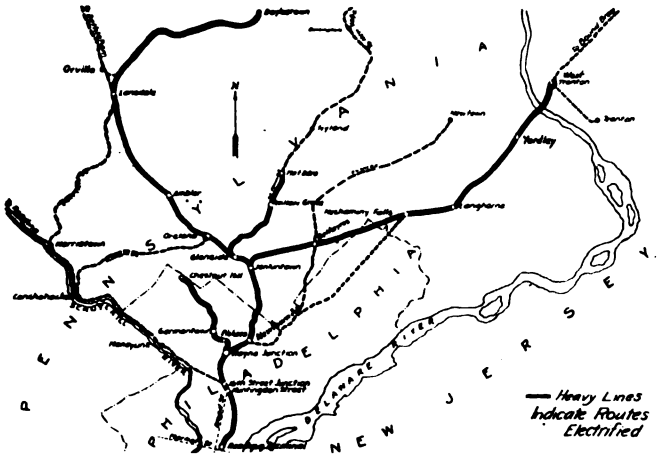
Re-Signaling of the Reading Electrified Territory

Interlockings reconstructed, automatic signals replaced, cab signaling added



Map showing territory involving changes in signals and interlockings

By A. H. Yocum
Signal Engineer, Reading Company, Philadelphia, Pa.

WHEN electric trains began running between Jenkintown, Pa., and West Trenton, on July 26, 1931, the Reading Company saw the major part of its Philadelphia Terminal electrification program completed. Because of the rapid growth of the Metropolitan Philadelphia district during the past several years it was necessary to keep adding to the train service and it was early recognized by the Reading that better, faster and more frequent train service must be established to care for the fast-growing suburban communities building up so rapidly along its lines. Accordingly a preliminary survey was started and the preparation of engineering details was begun for the electrification of certain portions of its lines. After a careful study, authority was granted for electrifying 63.4 miles of road embracing 141.8 track miles on the Philadelphia and New York divisions. The electrified territory consists of the districts listed in the table.

Table Listing Electrified Sections

From	To	Road Miles	Tracks	Date Signals in Service
Reading Terminal	Wayne Jct.	5.10	4	Aug. 3, 1930
Wayne Jct.	Jenkintown	5.70	2	Sept. 28, 1930
Jenkintown	Lansdale	13.60	2	Dec. 19, 1930
Glenside	Hatboro	2.30	2	
		4.40	1	May 25, 1931
Lansdale	Doylestown	10.00	1	June 6, 1931
Jenkintown	Neshaminy Falls	10.30	2	April 10, 1931
Neshaminy Falls	Yardley	9.60	4	May 11, 1931
Yardley	West Trenton	1.80	2	June 14, 1931
Wayne Jct.	Fishers	0.60	2	June 16, 1931

Northbound train on double-track near Elkins Park

Authority has also been granted for extending the electrified territory from Fishers to Chestnut Hill, a distance of 5.1 miles, double track.

Electric trains are operated out of the Reading Terminal in Philadelphia in three different directions, and will be operated in a fourth direction when the Chestnut Hill branch is finished. From the Terminal to West Trenton on the New York branch is 32.5 miles, while on the New Hope branch electric trains are operated as far as Hatboro, the end of the suburban territory, a distance of 18.6 miles. The Doylestown branch is completely electrified so that the multiple-unit cars run from Doylestown to the terminal, a distance of 34.4 miles. A number of the electric trains terminate at Lansdale which is the junction point between the Doylestown branch and the Bethlehem branch.

Traffic Conditions

The traffic in and out of the Reading Terminal consists of high-speed suburban and through service. Approximately 359 regular passenger trains of all kinds are scheduled in and out of the terminal each 24 hours. Because of the large number of trains operating in the electric zone, it is essential that freight service does not interfere to any extent with this operation, and consequently freight trains are kept out of the electrified territory as much as possible. New York Division freights

pass over the electrified section between West Trenton and Neshaminy Falls and in and out of Philadelphia over the Short Line. Through Baltimore & Ohio passenger trains, to and from New York, also use this route. Freight trains on the Bethlehem branch operate in electric territory between Lansdale and Jenkintown and to Tabor Junction, 3.8 mi. south of Jenkintown, where they move over the Berks Street line, which is for freight only, into Philadelphia. Also, a number of freight movements are made from the low-grade freight line to the short line. These freights, however, enter electrified territory only as they cross the plant at Newtown Junction. Under normal conditions trains are operated in this territory by time-table and signal indication, and without written train orders.

MU Cars are Equipped with Cab Signals

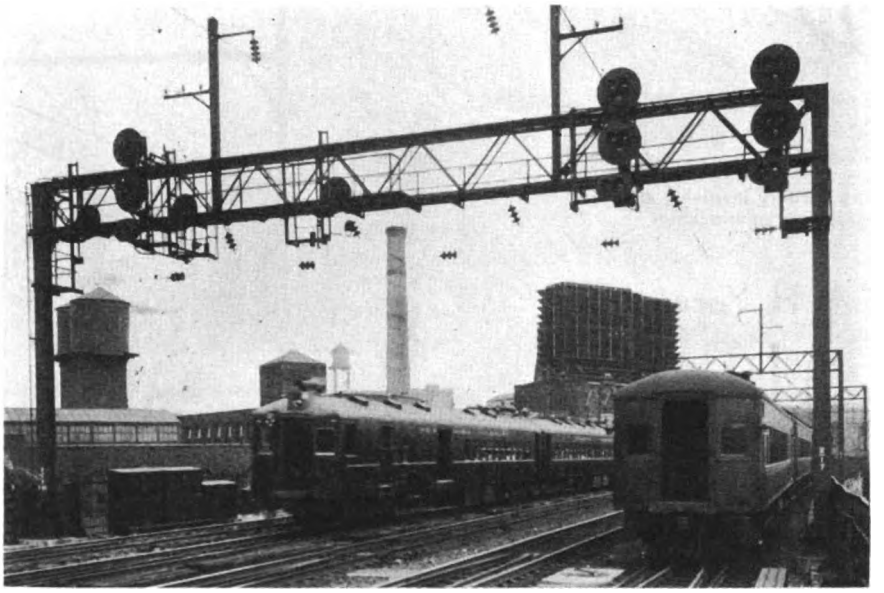
Automatic train control is in service on the Bethlehem branch from Jenkintown to Bethlehem. As electric trains operate over part of this territory, permission was granted to equip the multiple-unit cars with cab signals but without the use of automatic brake-application equipment. The change of a cab signal indication to a more restrictive one consequently does not initiate an automatic brake application but causes an air whistle to blow until acknowledged by the motorman. A cab signal is mounted in each end of each MU car and is of the coded continuous type providing four indications: green; yellow over green; yellow; and red. Receivers are mounted at each end of the cars and a directional relay is used to select the desired receiver for the corresponding direction.

Signal and Interlocking Changes

As in any major improvement, extensive changes had to be made in the existing equipment. Signals had to be relocated to handle the increased and faster service; substations and transmission lines had to be installed, track circuits changed over from direct current to alternating current; signal control circuits revised; interlockings revamped, etc. A total of 20 interlockings was involved in the change-over from steam to electric operation. The interlockings affected, and their size and type, are shown in an accompanying table. All change-over of apparatus was done under traffic, no interlockings or signals being taken out of service because of construction activities.

The signaling was completed by sections and placed in service as each section was ready for operation. The first section, from the terminal to Wayne Jct., represented the heaviest construction and changes. In this 5.1 miles of territory there is a total of six large power interlockings, train operation being almost exclusively in interlocking limits. In the next section, from Wayne Jct. to Jenkintown, a distance of 5.7 miles, there were one power, one electro-mechanical and one mechanical interlocking on which changes had to be made. The third section to go in service, Jenkintown to Lansdale, 13.6 mi., included three mechanical interlockings to be revamped. The only other electrified section in which interlocking changes had to be made was that stretch from Jenkintown to West Trenton, a distance of 21.7 miles, where there are six mechanical plants, one electric plant, and one combined electric and mechanical plant.

The changes made in interlockings could have been handled much easier if entirely new equipment had been installed, but the cost would have been much greater. Accordingly the work was engineered to use as much of the existing equipment as possible. Two major changes consisted of replacing the existing machine at the Terminal interlocking with a new Model-14 electro-pneumatic machine together with a spot-light type track model; while at Wayne Jct. the existing machine was replaced by a Model-14, Type-F machine.



Northbound MU train and southbound steam train at North Broad Street Station

On all existing electro-pneumatic interlocking plants, the d-c. lever and switch valve magnets were retained, the d-c. voltage being supplied by constant-potential copper-oxide rectifiers without the use of storage batteries. At Wayne Jct. and Newtown Jct. (two electric plants), the switch machines are operated by direct current, fed from storage batteries charged by RP-20 rectifiers. These interlockings likewise retained the d-c. lever magnets. At Wayne Jct. a-c. lever magnets and Type-F circuit controllers were installed in connection with other changes for the operation of the Federal switch machines which were continued in operation.

Among other changes made necessary by the electrification, on those sections between Reading Terminal and Jenkintown, and Glenside and Hatboro, and Lansdale and Doylestown, all existing relays were replaced with new a-c. relays. Between Jenkintown and Lansdale new a-c. relays were provided for signal control to replace the rectifiers-and-d-c. relay combination formerly

in use. Between Jenkintown and Langhorne all existing relays were retained. In general, interlockings not so equipped were provided with new steel relay cabinets for all relays. New light-type indicators for approach indicating or signal repeating were installed at those interlockings which previously were not so equipped. Three-position a-c. relays were installed for the SS control of signals at all interlockings, except those between Jenkintown and Langhorne, which were provided with switch-repeating relays at the time changes were made in the existing signal system between Jenkintown and Yardley. Any existing old-style time releases were replaced with new clockwork time releases. All interior and exterior wiring at the interlockings was replaced, and a-c. control circuits were provided, except at "DB" interlocking, where d-c. control circuits were retained, because of having been revised a short time previously. The d-c. voltage is supplied by constant-potential rectifiers. In the extensive changes made necessary, every safeguard was used to minimize possible failures.

In each tower an additional track diagram of the plant, mounted conveniently in front of the levermen,

Interlockings Changed Over

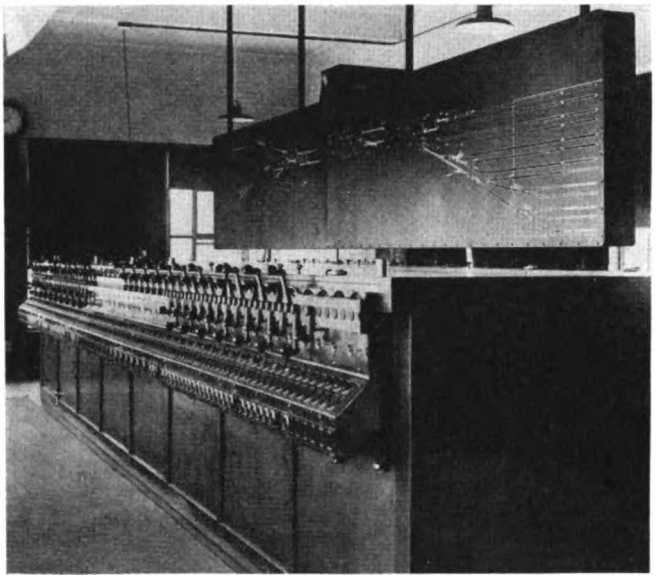
Location	Type Plant	Work. Lev.	No. SW.	No. Sig.	Layout
Terminal to Wayne Jct.					
Terminal	E. P.	75	56	77	Terminal
Brown St.	E. P.	36	27	41	Switch & Xovers
Jefferson St.	E. P.	22	16	31	Switch & Xovers
Diamond St.	E. P.	36	35	49	Switch & Xovers
16th St.	E. P.	38	37	33	Junction
Wayne Jct.	Elec.	52	49	70	Junction
Wayne Jct. to Jenkintown					
Newtown Jct.	Elec.	35	15	18	Junction
Tabor Jct.	Mech.	20	8	10	Junction
"KI" Jenkintown	E. M.	39	13	18	Junction
Jenkintown to Lansdale					
"DB" Tower Jenkintown	Mech.	28	11	13	Junction
Glenside	Mech.	28	14	14	Junction
Lansdale	Mech.	37	17	17	Junction
Jenkintown to West Trenton					
"JO" Jenkintown	Mech.	23	12	12	Junction
"NK" Bethayres	Mech.	8	2	8	Crossing
"SY" Neshaminy Falls.	Elec.	17	13	20	Junction
"JG" Neshaminy Falls.	Mech.	38	15	18	Junction
Langhorne	Mech.	37	15	20	Crossovers
Roelofs	Mech.	39	16	18	Crossovers
Yardley	Mech.	32	13	12	End 4 track
West Trenton	El. & Mech.	37	18	22	Junction

shows the sectionalizing limits for the overhead trolley, thus in emergency when it is necessary to cut off power on a certain section within the plant limits, the towerman is notified so that he will not inadvertently divert MU cars into a dead section of track. All sectionalizing switches are operated by a very elaborate supervisory remote control system, the control equipment of which is housed in a special building at Wayne Jct. and is in charge of a power dispatcher.

Extensive Changes in Signaling

Prior to the electrification, the automatic signals in service were of the Hall enclosed-disc type, spaced for handling the former lighter traffic into and out of the terminal. In the change-over from steam to electric operation, all signal bridges throughout the entire territory were replaced with catenary structures, and the new signals, which are the Style-TR color-light type (excepting the slow-speed signals, which are Style R, two-light type, horizontally mounted), are catenary supported or ground mounted. The catenary structures are provided with vertical angle-irons for the support of the signal units. The signal heads on the ground poles are placed 17.5 ft. above the top of the rail so that the motormen and enginemen obtain the best possible indications.

The customary control circuits for signals on multiple tracks are in use on these territories, but on the single-



New interlocking machine and illuminated track diagram at Race Street tower

track lines a modified overlap scheme is used. Between the Reading terminal and Wayne Jct., the signals burn constantly. In all other multiple-track territory the signals are approach-lighted; on single track they are continuously lighted. For signal lighting, 10-volt, 18-watt lamps are used. All automatic signals are equipped with a marker light which lights when the top unit lights. Alternating current switch indicators of the upper-quadrant semaphore type are used at the switches, but the switch stands are not electrically lighted.

The indications given on the high signals are red, yellow and green. The slow-speed signal is a two-light horizontal type giving a yellow and a red indication. The dwarf signals also give but two indications, yellow and purple. The aspects and indications are as shown in the accompanying table.

Because of the limited clearances, the type of relay shelter that was used necessarily varied at different locations. In general, the relay cases are of wood mounted on foundations.

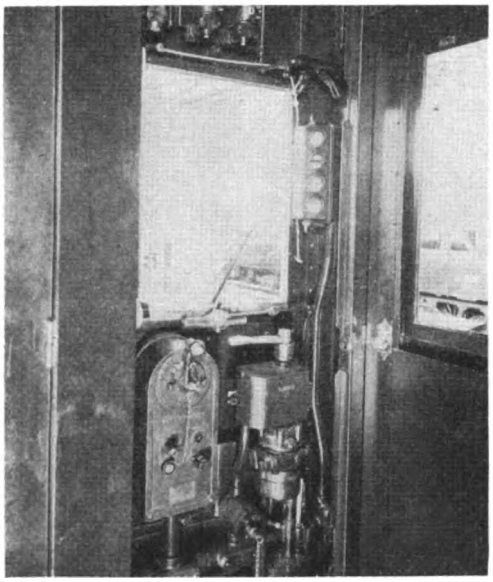
The resistance of signal grounds is not greater than 25 ohms and enough ground rods were installed at each particular location to meet this specification. Between Reading Terminal and Wayne Junction, because of the elevated structure and other conditions, special arrangements were necessary for obtaining low resistance grounds.

Track Circuits

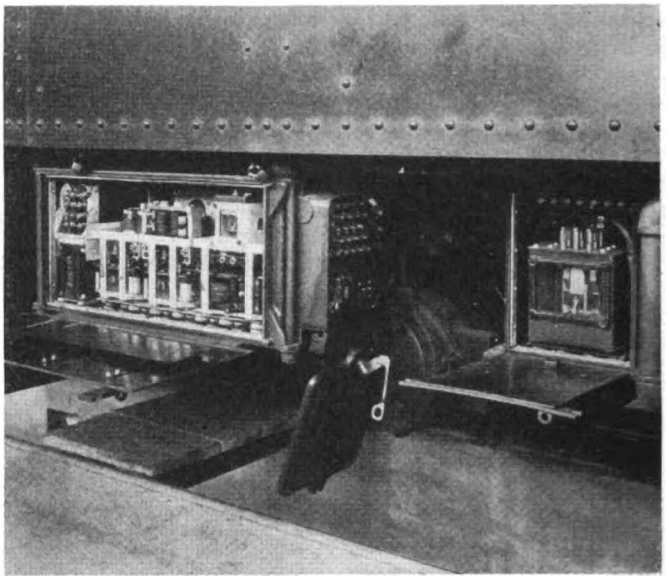
At highway crossing locations, in addition to the HC-type flasher units, a change-over relay and an RT-10 rectifier were installed for charging 5 cells of storage battery for emergency lighting.

In electrified territory there are 270 single-rail track circuits, having a maximum length of 1,200 ft., and 284 double-rail track circuits with a maximum length of 6,500 ft. Between Reading Terminal and Wayne Junction, single-rail track circuits are used in interlockings wherever possible, because of their lower first cost. These single-rail track circuits are so installed that in the event cab signaling or train control is later added they can be changed over to double-rail track circuits at a minimum expense, thus providing a future saving.

New U-4 switch boxes were installed throughout, with the exception of the sections between Jenkintown and Lansdale, and between Langhorne and Yardley, which were provided with new switch boxes at the time the changes were made between Jenkintown and Yardley. Heavy-duty switch boxes were installed for the proper operation of the existing train-control system between



Cab signal in an MU car



Amplifier equipment and directional relay

Fuse protection for all single-rail track circuits is provided to avoid burnouts due to momentary high voltages imposed upon the single rail. In general, the double-rail track circuits are in service from Wayne Junction to the different terminals of the electrified sections. The track relays will be applicable to coded train-control circuits if this should be installed at a future date.

In laying out the track circuits, the following conditions were taken into account: A minimum ballast resistance of 3 ohms per 1,000 ft.; 100-lb. rails bonded to capacity; maximum 25-cycle propulsion current of 75 amp. per rail; relays and transformer track leads to be twin-conductor parkway cable except between Jenkintown and Yardley and between Jenkintown and Lansdale, where single-conductor parkway was already installed. In train-control territory between Jenkintown and Lansdale a minimum axle current of 2 amp. is used. All relay and transformer track leads are attached to the rail as close to the insulated joint as possible, in order to obtain maximum broken-rail protection.

As a-c. propulsion is used in the electrified territory, a high-impedance bond is used at the transformer end of the track circuit and one of low impedance at the relay end. This arrangement is necessary to obtain proper broken-rail protection. In the case of 100-cycle signaling, the bonds have impedances of 4 ohms and 1 ohm. The impedance bonds are located between the rails of a given track and have a capacity to withstand 75 amp. per rail return traction current and their connections are welded to the track. In cross-bonding at substations and siding locations, a 4-ohm bond is used in each track.

Track circuits and other apparatus at each interlocking are fed by separate 110-volt distribution mains energized by centrally-located distribution transformers. A spare transformer is provided at each interlocking, together with a suitable arrangement of switches in order that it may be cut into service with a minimum of delay.

Jenkintown and Lansdale. In all sections, switch protection is provided by breaking the signal control wires over the switch boxes. In the automatic train-control territory the track is shunted over the heavy-duty switch

Aspects and Indications

INTERLOCKING SIGNALS

Rule No.	Aspect	Name	Indication
601A	Red–Red–Red / Red Red / Purple	Stop	Stop
601B	Yellow–Red–Red / Yellow Red	Approach	Approach next signal prepared to stop
601C	Green–Red–Red / Green Red	Clear	Proceed at speed
601D	Red–Yellow–Red	Restricting	Proceed at restricted speed prepared to stop at next signal
601E	Yellow–Green–Red	Approach Restricting	Approach next signal at restricted speed
601F	Red–Green–Red	Clear Restricting	Proceed at restricted speed
601G	Red–Red–Yellow / Red Yellow / Yellow	Slow Speed	Proceed at slow speed prepared to stop

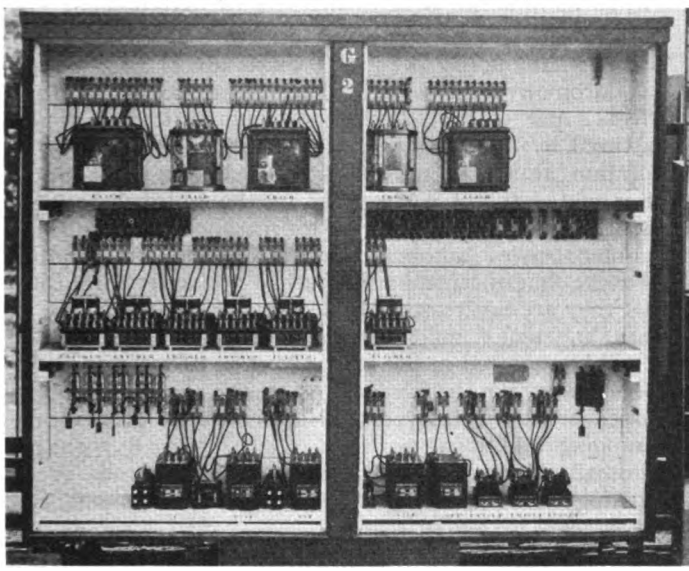
AUTOMATIC SIGNALS

501AA	Red–Red	Stop and Proceed	Stop then proceed in accordance with rules
501B	Yellow–Red	Approach	Approach next signal prepared to stop
501C	Green–Red	Clear	Proceed
501E	Yellow–Green	Approach Restricting	Approach next signal at restricted speed

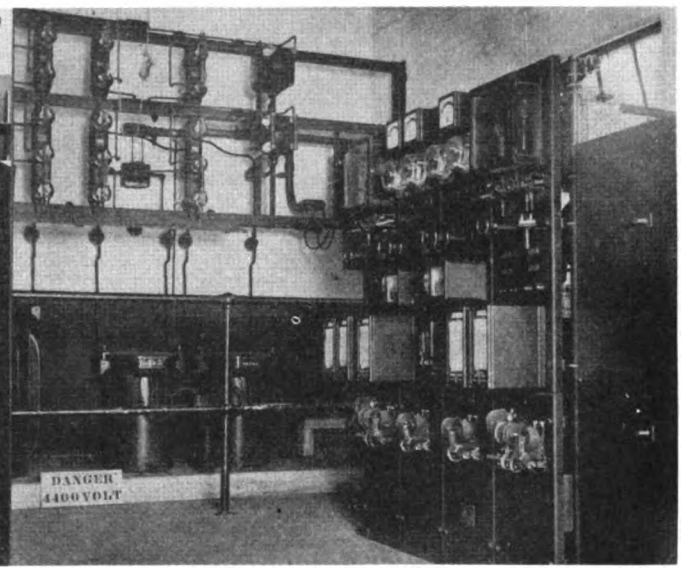
boxes, which are used in connection with T-10 hand-operated switch movements.

The track relays are of the Union centrifugal-frequency type; the track transformers are of the W-10 type on double-rail track circuits under 1,200 ft. in length. The adjustable resistors used between the transformer secondary and the relays are the General Electric SU-32-A-11 type with a Union VT-10 reactor in series with the local element of the relays. On double-rail track circuits over 1,200 ft. a VG-5 type reactor is used between the transformer secondary and the relays. On single-rail track circuits the resistors in the relay leads are SU-32-A-15 with the VT-10 reactors in series with the local element of the track relay, and in the transformer lead the SU-34-A-9 reactor is used.

Rail connections are made by means of parkway cable buried in the ground, terminating in junction boxes near the insulated joints. The connectors between the junction box and the rail are stranded Copper-weld wire with a plug for plugging into the rail. The rail bonding consists of Ohio-Brass and American steel-wire welded bonds. The fouling connections consist of the plug type stranded Copper-weld wires carried along the ties. The continuous type of insulated joint is used throughout. The maximum stagger allowed between insulated joints is 8 ft. but as a rule the insulated joints are placed opposite each other.



An outdoor instrument housing



Interior of signal sub-station

Power Supply and Distribution

The signal power transmission over all sections, excepting those between Yardley and Bound Brook Junction, is 4,400-volt 100 cycle single-phase. Between Yardley and Bound Brook Junction, 4,400-volt 60-cycle 3-phase transmission is in use. Under maximum load conditions the line drop does not exceed 4.3 per cent. Hard-drawn copper wire, No. 2 and No. 4, is used for transmission purposes in cables. Where the transmission line is carried on catenary structures (between Glenside and Hatboro 6.7 mi.; and between Lansdale and Doylestown, 10 mi.), it is strung on brackets and No. 1 copper stranded wire is used. For the section between Jenkintown and Lansdale No. 4 copper wire in double steel-taped cable is carried on the pole line, except in duct-line territory.

Between Reading Terminal and Jenkintown the signal transmission line is to take care of only the power that is required for the operation of the signals, and the future addition of coded continuous train control. On the following stretches of the territory involved in this installation, station-lighting loads, also, feed from the signal transmission line:

Glenside to Hatboro—5,000 watts.
Wayne Jct. to Neshaminy Falls via Jenkintown—15,600 watts.
Wayne Jct. to Neshaminy Falls via New York short line—7,500 watts.
Jenkintown to Lansdale—15,100 watts.
Neshaminy Falls to Yardley—6,000 watts.

The wire construction through the various sections is as follows: From the Reading Terminal to North Broad Street station, the transmission line is carried in Kerite parkway cable encased in Elastite trunking to prevent any possible damage caused by the picks of the trackmen, as physical conditions prevented the placing of this cable at any great depth beneath the surface of the ground. The low-voltage cables, also, are parkway and are buried 30 in. underground wherever possible. The high and low-voltage cables are covered with 4 in. of clay as an added protection. The 4,400-volt transmission cable and the low-voltage cables are all in the same trench.

From North Broad Street station to Jenkintown the high and low-voltage cables are of the lead-covered type and are carried in a duct line. In the territory between Jenkintown and Lansdale the 4,400-volt 100-cycle line is carried on the pole line some in lead cable and the remainder in open line, excepting through towns, where the clearances prohibit, a duct line is used.

The signal control circuits are carried in Kerite double-steel-taped aerial cable supported by the pole line except where duct line is installed. At such locations lead cable is installed in the duct line for the high and low-voltage wires.

Signal Sub-stations

The signal substations for the present installations are eight in number and are located as follows: Reading Terminal, Wayne Junction, Jenkintown, Neshaminy Falls, Yardley, Skillman, Hatboro, and Orvilla.

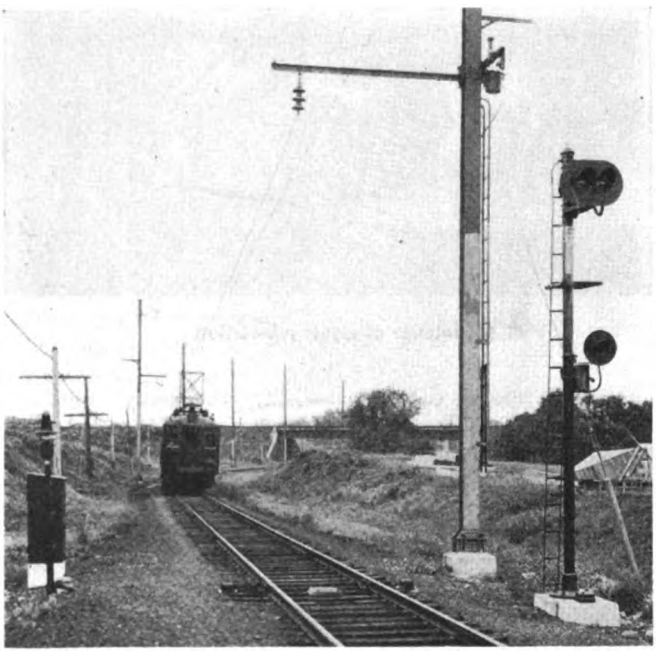
The Jenkintown and Orvilla substations were used for train-control territory in service prior to the electrification, and had sufficient capacity to feed the territory between Lansdale and Doylestown in addition to the territory between Jenkintown and Orvilla. The Glen-

side to Hatboro section is fed from a pair of feeders extending from Jenkintown to Hatboro and connected to the Wayne Junction-to-Neshaminy Falls power line. The substations feed the following sections:

The Reading Terminal has an emergency feed to Wayne Junction. Wayne Junction feeds normally to Reading Terminal, to Neshaminy Falls by way of the short line, and also by way of Jenkintown and Hatboro. A spare converter set is provided at this substation for emergency use. The Hatboro station provides an emergency feed to Glenside. Neshaminy Falls provides an emergency feed for Wayne Junction and Hatboro and

Motor-Generator Sets

Location	Kv-A
Reading Terminal	120
Wayne Jct.	120
Neshaminy Falls	120
Yardley	30
Jenkintown	60
Hatboro	30
Orvilla	(2) 60
Bethlehem	60
16th Street	10–50
Shawmont	10–50
Nicetown	10–50
Gladwyn	10–50



On single-track territory on the Hatboro branch—Note special signal

Yardley. Skillman feeds normally to Yardley. Yardley provides normal feed to Neshaminy Falls. Orvilla provides emergency feed to Jenkintown and to Bethlehem as well as to Doylestown. Jenkintown furnishes normal feed also for the Doylestown branch. Three phase, 60-cycle power is available at the different substations.

The motor-generator set, switchboard and transformers at Reading Terminal and Wayne Junction were furnished by the Westinghouse Electric and Manufacturing Co. This class of equipment at Jenkinstown, Orvilla, Bethlehem, Hatboro, Neshaminy Falls and Yardley, were furnished by the General Electric Co.

All signal material was furnished by the Union Switch & Signal Company and installed by its construction forces under the jurisdiction of the signal engineer of the Reading Company.

G. N. Asks to Remove Train Control

COMMISSIONER Frank McManamy of the Interstate Commerce Commission will conduct a hearing at St. Paul, Minn., on September 3 on a petition filed with the commission by the Great Northern for authority to discontinue further maintenance and operation of the automatic train-stop and train control devices on its line between New Rockford and Williston, N. D., 229.3 miles, and for an order vacating, insofar as they pertain to the Great Northern, the commission's orders of 1922 and 1924, as amended, pursuant to which the devices were installed.

The petition shows that the cost of maintenance and operation of the automatic train-control for 1928, 1929 and 1930 amounted to $26,954 for roadway and $27,564 for locomotives, a total of $54,518, or an average of $18,172 per year or $1,514 per month. It was manufactured by the Sprague Safety Control & Signal Corporation at a cost of $368,992, including installation. It is stated that the character of the railroad between these points is such as not to reasonably require the maintenance of automatic train-stop and train-control devices; that the company's record for safety indicates that they are not reasonably necessary on any part of its lines, and that a much greater return for money which it will be required in the future to spend for maintaining the devices can be realized in the way of safety to passengers and employees and protection of property by equipping additional portions of the railroad with the automatic block system, by eliminating dangerous grade crossings with highways, by making improvements and betterments.

For example it is stated that the $1,500 per month expended for maintaining the devices would more than equip a dangerous highway crossing with the most efficient automatic signal protection "and one such crossing so equipped each month would go far toward reducing the number of collisions between trains and automobiles at public crossings which are a constant hazard to both persons using the highway and to passengers and employees on trains."

It is stated in the petition that the territory on which the devices were installed is one of light traffic density, that the number of passengers carried on the Great Northern decreased from 8,168,937 in 1916 to 1,694,437 in 1930, and that the trend has continued downward: that the reduction in passenger-train miles on the system for 1931 will amount to almost 20 per cent below the figures for 1930. It is also stated that while during 1930 the number of collisions per million locomotive miles run on all railroads of the United States having total locomotive miles of 20,000,000 or more ranged from 0.60 to 3.84, the Great Northern had 1.43 collisions per million locomotive miles, the tenth lowest of the railroads mentioned.

In conclusion it is stated that "of the railroads now maintaining automatic train-stop and train-control devices petitioner is the last in the order of traffic density in the territory protected by these devices of any railroad in the country with the exception of a subsidiary of the Southern Railway. While train-stop and train-control devices may be justified on certain railroads under certain conditions, they are not justified under the conditions which obtain on petitioner's railroad."