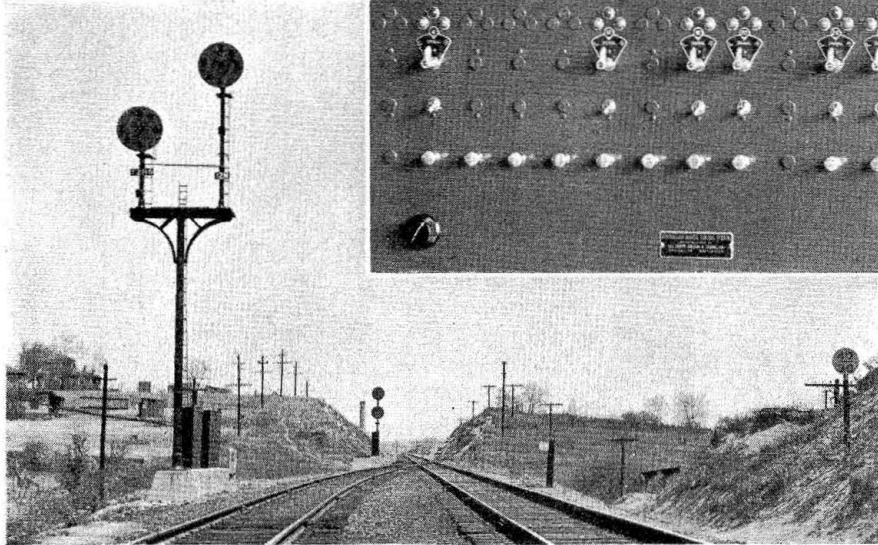


Right—Panel of the control includes eight traffic direction levers mounted just below the track diagram. Below—Signals 12LS and 12M at the east end of Kinney



C.T.C. Installed on Norfolk & Western

Local field controls handled by coded track circuits without line circuits on 22-mile section of single track

BETWEEN Phoebe, Va., and Forest, 22 miles, the Norfolk & Western has two single-track main lines. The original line, involving grades up to 0.94 per cent, passes through the City of Lynchburg, Va., and is used primarily for passenger trains, although light tonnage freight trains can be handled on this line. Also between Phoebe and Forest, the Norfolk & Western has a second single-track line known as the Lynchburg belt on which the maximum grade is 0.5 per cent. Practically all of the freight trains in either direction are operated over this belt line, not only because of the better grades, but also to avoid delays which might be occasioned by operating such trains on the old line

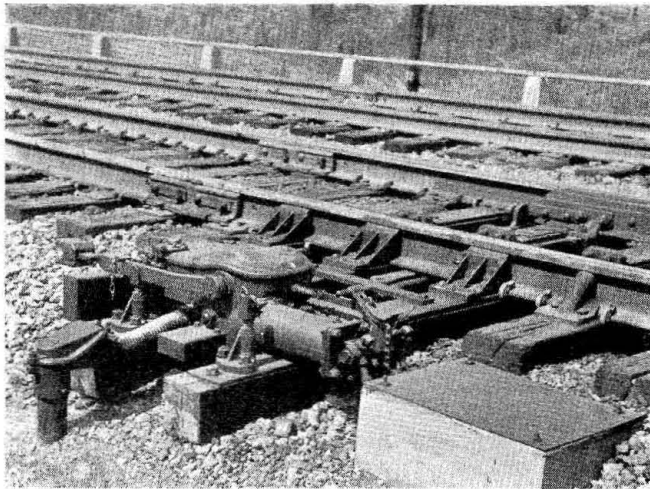
through Lynchburg. For many years, both the old line and the belt line have been equipped with automatic block signals for train movements in either direction. As a part of an extensive signaling replacement program on various sections of this road, the semaphore signaling on both lines between Phoebe and Forest has been replaced with modern position-light signaling, and in addition, centralized traffic control has been installed on the 22-mile single-track belt line, the control machine being located in the tower of the interlocking at Forest.

This C. T. C. installation is of special interest for several reasons. In the first instance, the switches were equipped in accordance with the requirement of service and practices of train operation. In view of the fact that the through trains use only certain passing tracks, the new installation of power switches and spring mechanisms was confined to these passing tracks. A major portion of the freight traffic consists of loaded

coal cars eastbound and empty coal cars westbound, therefore, eastbound trains are given preference to hold the main line while westbound trains take siding for meets. For this reason, at certain passing tracks the east end switches are equipped with power machines, but oil buffer spring mechanisms with mechanical facing-point locks were installed at the west switches. At other passing tracks, which are not used ordinarily by through trains, the hand-throw stands remain in service. On certain other switches at connecting tracks or at certain crossovers, which are used only under special circumstances, electric switch locks, controlled by the C. T. C. system, were installed.

Track and Signal Layout

The track and signal diagram herewith shows only the belt line between Phoebe and Forest. At the east end of the territory, a passing track starts in the Phoebe interlocking and extends westward on the north side of



One of the dual-control electro-pneumatic switch and lock machines

the main line. Ordinarily only westward trains use this passing track, and, therefore, the west end switch

aspect, depending whether one or two automatic blocks are unoccupied. After the train is clear of the passing track, a trainman places the switch normal.

The passing track at Posm is used by westbound freight trains when

new semi-automatic signals being included in the C. T. C. system. The C. T. C. operator also has charge of trains enroute between Kinney and Montview. The connecting track from the Montview-Kinney line, which curves to the south at Montview, is not used in regular through train service, and, therefore, this switch is operated by a hand-throw stand, and the new electric lock on this switch is controlled by the C. T. C. operator at Forest.

The junction switch at Kinney as well as the switch at the west end of the N. & W. passing track at Kinney are equipped with new power switch machines. As this passing track is used ordinarily by through freight trains, a power-switch machine, under control of the C. T. C. operator was installed at the east end.

The switch at the east end of the passing track at Forest is equipped with a power machine, controlled by the C. T. C. operator so that trains can enter or depart from this passing

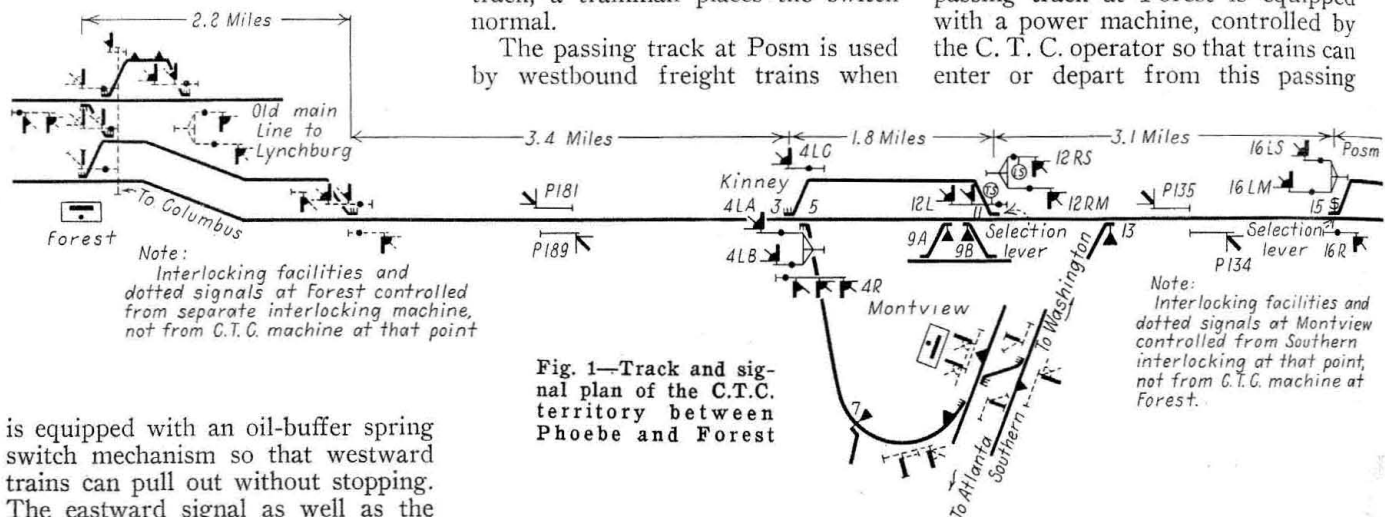


Fig. 1—Track and signal plan of the C.T.C. territory between Phoebe and Forest

is equipped with an oil-buffer spring switch mechanism so that westward trains can pull out without stopping. The eastward signal as well as the two westward signals at this switch are controlled from the C. T. C. machine.

The passing track at Bray is not ordinarily used by through trains, and, therefore, the previously existing hand-throw switch stands were retained in service. The new signals at each end of this passing track, however, are controlled by the C. T. C. system. If a westbound train, for example, is to be directed to take siding, the "take-siding" aspect is displayed on the mast of the westward station-entering signal 28L. After the train has stopped and a trainman has reversed the switch, a 45-deg. aspect is displayed on the lower arm of signal 28L, thus authorizing the train to enter the passing track, after which a trainman places the switch normal. When a westbound train, for example, is to be directed to depart from the Bray passing track, a "leave-siding" aspect is displayed on the westward signal 24LS, which directs that a trainman is to reverse the switch, after which the signal 24LS displays either a 45-deg. or a 90-deg. position-light

taking siding for meets with eastbound trains. For this reason, a power switch machine, under control of the C. T. C. operator, was installed at the east switch, and an oil-buffer type spring switch mechanism with an automatic mechanical facing-point lock was installed at the west switch. The new signals at each end are controlled by the C. T. C. system.

At Kinney, on the belt line, there is a junction with a single-track line which extends 0.4 mile to Montview where a connection is made with the double-track main line of the Southern between Washington, D. C., and Atlanta, Ga. Certain trains of the Southern enroute to and from Knoxville, Tenn., or beyond, are routed over the Norfolk & Western tracks via Montview, Kinney, Forest and Bristol, Tenn. When making the change-over to C. T. C., the interlocking on the Southern at Montview was continued in service but the mechanical interlocking at Kinney was removed, the new power switches and

track without stopping, and the signals, controlled by the C. T. C. system, are arranged accordingly. The switch at the west end of the Forest passing track is included in the interlocking. Electric switch locks on certain hand-operated switches as indicated on the diagram are controlled by the C. T. C. operator.

Unlock by C.T.C. Control

In order to clear an eastward interlocking signal governing to the belt line, the leverman at Forest must first manipulate the C. T. C. machine to effect an unlock, provided the traffic lever is not already in the proper position. Likewise, before the leverman at Phoebe can clear a westward interlocking signal governing to the belt line, the corresponding traffic lever in the C. T. C. machine at Forest must be in the proper position, and the same arrangement applies when the leverman at Montview is to clear an interlocking signal for a train to go from

Montview to Kinney. The semi-automatic signals at the various passing tracks on the belt line and at the junction at Kinney are, of course, controlled from the C. T. C. machine. With this arrangement, all train movements are directed by signal indications which supersede time-tables and train orders.

The average traffic handled daily on the belt line includes about 20 Norfolk & Western freight trains, and in addition the Southern operates six passenger trains and no freight trains daily on the Montview-Kinney-Forest territory.

No Local Line Control Circuits

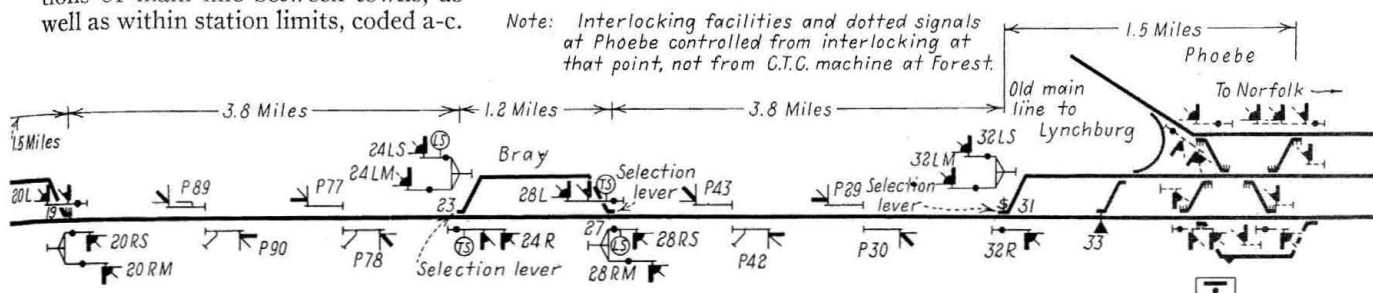
The new signaling system is of the straight a-c. type. On the passing sidings, conventional type neutral a-c. track circuits are used, but on the sections of main line between towns, as well as within station limits, coded a-c.

tions described previously in these columns, local line circuits in the field were used for the local controls of signals and for effecting traffic directional control, as well as compliance with I. C. C. Rule 412. The interesting and novel feature of this new C. T. C. installation on the Norfolk & Western is that track circuits exclusively are used for the control of signals and to effect traffic direction locking as well as compliance with I. C. C. Rule 412, so that no local line wire circuits, for these purposes, are required.

Traffic Direction Control

On the new C. T. C. control machine, at Forest, eight traffic-direction levers are mounted in a row just below the illuminated diagram, each of these levers can be operated either to

automatic signals; and, likewise, a traffic-direction lever is provided for the territory within the limits of each passing track on the main line only. There is no traffic lever for the side track between ends of passing sidings. Just above each traffic-direction lever, on the diagram, there is an indicator, including two arrows and two blue lamps, one or the other of which is lighted to show the direction for which traffic is established in the section controlled by the corresponding level below. Other than these special traffic direction features, the control machine is of the conventional type. The two-wire time-coding system utilizes 14-step code, and includes equipment for the control of a total of 35 stations. The outgoing controls and returns of indications, as applying to the traffic direction locking, are han-



track circuits are used, not only to accomplish the automatic controls of signals with reference to track occupancy, but also they enter into the circuits of the traffic-direction station-to-station control of station-leaving semi-automatic signals, the indications of which direct train movements under the control of the C. T. C. operator. With this arrangement, no line circuits, other than the two C. T. C. line wires, are required for the control of signals or power switches. In the automatic controls of signals, code in a track at the rate of 180 per minute causes the clear aspect to be displayed; code at 120, the Approach Medium; and code at 75, the Approach, and the absence of code or steady flowing energy, not coded, causes the Stop aspect to be displayed on the signal.

The operations of coded track circuits, as applied to strictly automatic signaling on the Norfolk & Western, were explained in an article published on page 96 of *Railway Signaling* for February, 1940. The following discussion, therefore, is confined to the new and novel features of using coded track circuits as applied with reference to the C. T. C. traffic-direction of semi-automatic signals in this new installation.

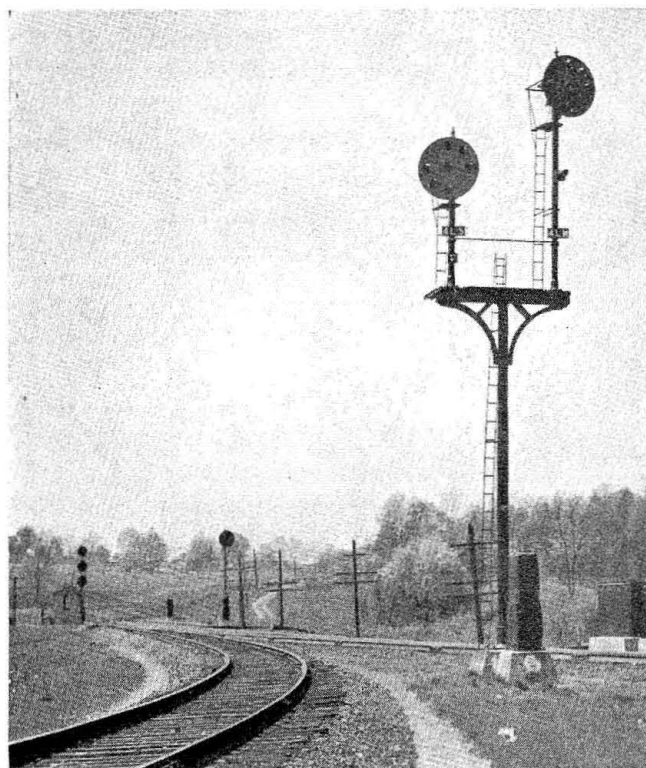
In many of the C. T. C. installa-

the left or to the right position, but there is no center position. A traffic-direction lever is provided for each section of single track between opposing station-leaving head-block semi-

dled by the C.T.C. line coding system.

Normally steady energy is fed from the entrance end of a station-to-station block toward the exit end, for the direction of traffic established by the

View from Southern toward signals 4LS and 4LM at the east end of Kinney layout



energize relay 10LCDR if 75 code is being received, and to energize relays 10LCDR and 10LDR if 180 code is being received. The relay for the control of signal 10LA, namely 10LAHR, will be controlled over relay 10LCDR in the usual manner.

As the train passes signal 10LA it occupies track circuit 9T. Relay 10LTCTM will continue de-energized so that relay 10LTR will continue to respond to code even though relay 10LHSR closes its back contact when track circuit 9T is occupied, at which time relay 10LASR will close its front contact, thus completing the circuit of relay 10LTCTM if it were not for the front contact of relay 9TP in its control. When the train passes signal 10R, it shunts energy away from track relay 10LTR so that relays 10LCDR and 10LDR are de-energized in the usual manner.

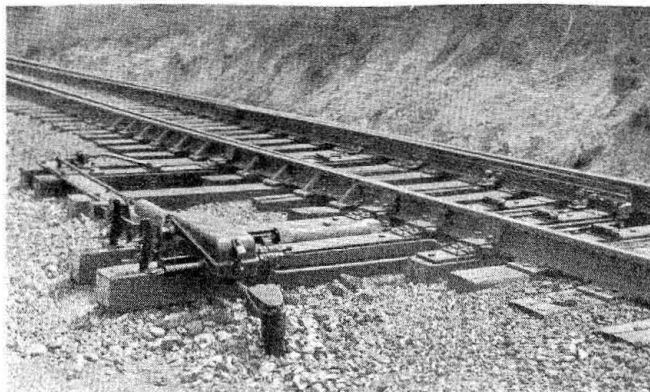
As a train proceeds through the block, coded energy continues to be fed from the west end of the block while steady energy will be fed at the east end of the block, because when the train vacates track circuit 9T relay 10LTCTM will be continuously energized by the circuit from battery through back contact of relay 10LHSR and back contact of relay 8EFSR and front contacts of relays 9TP and 10LASR, if a code is not sent to energize relay 10LHSR for a following move.

When the rear end of the train passes signal 6L, the steady energy applied at the east end of the block will energize track relay 6RTR at the west end of the block, which is connected to the track circuit through rectifying unit 6RRU, and the back contacts of relay 6RTCTM. The latter relay, it will be noted, remains de-energized because its control circuit is open at the front contact of relay 5TP while the detector circuit is occupied.

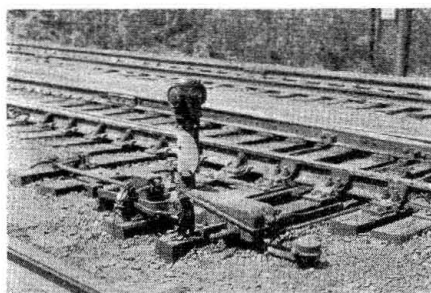
Office—Field Checks

Under these conditions the traffic may be reversed. As shown in Fig 2, relay 8WFK on the C.T.C. machine will be energized, through the line code equipment by a circuit to terminal 4, front contact of relays 8WFSR and 6RTP. With relay 8WFK energized relay 8LPR, Fig. 2, may be energized when traffic lever 8 is moved to the E position. This relay is of the biased polarized type and will retain its polar contact closed in the last position of energization. The preliminary movement of lever 8 operated a push-button which caused the energization of code-starting relays 234ST and 236ST so that codes will be sent to the storage units in the field corresponding to this

Spring switch and mechanical facing-point lock at the Posm passing track



numbering. When the code is transmitted with the normal polar contact of relay 8LPR closed, then code to station 236 will include a character for the energization of relay 8EFSR. This character will be missing from the code transmitted to station 234 because of the circuit being open at the reverse polar contact of relay 8LPR so that relay 8WFSR will be de-energized. It will be noticed that if steady energy were not being received at the west end of the block, relay 6RTP would be de-energized



Model-T-21 hand-operated stand with an electric lock

and the C.T.C. code from the office would be ineffective in de-energizing relay 8WFSR.

With relay 8EFSR energized, the control of relay 10LTCTM is transferred from steady energy to coded energy of 75 or 180 code, so that coded energy instead of steady energy is now applied at the east end of the block. This coded energy will be detected at the western end of the block by relay 6RTR, which when it closes its front contacts will cause the energization of relay 6RTP, which is sufficiently slow in releasing to bridge the code action of relay 6RTR. The energization of relay 6RTP will open the control of relay 6RTCTM if it has been responding to code, as may be the case if the code is transmitted to energize relay 8EFSR before the code is transmitted to de-energize 8WFSR. Later when relay 8WFSR is de-energized, relay 6RTCTM will be continuously energized by the circuit from battery through back contact of relay 6RHSR, back contact of relay

8WFSR and front contacts of relays 5TP and 6RASR, as described previously for a similar circuit controlling relay 10LTCTM.

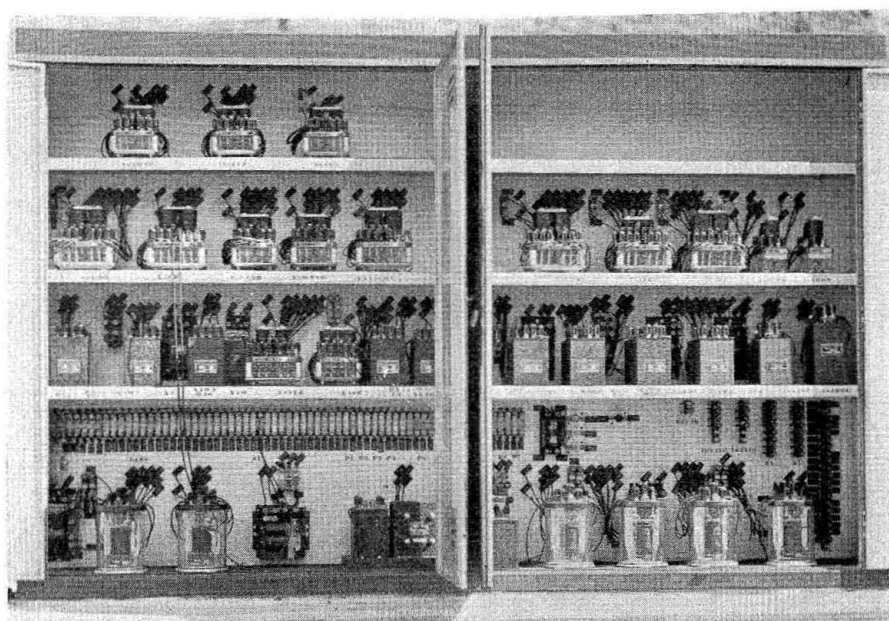
When relay 6RTCTM is continuously energized, steady a-c. energy is applied to the track circuit at the western end of the block, which will be detected at the eastern end of the block by relay 10LTR during the off period of the code to which relay 10LTCTM is responding. The energization of relay 10LTR will cause the energization of relay 10LTP, which will bridge the coding action, and, when its back contact is opened, will cause the de-energization of relay 10LTCTM so that coded energy is removed from the eastern end of the block until such time as signal 6RA or 6RB is cleared.

With relays 8EFSR and 10LTP energized, a code will be transmitted through storage unit 236 to energize relay 8EFK on the C.T.C. machine. The energization of this relay will cause relay 8FK on the C.T.C. machine to close its reverse polar contact. This relay had previously been energized over a front contact of relay 8WFK, but that relay would have become de-energized when the traffic change was effected. The polar contact of relay 8FK controls the traffic direction indication lights.

Intermediate Signal Controls

The operation of the circuits at the intermediate signal location is shown in Fig. 3, without referring to the detailed description at the ends of the block, which has previously been recounted.

With the entrance signal at the eastern end of the block clear or with a westbound train approaching signal W, coded energy will be received from the western end of the block and applied to the track section in approach to signal W. Under these conditions, steady energy from the eastern end of the track circuit will be absent so that relay ETR and its repeater ETP will be de-energized. Track relay WTR and its repeater WTP will be



Interior of double instrument case at signal P-186 at Terrell passing track

energized. Relay WTR will follow code of 75 or 180 depending upon the position of the relay 6LAHR at the western end of the block. This coded action will be detected in the usual manner by the decoding transformer circuit so that relay WHR will

be energized. Relay WTR will follow code of 75 or 180 depending upon the position of the relay 6LAHR at the western end of the block. This coded action will be detected in the usual manner by the decoding transformer circuit so that relay WHR will

With relay WHR energized, relay WS will be energized. Relay ECTM will now be energized by the circuit from battery, back contact of relay

contact of relay WTP, and a front contact of relay WHR. The relay WS is stuck up by the circuit including the back contact of the WTP relay. Thus the WS relay will be energized when the 10L signal is cleared or when a train passes 10L, and will remain energized until the train clears the block protected by the intermediate signal "W."

When the westbound train passes signal W and completely clears track section ET, coded energy of 75 code will be applied to track circuit ET so that signal 10LA may be re-cleared for a following move. Relay ECTM under this condition will respond to 75 code by the circuit which includes back contact of ETP, front contact of 75CT, front contact of WHR and ES. When the train clears the block between signal

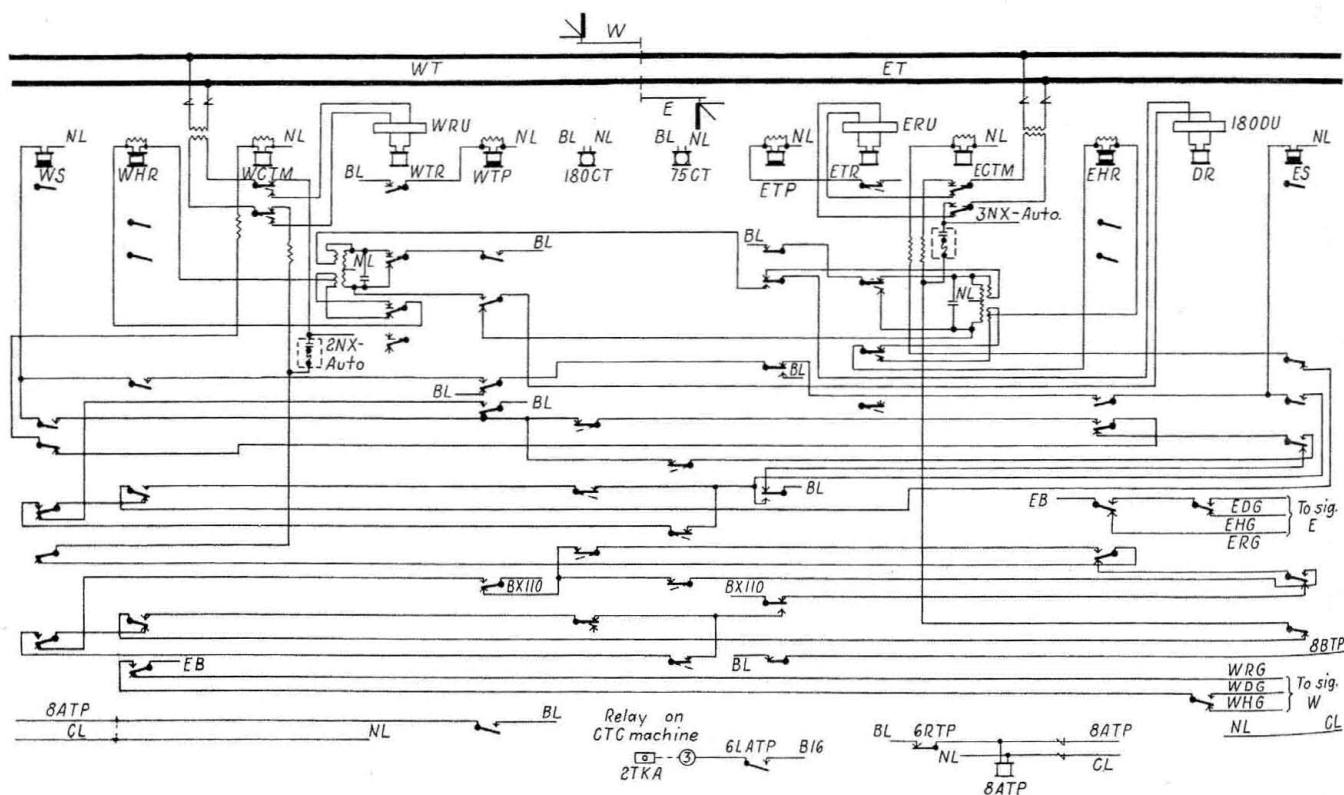


Fig. 3—Typical control circuits for intermediate double automatic signal location.

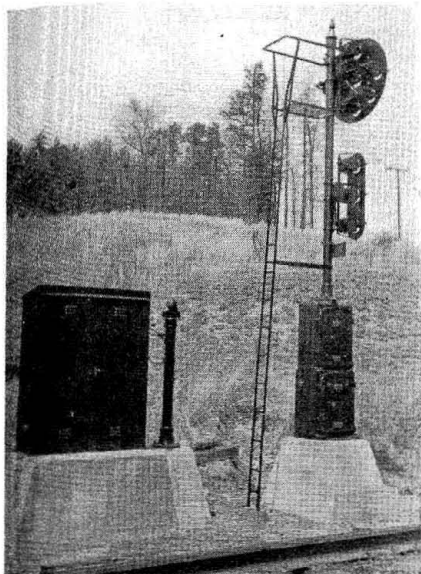
be energized for both 75 and 180 codes while relay DR will be energized if 180 code is being received. A common 180 decoding unit and D relay are used for the eastern and western signal so that the circuit to the 180 decoding unit is selected over a front contact of relay WTP to the

ETP, front contact on 180CT, front contacts on relays WHR and WS. Relay ECTM is thus responding to 180 code and energy of that code is applied to the western end of track circuit ET. Relay WS is picked up over the circuit taking battery over a back contact of relay ETP, a front

W and signal 6L, relay WHR will respond to code and relay WTP will be energized so that relay ECTM will follow 180 code instead of 75 code.

If signal 10 was not re-cleared after the train passed, the WS relay would remain energized until WTP picked up. The steady energy applied

at the eastern end of the track section would be detected by track relay ETR during the off period of the code to which relay ECTM is responding. Thus with a westbound train between signal W and signal 6L, relay ECTM would be responding to 75 code and relay ETR would respond to the steady energy the first time relay ECTM closed its back contacts after track section ET was vacated. The energization of relay ETR also energizes relay ETP, which opens the control of relay ECTM, thus continuously connecting track relay ETR to the track circuit. When the train



Instrument case and signal 89

passes 6L, the WTP picks up at signal W and steady energy is fed to the circuit WT by energization of the WCTM relay as follows: battery through a front contact of ETP, back contact of ES, back contact of EHR and back contact of WS. This steady energy will be detected at the west end of the block by relays 6RTR and 6RTP when the train passes signal 6L, as previously described.

When a change in traffic direction is effected from westbound to eastbound and the steady energy at the eastern end of the block is changed to coded energy, relay ETR at the intermediate signal will respond to the coded energy, with the consequent energization of relay EHR, through its decoding circuit in the usual manner. The energization of relay EHR with relay ETP energized and WTP de-ener-

gized, will cause relay ES to pick up. Relay WCTM will now respond to 180 code by the circuit from battery, back contact of relay WTP, front contacts on relays 180CT, EHR and back contact of WS.

Subsequently, prior to the clearing of signal 6RA or 6RB, and after the receipt of coded energy at the western end of the block, steady energy will be applied at the western end to energize relay WTR, at the intermediate signal, during the "off" period of the code to which relay WCTM is responding. The energization of relay WTR will cause the energization of relay WTP, thus opening the circuit of relay WCTM and removing coded energy from the eastern end of the track section. The energization of WTP will de-energize the ES and cause the ECTM to be steadily energized, thus sending steady energy into the track circuit ET. This steady energy will be detected at the eastern end of the block by relays 10LTR and 10LTP as previously recounted.

Indications on the C.T.C. machine are furnished for the track section between signal 6L and signal W and between signal E and signal 10R by providing circuits for relays 8ATP and 8BTP. When traffic is aligned for the westbound direction and steady energy is being received at the western end of the block, relay 8ATP is energized over the front contact of relay 6RTP and when steady energy is removed from the eastern end of the track circuit it is energized over a front contact of relay WTP. When traffic is aligned for the eastbound direction, relay 8ATP would be controlled over relay WTP when steady

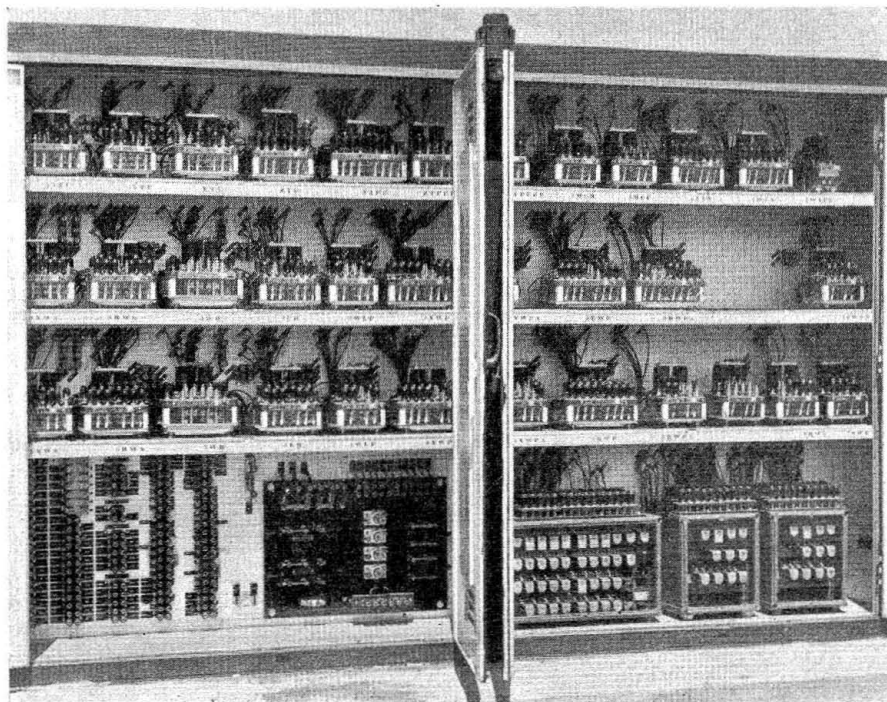
energy is present and over relay 6RTP when steady energy is removed.

The coded a-c. track circuits used in this arrangement of signaling are operated satisfactorily and provide broken rail protection up to 9,000 ft. in length where the minimum ballast resistance does not drop below 3 ohms per 1,000 ft. and where capacity bonding is used. Each rail joint is bonded with a Raco type RA421-1, mechanically-applied rail head bond.

General Construction Features

The new position-light signals are the PL-2 type, equipped with deflecting prism cover glasses instead of the novial conical cover glasses, as used on the conventional type. The new deflecting lenses increase the spread of the light beam which is an advantage on curved track.

At the switch locations and at intermediate signal locations, new sheet-metal cases were installed for housing the relays and coding equipment. At a few locations some apparatus is housed in the cases which formerly contained the Style-S semaphore mechanisms. In these cases, 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 head-



Double instrument case including coding apparatus in lower shelf



Eastbound freight train approaching the west switch at Posm, equipped with A-20 S. & L. movement

quarters. Number 16 flexible wire with 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 apparatus is placed on the shelves, and the wires are connected. A Raco insulated nut is placed on every instrument terminal post which is in service. Aerial cable is used for drop wires between the cases and the line poles, a 5/16-in. strand Copperweld messenger 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.

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 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.

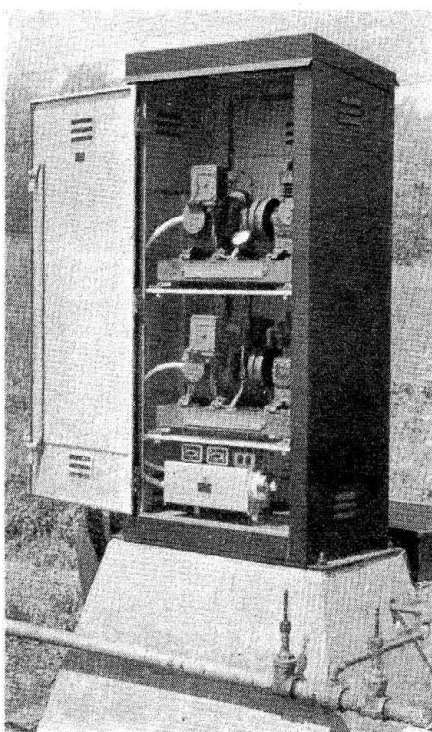
Electro-Pneumatic Switch Machines

Each of the power switches is operated by a Type A-20 dual-control electro-pneumatic switch machine. When the selector lever is operated, the air supply to the switch machine is cut off, the valve control circuits are opened, and a code is sent to the office indicating an open switch and an occupied track circuit. Each selector lever is locked with a standard switch padlock in order to prevent unauthorized movement of this lever. The hand-throw lever is, of course, also padlocked. Each switch layout is equipped with the standard arrangement of lock rods and a point detector which is set to operate if the switch

point is open more than 3/16 in. Each switch layout is equipped with three 3/4-in. by 7-in. insulated gage plates, with Ramapo adjustable rail braces. An adequate number of rail anchors are installed to prevent creeping of the rail and resultant improper operation of the lock rods.

The compressed air for the operation of the switch machines is supplied by small-capacity motor-driven compressor sets. Duplicate compressors, each rated at 3.5 cu. ft. per min., are located at each switch. The compressors are controlled automatically, the one in normal operation being set to cut in at 55 lb. and cut out at 70 lb., while the auxiliary compressor is set to cut in at 45 lb. and cut out at 60 lb.

A hand-operated switch is provided to interchange the compressors from normal to auxiliary service for periods of a month, so that the wear on the machines will be about equal.



Air compressors in case

Each of the 3.5-cu. ft. compressors is driven by a 110-volt a-c. motor, rated at 3/4 hp.

Pole Line and Power Supply

The change-over from the previous semaphore signaling to the position-light signaling with coded control also included a change in the a-c. power distribution line from single-phase, 60-cycle, 4400-volt, to three-phase 60-cycle, 4400 volts. The new three-phase line is fed at Lynchburg. If this source of power should fail, General Electric Company automatic switching equipment transfers the feed to Bedford. The time required for this automatic transfer to take place is about 1/2 sec., 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 partially rebuilt in 1937, and completed in 1940, 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. 4 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. 4 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 3/4-in. by 8-ft. Copperweld ground rod at every eighth pole, as well as at the signal and transformer locations.

The old line transformers were discarded, new General Electric Spiracor type single-phase transformers, rated at 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.

This signaling project was planned and installed by the signal forces of the Norfolk & Western, under the direction of D. W. Richards, superintendent telegraph and signals. The major items of equipment were furnished by the Union Switch & Signal Company.