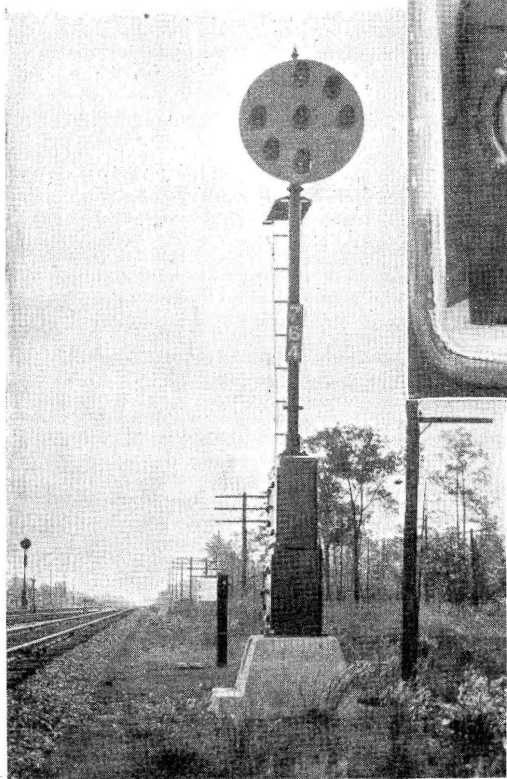


Right—The three code transmitters at the "sending" end of a track circuit. Below—Typical signal



Coded Signaling

On 81 miles of double-track, semaphores are being replaced with position-light signals controlled by coded-track circuits without line circuits; cab signaling also can be operated from the new track circuits

THREE-POSITION, upper-quadrant semaphore automatic block signals, operated and controlled by 25-cycle alternating current, were installed in 1913 on 81 miles of double-track on the Norfolk & Western between Norfolk, Va., and Petersburg. This automatic block signaling equipment is being entirely replaced by a new system of position-light signals, spaced to provide longer braking distances, and controlled by coded track circuits without line control wires, and the coded track circuits are arranged also to control cab signals at such time in

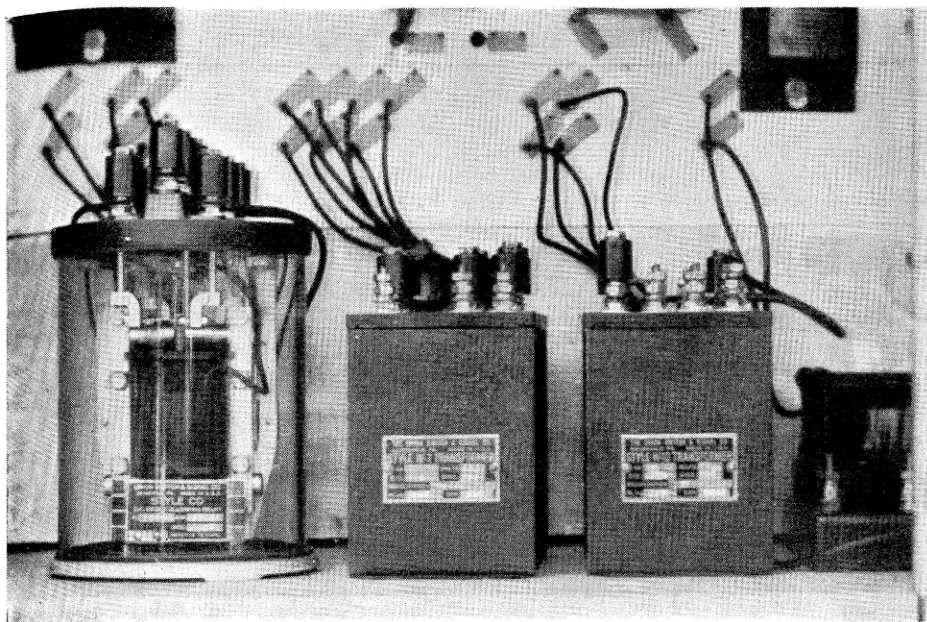
the future as the necessary equipment may be installed on the locomotives assigned to this division.

Character of Line and Traffic Handled

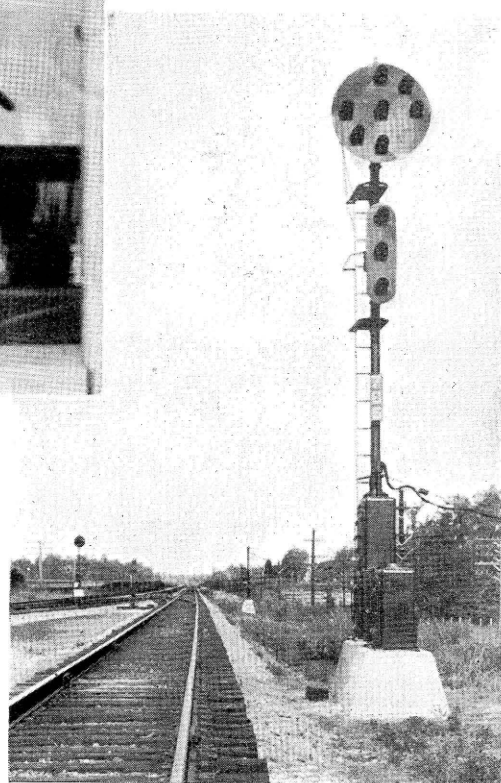
Norfolk, the eastern terminal of the Norfolk & Western, is located on Hampton Roads. This road handles local as well as through passenger and freight traffic between Norfolk on the east and Cincinnati, Ohio and Columbus on the west. Although considerable fast merchandise and manufactured goods are handled, the vast majority of the tonnage on the eastern portion of the road consists of coal which is moved from mines in Virginia and West Virginia to tidewater at Norfolk. Large yards are provided at Norfolk for handling various classes of freight traffic including coal, special docks and equipment for unloading coal cars directly into ocean-going vessels being used at Lambert Point just north of Norfolk. In addition to two scheduled merchandise freight trains in each direction daily, the line between Norfolk and Petersburg handles from 8 to 10 eastbound

trains of loaded coal cars, as well as an equal number of westbound trains of empty coal cars, each day. In addition, this line handles four passenger trains in each direction daily as well as a local freight train each direction daily except Sunday.

Practically the entire territory between Norfolk and Petersburg lies on the coastal plain. The original single-track line on which passenger trains and local freight trains are operated, extends through the city of Petersburg. From Petersburg to Poe interlocking, 3.5 miles, this line encounters several curves and ascending grades of up to 0.79 per cent. From Poe, a single-track, low-grade line used by through freights, extends around Petersburg to connect with the main line at Jack, about nine miles from Poe. From Poe eastward to Norfolk, the line is double track and traverses open flat territory with a few rolling grades. The line is practically straight, a section of tangent 52 miles long extending from Poe to Suffolk, where a 3-deg. curve is made to another section of tangent extending 18 miles almost to Norfolk. The track is well constructed with 130-lb. rail, treated



Left—Code-following relay and two decoding transformers at "receiving" end of track circuit. Below—Typical four-aspect block signal



Control System

on the Norfolk & Western

ties, and stone ballast. The track and line conditions, therefore, make it practicable and safe to operate trains at high speeds, and the practice of operation is to keep trains moving at maximum permissible speeds without unnecessary stops. Although passing tracks, located between the two main tracks, are provided at nine towns, as a rule the through freight trains are operated between Norfolk and Poe without leaving the main line or without stopping, except perhaps for coal and water at Dwight. In many instances, freight trains are run on comparatively short time ahead of passenger trains, and such operation can be made successful only by making provisions to eliminate stopping the freight trains. Likewise eastbound freight trains are moved out of Poe on comparatively short time behind passenger trains. This section between Norfolk and Petersburg is, therefore, one of the most intensively operated high-speed territories on the Norfolk & Western. Under these operating conditions, a most modern, efficient

and reliable system of signaling was required.

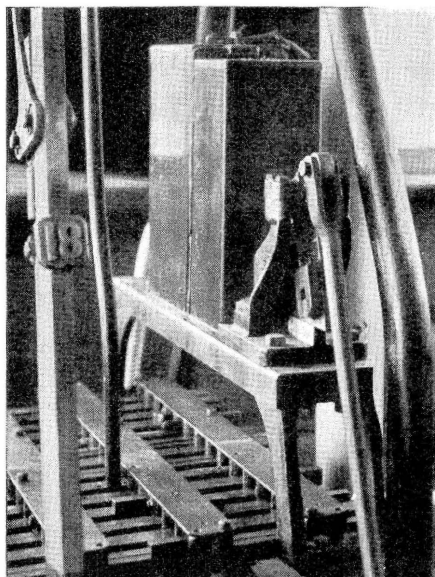
In the previous semaphore signaling system, the signals were spaced from 4,000 ft. to 6,000 ft. apart in the sections between station layouts. Taking all factors into consideration it was decided that where three-aspect signals were to be used, the block lengths should be approximately 9,000 ft. long, and that where shorter blocks, in the vicinity of passing tracks or in approach to interlockings were necessary, signals displaying four aspects should be used. The new signaling was laid out on this basis, which resulted in relocating many of the signals and removing others, a total of 85 signals being eliminated.

Code Control System Adopted

With the desire to provide the most modern system of signaling control which would afford reliable service free from interruptions due to broken line wires or false-clear failures caused by crosses of line wires, and

also looking forward to the possible application of cab signaling, it was decided that the coded track system of signaling controls should be adopted for this new signaling project.

In this new system no line control circuits are used for the control of the wayside signals or for the control of the proposed cab signaling, the controls all being accomplished by means of the track circuits. The control apparatus and signals for this installation were furnished by the Union Switch & Signal Company. Each track circuit is fed by a track transformer similar to that used for an ordinary a-c. track circuit, the new feature being that the feed to the 110-volt primary of this transformer is interrupted a certain number of times each minute by a device known as a code transmitter. At the signal, the various codes actuate relays to cause the signal to display proper aspects. If the controls are to be set up for the signal controlled by the block to display the Approach aspect, the feed is interrupted 75 times per



New electric locks at interlockings

min. For the Approach-Medium aspect the interruptions are at the rate of 120 per min., and for the Clear aspect 180 per min. An uninterrupted current or the absence of current on the track circuit causes the most restrictive aspect such as Stop or Stop-and-Proceed to be displayed.

Pole Line and Power Supply

The change-over from the previous a-c. semaphore signaling to the position-light signaling with coded control also included a change in the a-c. power distribution line from single-phase, 25-cycle, 440 volts, to three-phase, 60 cycle, 4400 volts. The new three-phase line is fed at the two end-stations, Norfolk and Petersburg, as well as at a middle point, Windsor. Power is normally fed from Windsor in each direction. If this source of power should fail, General Electric Company automatic switching equipment transfers the feed to the Norfolk and Petersburg sub-stations. The time required for this automatic transfer to take place is about $\frac{1}{2}$ second, resulting in an off period of such short duration that the automatic block signal controls are not affected. The pole line in this territory was completely rebuilt in 1937, using Class 3, 35-ft. Southern yellow pine poles, pressure treated full length with creosote. These poles are spaced 132 ft., i.e., 40 to the mile. The two wires formerly used for the single-phase line are No. 2 solid bare copper located on a 5-ft. crossarm placed 42 in. from the top of the pole. The additional wire, required for the three-phase line, is a No. 2 copper and is located on a pole-top pin. A static ground wire, consisting of three No. 10 Copperweld wires stranded together, is run on special angle-iron fixtures, which place this

wire 24 in. above the top of the pole; the wire is grounded to a $\frac{3}{4}$ in. by 8 ft. solid copper ground rod at every eighth pole as well as at the signal and transformer locations.

The 25-cycle line transformers were discarded, new General Electric Spiracor type single-phase transformers, rated at $\frac{3}{4}$ kv.a., 4600-115 volts being installed at each signal location. These transformers are protected on both primary and secondary sides by General Electric Company pellet-oxide type arresters and Thyrite discharge resistors connected to the rails. A Trip-o-matic fused cut-out is connected in series with each of the leads to the primary coil of each transformer, a feature of this device being that when the fuse blows, the door drops open, thus providing a visual indication which can be seen readily by a maintainer on the ground or on a motor car.

Construction Procedure

Where a new signal was to be located at the same place that an old one was in service, the old signal was set off the foundation onto a temporary foundation of timbers, and then the new signal was erected on the old foundation. At locations where no

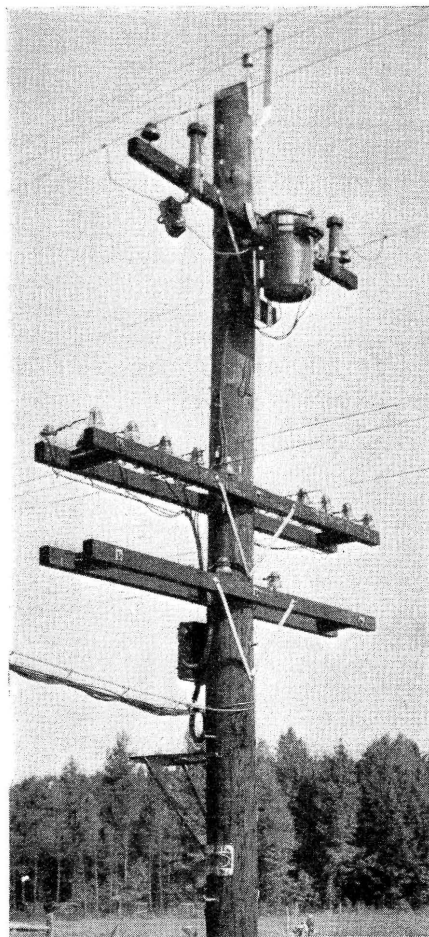
signal was previously in service, a new concrete foundation was constructed.

The old cases were of the double type with the Style-S mechanism in the upper case and the instruments in the lower case. As the work progressed, the equipment was removed from these old cases and they were cleaned and painted. By means of a cutting torch, the top of the masts were cut off, so that the center lamp of a new position-light signal would be 19 ft. above the top of the rail. An oblong hole, 2 in. by $3\frac{1}{2}$ in., was burned in the mast at a point 36 in. from the top, this hole being used as an outlet for wires to be run up the mast and out through a flexible metal conduit to the light signal head. The cases and masts were transported to the new locations on push cars, hauled by motor cars. After the cases and masts were erected, the ladders were reconstructed to include new platforms. The position-light signal heads were then mounted in place.

At locations where no signal had been in service, new insulated rail joints were installed and temporary jumpers were placed around the joints. Track circuit connections were installed between the cases and the rails, using single-conductor No. 9 stranded underground cable, Raco bootleg outlets and stranded Copperweld connections to $\frac{3}{8}$ in. plugs in the rails. The connections under the track, between signals, are in No. 14 solid wire underground cable. These underground cables are protected with non-metallic covering and with mummy finish coating. All insulated wires and cables are of Kerite manufacture.

Mounting boards were made of 1-in. poplar to fit the rear of the cases, and new boards were made to fit in the bottom of the case. The rear boards are screwed to 4-in. uprights which are bolted to the upright bolts through the cases, and 4-in. wiring space is provided behind the boards. These boards were made in the shop at Roanoke, Va., and are wired, with terminals, tags and apparatus in place, in the tool cars at field crew headquarters. No. 16 flexible wire with $\frac{3}{64}$ -in. wall of insulation and braid, with Bee wire eyelets is used for all case wiring.

When a board is installed in a case at the field location, the relays, code transmitters and other apparatus are placed on the shelves, and the wires are connected. A Raco insulated nut is placed on every instrument terminal post which is in service. The cables between the cases and the line poles are made up of single-conductor No. 14 solid copper wire with $\frac{5}{64}$ in. wall insulation, tape and braid, a $\frac{5}{16}$ -in. stranded Copperweld mes-



Line transformer location

senger being used with Raco cable straps spaced 18 in. A strain type porcelain insulator is located in the messenger about 2 ft. from the mast in order to prevent the messenger acting as a ground. The line cable terminates on Raco lightning arresters which are mounted in a Raco cast-iron box attached to the pole below the crossarm.

Change-Over Procedure

The construction work was handled in zones of about eight miles, each of which extends between sectionalizing switches in the a-c. power distribution line. The work progressed from Petersburg eastward and from Norfolk westward. The 25-cycle single-phase power had been fed from

ers to the line were closed. The new sectionalizing switch at the other end of the zone was then closed to feed 60-cycle, three-phase power throughout the zone. At locations where the signals were not moved, the necessary changes were made in the wires extending to rail connections, and at new locations, temporary jumpers around new insulated rail joints were removed and track connections were completed. The new signals were then in service, and the old semaphores were placed out of service, the blades and lamps being removed at once, and each entire signal was dismantled and removed as the next operation in the procedure.

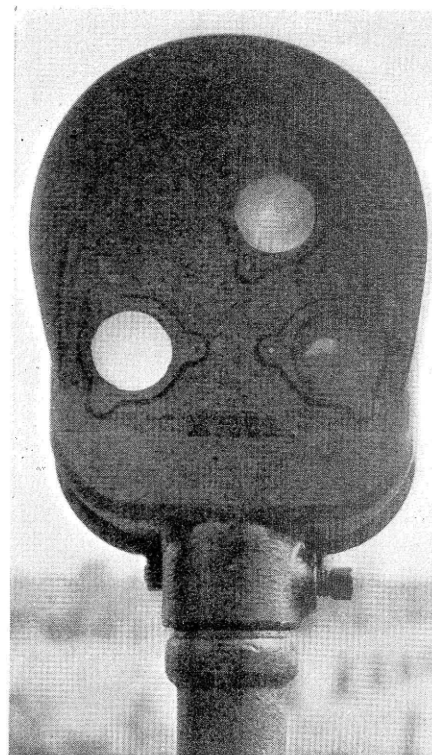
In scheduling a change-over, care was taken to choose a time of day when no passenger trains and a minimum number of freight trains would be affected. A bulletin was issued by the operating department advising engine and train crews that the old semaphore signals within a certain zone would be cut out of service at such and such an hour on a certain date, and that the new position-light signals would be considered as in service when the lamps were lighted in such signals to display aspects which should be observed.

Typical Circuits for Single-Direction

On the double-track, which is signaled for single-direction train operation on each track for right-hand running, the track circuits are fed in the direction toward the signal for the block involved, in other words, toward an on-coming train, a feature which is necessary for cab signal operation. The track circuits are so adjusted that a minimum axle current of two amperes flows when a track circuit is occupied; this current is adequate to operate cab signal apparatus. In order to transmit this current the rails are bonded with Raco rail head bonds.

Referring to Fig. 1, track circuit O2T is fed by track transformer (4) with a current-limiting reactance (5) in series with the feed to the rails. The 110-volt primary of this transformer is fed over a coding contact on the 180 code transmitter and over a front contact of the 2H relay to the primary of the track transformer when the block in advance is unoccupied or 110 volt a-c. energy is fed over a coding contact of the 75 code transmitter and a back contact of the 2H relay to the primary of the track transformer, when the block in advance is occupied.

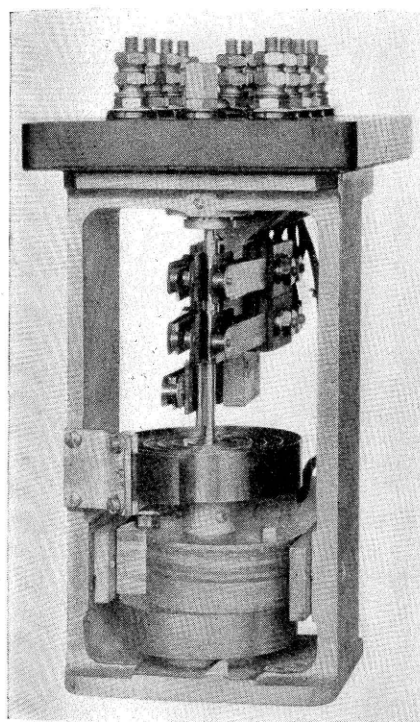
A set of code transmitters is required at each signal location, one to transmit the 75 code, another to transmit the 180 code, and if 120 code is used, a third for that code. The code



Position-light type switch indicator

transmitters operate on 10 volts d-c. supplied from a rectifier. As this is the first extensive new signaling installation on which these oscillating type, d-c. operated, transmitters have been used, a brief explanation will be given. As shown near the top of the shaft in the illustration a transmitter is equipped with two front and two back independent contacts with tungsten points for interrupting 110 volts a-c. which feeds the primaries of the track transformers. The use of tungsten insures long life in this service. If only two track circuits are to be fed from a transmitter, the two front contacts can be connected in multiple and the two back contacts in multiple, thus prolonging the life of the contacts, especially on long track circuits.

The contacts in a transmitter are operated by connections from a vertical shaft mounted in pivot ball-bearings at the top and the bottom. This shaft revolves back and forth, the motion being initiated and continued in operation by a d-c. magnet located near the bottom of the frame. The Z-type armature, which is mounted on the shaft, is about 1-in. thick and acts somewhat as the balance wheel of a watch. When the coils of the magnet are energized, the shaft is revolved against the bias of the coil spring. The magnetic effect is gradually reduced due to the construction of the Z-armature. In the meantime two track feed contacts on one side are closed and the contact at the bottom, to feed the magnet, is



Code transmitter with cover removed

Dwight, and connections were made at Petersburg and Norfolk to feed the 60-cycle, three-phase power from each end toward Dwight. Having completed all the signals on a section, with the wiring and instruments in place, and with the new line transformers installed but with the fused cut-out plugs open, a section was ready for change-over. Men were stationed at each signal location.

The first operation was to open the power line sectionalizing switch at the end of the zone, thus cutting off the 25-cycle single-phase power. The plug cut-outs in the connections to the primaries of the 25-cycle line transformers at each signal location were then opened, and the new cut-outs to connect the new 60-cycle transform-

opened. When the momentum of the Z-armature is overcome by the force of the spring, the motion of the shaft is reversed. Then the momentum set up in this direction causes the shaft to revolve past center to close the two contacts on the other side to feed

are in operation continuously, and tests conducted previously prove that they will withstand several years of operation without developing defects or improper operation.

Referring to Fig. 1, track circuit 2T, which controls signal 2, feeds

transformer produces a low frequency alternating current in the secondary windings of that transformer. A second contact on the code following track relay, which operates in synchronism with the first contact, is used to mechanically rectify the alternating

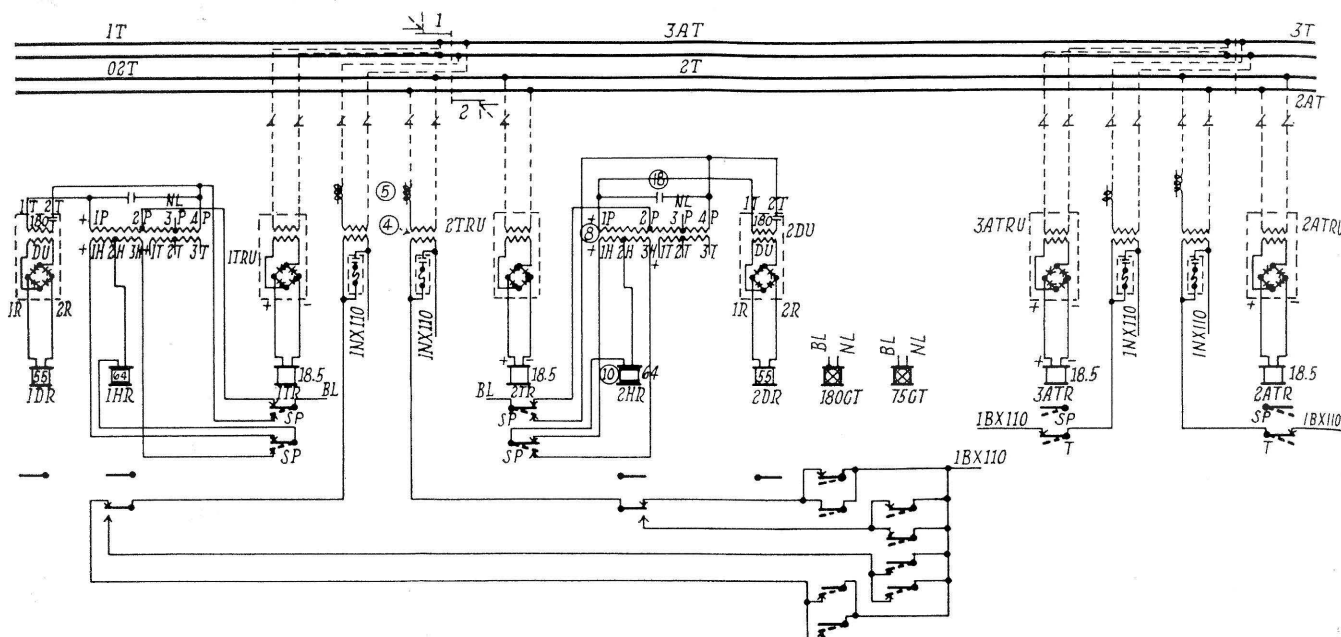


Fig. 1—Diagram of typical track code control signaling circuits

track circuits, and in the meantime the contact to feed the magnet is closed, thus causing the magnet to again reverse the direction of rotation of the shaft, thus starting the cycle again. Each transmitter is balanced to operate a certain number of times per minute, such as 75, and the period of operation does not vary although the d-c. current may vary several volts from normal. All of the transmitters

are in operation continuously, and tests conducted previously prove that they will withstand several years of operation without developing defects or improper operation. Referring to Fig. 1, track circuit 2T, which controls signal 2, feeds

transformer-rectifier unit 2TRU. In this unit the interrupted a-c. goes through a small transformer which produces a full-wave rectifier which produces interrupted direct current to feed the 18.5-ohm d-c. relay 2TR. This relay is picked up by each pulsation of current in the track, and is released between impulses; therefore, it is known as a code-following track relay. Direct current energy from a rectifier is connected over a front contact of the track relay 2TR when that relay is energized, causing current to flow in one direction through the primary winding of the decoding transformer (8), from terminal 2P to the common tap 3P. When the track relay is de-energized, direct current energy flows, over a back contact of that relay, in the opposite direction through the primary winding of the decoding transformer from terminal 4P to the common tap 3P. Consequently, when the code following track relay is responding to code, current flows alternately in one direction and then in the other direction through the primary winding of the decoding transformer. This reversal of current in the primary winding causes the flux in the core of the decoding transformer to build up, first in one direction and then in the other direction, at the rate of operation of the code-following track relay. This reversal of flux in the core of the

current energy induced in the "H" secondary winding of the decoding transformer; so that uni-directional current will flow in the winding of relay 2HR. This current, while uni-directional, is not of uniform magnitude because the induced voltage is not constant. The induced voltage is highest while the flux in the decoding transformer is reversing, immediately following a change in position of the track relay.

Relay 2HR can receive energy only from the decoding transformer, and then only if the flux in the core of that transformer is being constantly reversed. Therefore, relay 2HR cannot be energized if the track relay remains either permanently energized or permanently de-energized. The second or "T" winding shown on decoding transformer (8) is required only in interlocking track circuits. Both secondaries are identical and, where required, may be used interchangeably.

The 2HR relay (10) is a slow pick-up, slow-release, 64-ohm d-c. relay. It is desirable to have this relay somewhat slow in releasing to insure that it will remain energized during the periods of low energization when the track relay is responding to 75 code and during the longer periods of low energization which may be encountered in transferring from one code to another. Furthermore, it is de-



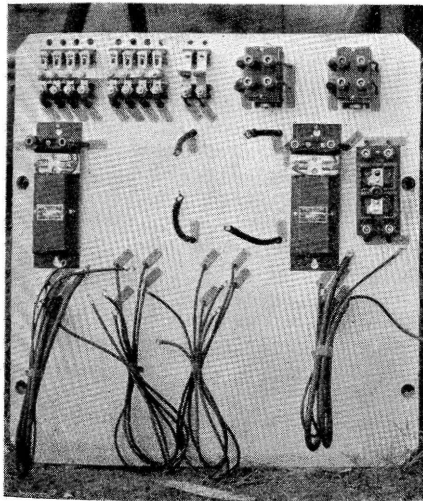
Instrument case at crossing signal location

Typical position-light
automatic block signal
location on double-track

sirable to have this relay somewhat slow in picking up to avoid closing the front contacts of this relay when the track relay makes a single change of position from energized to de-energized or de-energized to energized.

This single change of position occurs in blocks containing highway crossing protection, where steady non-coded track circuit energy is used for release of the highway crossing protection.

The decoding transformer is designed with an auto (step up) winding. Spark arresting condenser (18) is connected across the full primary and auto winding of the transformer to reduce the sparking of the contacts on the code-following track relay to



Equipment mounted on panel at
headquarters

a minimum. The code-following track relay is equipped with silver-platinum contact tips. This type of contact is most satisfactory for opening and closing circuits carrying the 13 volt d-c. energy fed to the primary winding of the decoding transformer.

The 180 decoding unit, 2DU, has its input terminals 1T and 2T connected across the full primary and auto winding of the decoding transformer between terminals 1P and 4P. This input or primary circuit of the decoding unit includes the primary winding of a transformer and is electrically tuned by a series condenser, contained within the unit. This tuned circuit is resonant at 3 cycles per second only, corresponding to 180 code cycles per minute. The secondary winding of this trans-

former is connected to a copper oxide rectifier to convert the a-c. energy induced in this winding to d-c. Relay 2DR is connected to the rectifier terminals of the decoding unit. The selectivity of the 180 decoding unit is such that the 2DR relay can be energized or remain energized only on 180 code.

Where an additional proceed indication, such as "Approach-Medium," is required for a wayside signal, it is necessary only to add a 120 decoding unit and an additional DR (BDR) relay, and to provide the necessary controls in conjunction with feeding 120 code, a-c. energy to the track circuits in accordance with traffic conditions ahead. The 120 decoding unit is electrically tuned to pass the 2 cycle alternating current produced when the code-following track relay is responding to the 120 code, thus the BDR relay is energized only on 120 code.

The circuit for the 2HR relay is in no way tuned, so that this relay responds to either 75, 120 or 180 code, but will remain de-energized when the code-following track relay is steadily energized or steadily de-energized.

A line rectifier at each signal location has sufficient capacity to feed the decoding circuits and the code transmitters at a double signal location.

At each double signal location two small lighting transformers are used, one for each signal, to give individual adjustment of the signal lights for each signal. The position-light wayside signals are controlled in the usual manner over the 2HR and 2DR relays.

The coded 60-cycle track circuits covered by this arrangement of signaling may be operated satisfactorily and will provide broken rail protection up to 9000 ft. in length where the minimum ballast resistance does not drop below 3 ohms per 1000 ft. and

where capacity bonding (rail-head bonds or equivalent) is used. The cut-section location shown on Fig. 1 is required only for blocks exceeding 9000 ft. in length or in blocks where the ballast resistance falls below a minimum of 3 ohms per 1000 ft. or in blocks exceeding 7000 ft. in length if less than capacity bonding is used.

At the cut-section location, the d-c. code following track relay is energized through the transformer rectifier unit from the first track circuit, the same as at a signal location. This track relay directly codes the energy fed to the primary winding of the track transformer for the second track section. Whatever code is received in the first track circuit is directly repeated to the second track circuit. The track transformer with its limiting reactor and its spark arresting condenser is the same as at the signal location.

The track relay at the cut-section is equipped with one set of tungsten contacts front and back, and one set of silver-platinum contacts (front and back). The tungsten contact is desirable because the code following relay at this location codes 110 volt a-c. energy. The silver-platinum contact is desirable so that this relay may also be used for coding a d-c. circuit. The two-point track relays for both signals and cut-sections, use the same contact spring brackets as the four-point track relay required in conjunction with highway crossing controls which has one set of tungsten contacts and three sets of silver-platinum contacts. The track relay used at cut sections may very readily be converted to this four-point relay, should that become desirable.

(Editor's note—A second article, concerning the circuit required for highway crossing protection and single-track operation, will appear in a later issue.)

