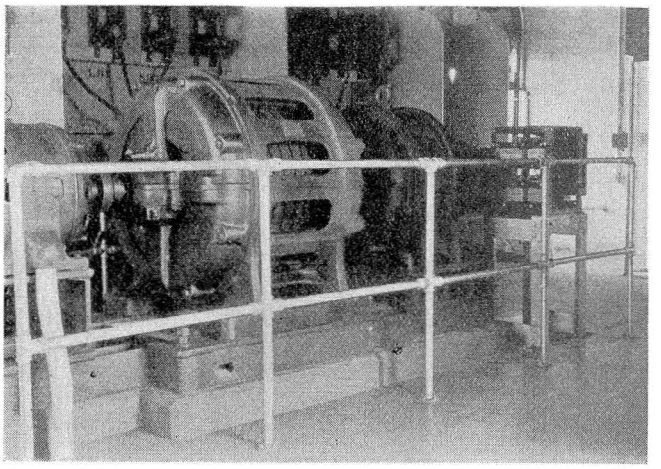
than those required for the coded track circuits—, and automatically reducing the coded track voltages to the correct values when the track is occupied. The rails are bonded with pin-type bonds.

Signals

All wayside signals are of the position-light type and in most cases the high signals are mounted on the catenary anchor bridges. To obtain the best possible vision, they are attached to a special support which is secured to the bridge chords. The support is adequately screened for protection from the 11,000-volt trolley. The high signals are three-position. Two-arm signaling is used at all the interlockings. The signals are spaced for train speeds of 75 miles per hour, but by revising to three-block indications, the speed can later be increased to 90 miles per hour if desired.

Duct Line Construction

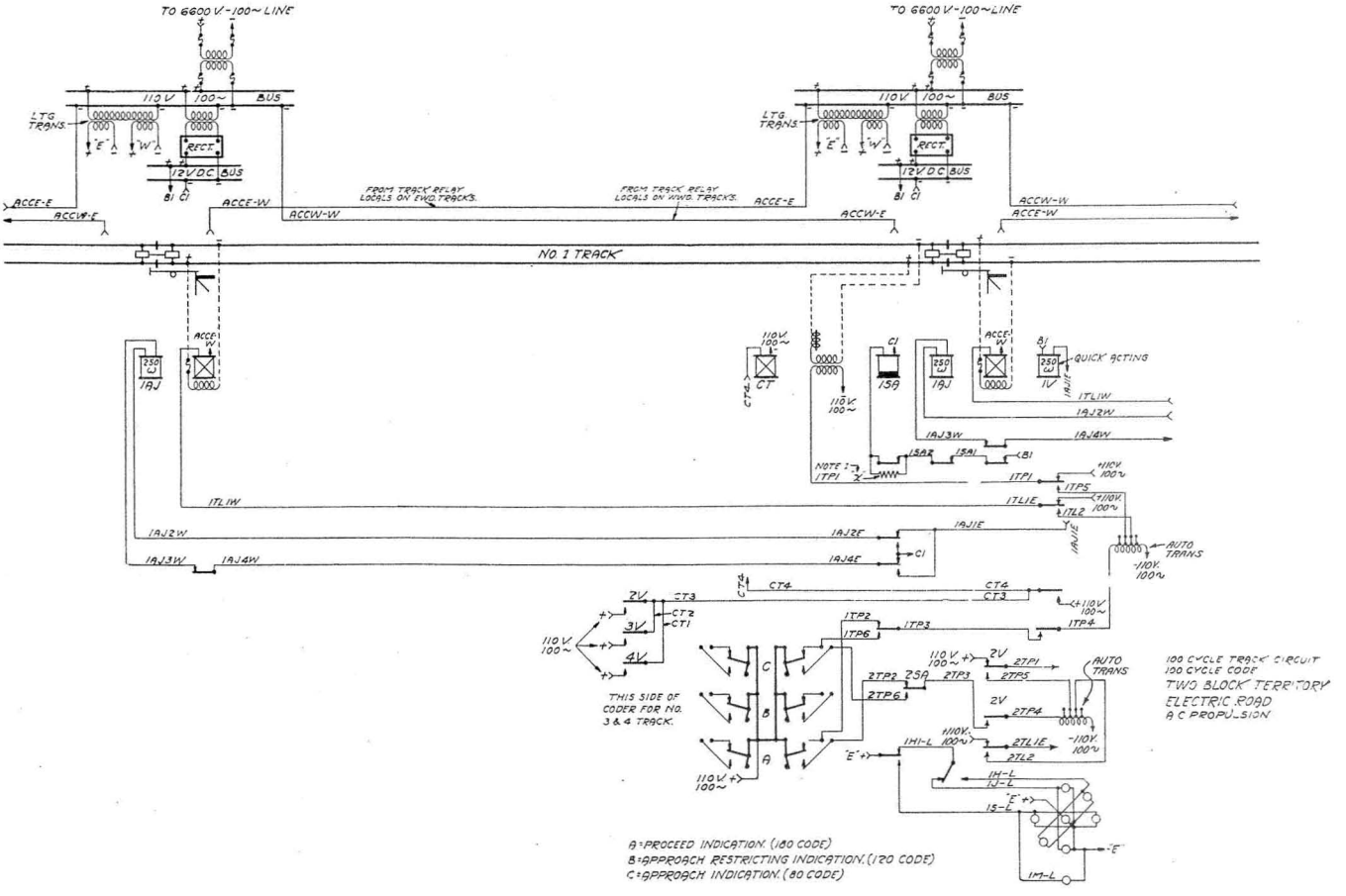
The telephone and signal circuits on the New York division, from Liddonfield to Trenton, were carried over line wires before this section was electrified. The pole line originally consisted, in some locations, of six 10-pin arms along one pole line and, in other locations, of three arms on each of two 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



Motor-generator set at Morrisville substation

cable as the only satisfactory method of economically obtaining the desired safety.

The 18 miles of six-duct conduit installed on the New York division between Liddonfield and Trenton consists of 2-by-3 multiple tile laid three wide and two high on creosoted plank with the top and sides encased in 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 ducts. The majority of the



Coded track circuits in automatic territory

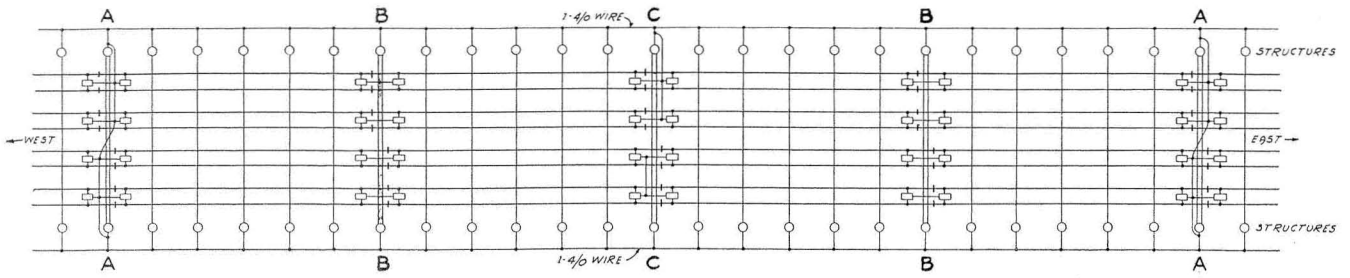
manholes were cast in place. The P.R.R. overhanging-type of manhole frame and cover was used in all cases where surface traffic was not encountered.

The conduit was located so that the manholes were approximately on line with the catenary poles. This was 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.

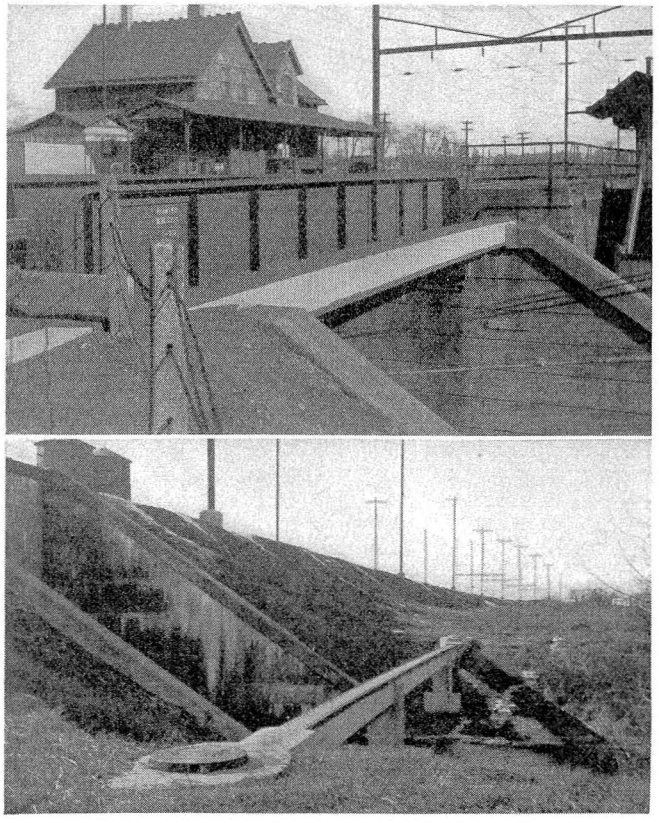
A special type of I-beam conduit was used to carry the duct across streets and streams where the clear span was less than 70 ft. This type of construction places a conduit in vertical formation on each side of the web and the entire formation is encased in concrete. This construction permits the duct 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 held 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.

The general practice followed, for running laterals where the signal bridge is less than 100 ft. from a manhole, was to add two ducts laid from the manhole to a point directly below the signal bridge, from which point short pipe bends were used for cable protection up to the signal bridge. Where a manhole was not readily available the duct line was broken out at a point opposite the signal bridge and a pull box was installed at this point, from which a short pipe extended up to the signal case.



Arrangement of power bonding and structure grounding



Above—Conduit over street at Croydon
Below—Conduit over Otter creek at Bristol

A 27-conductor lead signal cable occupies one duct in automatic territory. A 37-conductor lead cable is used in three-block-indication territory in the approach to interlockings, with a 61-conductor lead cable in service between home signal bridges of interlockings. Two Type-H lead telephone cables occupy two ducts throughout the 18-mile section. The trunk cable contains 38 pairs and the local cable 34 pairs.

All cables are bonded together at various points and the cable line has been in part surveyed. One drainage bond, which was installed at Neshaminy creek as a result of this survey, has one of the modern reversing switches installed in connection with it. At locations where messenger attached to structures is used to support cables carried across streets and streams, an insulated joint is placed in cable sheath at either side of the section supported by the messenger. This insulates the section, and an insulated cable, which is bonded to the cable sheath, is used as a jumper, thereby maintaining a closed circuit of the through lead-cable sheaths. The completion of the survey may develop the necessity of some further drainage measures elsewhere, as there is a fairly large area in which the cable is at times 0.1 or 0.2 volt positive to earth.

Telephone Construction Data

The telephone trunk cable is 38-pair 13-gage quadded and the local cable is 34-pair having 7 quads of 13-gage and 20 pairs of 16 gage. The specification for the Type-H cable calls for a test voltage of 1,000 volts between conductors and 3,500 volts to ground.

To afford protection to switchboard operators, No. 26 and No. 30 protector blocks are used where the circuits enter a switchboard and, as a further protection, and in order to limit the induced voltages to values below the breakdown of the conductor insulation, certain circuits are drained by connecting either No. 70A or No. 77 coils to the ground at cable terminals. The drainage of part of the conductors has been found to afford sufficient shielding to other undrained circuits to provide the necessary protection on the latter.