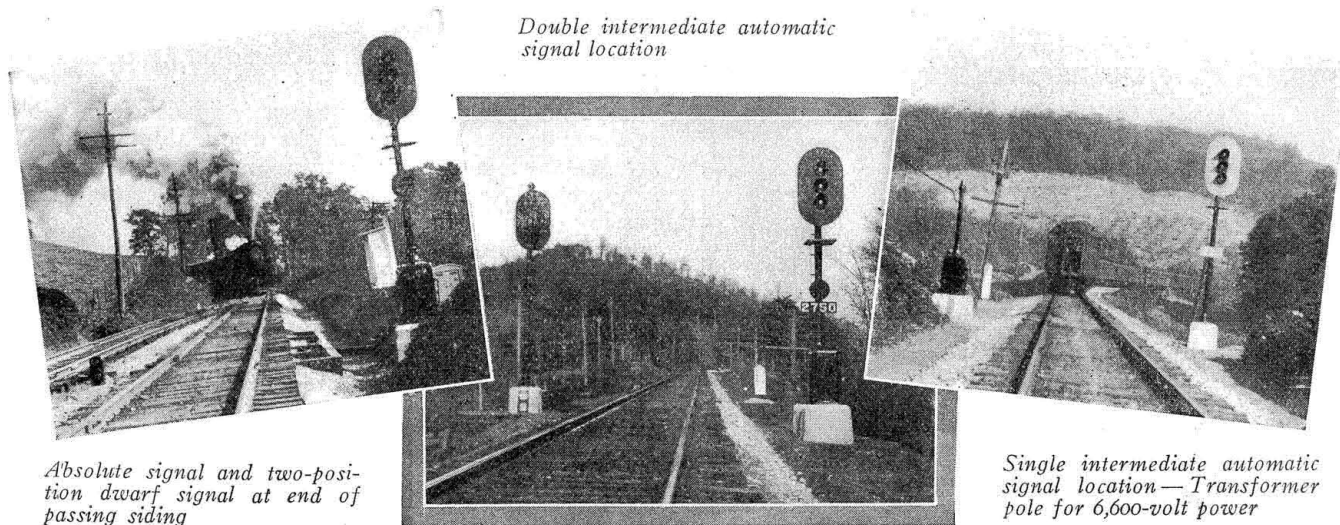


C. & O. Signaling and Train Control Facilitate Operation

*Union intermittent inductive type of A.T.C. employed on
125 miles of main line*



Absolute signal and two-position dwarf signal at end of passing siding

Double intermediate automatic signal location

Single intermediate automatic signal location—Transformer pole for 6,600-volt power

THE present train control installation on the Chesapeake & Ohio which was placed in service November 1, 1926, is the intermittent inductive automatic train stop system of the Union Switch & Signal Company, which replaced an intermittent electrical contact type of device, which had been in service approximately ten years.

Experiments were first started with a seven-mile section of train control without wayside signals between Gordonsville, Va., and Lindsay, this being a part of the line included in the present installation and was placed in service on May 15, 1917. This installation was later extended to Charlottesville and was placed in service with 38 equipped locomotives on June 9, 1919. At the same time automatic signals of the color-light type approach lighted from primary battery were installed between Gordonsville and Charlottesville, a distance of 21 miles.

In March, 1920, plans were made to extend the installation of automatic signals and train control approximately 40 miles west from Charlottesville to Staunton, Va. On the latter section the signals were of the color-light type, continuously illuminated from a 3-phase, 6,600-volt, 60-cycle power line, through step down transformers, and were placed in service December 14, 1922. The automatic train control on the latter section was designed for a-c. operation, and with 24 additional equipped locomotives was placed in service January 16, 1924.

The first order by the commission required the installation of train control on a passenger locomotive operating district between Richmond, Va., and Clifton Forge. An order by the commission dated December 30, 1924, permitted the installation of train control between Gordonsville and Staunton, a distance of approximately 61 miles, to apply as the first order installation. This installation was inspected by the commission in August and September, 1925, after which it was removed from service. The second order by the commission designated the same territory as for the first

order. On December 23, 1925, the C. & O. petitioned the commission asking to substitute that portion of its line between Orange and Gordonsville, Va., which is a connecting line nine miles in length with the Southern on the eastern end of the first ordered territory, and the section between Staunton, Va., and Clifton Forge, on the western end, making a continuous section from Orange to Clifton Forge, a distance of approximately 125 miles of main line. This authority was granted on January 2, 1926, after which it was decided to change to the present type of device; after careful consideration had been given to the numerous other types of train control devices on the market. This work was started in February, and both first and second order sections were completed and placed in service November 1, 1926.

Character of the Line

The territory from Orange to Charlottesville, 30 miles, includes a portion of the Richmond division, and the 95-mile section, Charlottesville to Clifton Forge, is a portion of the Clifton Forge division. Beginning at Orange, the line traverses an open, rolling country with a maximum curvature of 10 deg. at the junction with the Richmond line and a maximum grade of approximately 1 per cent. From Charlottesville to Clifton Forge, the line crosses a mountainous section with numerous curves ranging from 2 to 8 deg. and grades as high as 1.36 per cent. Starting at Charlottesville the line gradually ascends at the rate of approximately 1.0 per cent for a distance of about 22 miles, and after passing through three tunnels, the longest of which is Blue Ridge Tunnel, about 0.75 of a mile in length, descends at the rate of approximately 1.25 per cent for a distance of about 3 miles, then crosses the Shenandoah Valley, a distance of 10 miles, to the foot of the second mountain range. The line again ascends for a distance of about 16 miles to the railroad's highest point between Staunton and Clifton Forge. For the next 42 miles the line passes through four tunnels and

traverses mountainous country to JD interlocking at Clifton Forge, the western end of the territory.

Variable block lengths are based upon a time interval. Probably the first and most important problem was the economic determination of the length of blocks, and the location of the signals. Both operating and signal officers were of the opinion that the old signals between Gordonsville and Staunton were too close together, in many cases less than a mile apart, for the traffic using the line, especially since block signals were 1.5 to 3 miles apart on other sections of the road with



"Head-in" signal at end of siding—Opposing absolute automatic signal in left background

three to four times the traffic. Transportation conditions required that the length of the blocks be determined on a time interval rather than on space interval, using the slowest train on the division as a basis. Observers rode trains over the entire 125 miles and noted the passing time at the mile post as well as at the switches of the passing tracks. From these records the intermediate signals were located. The block lengths varied from 1 to 3 miles, depending upon the distance and grade between passing sidings. By relocating the signals according to this method it was found possible to retire about 60 automatic signals from the old 61-mile installation, and install them on the new 64-mile territory with considerable saving in capital expenditure.

One or more intermediate signals are located between passing tracks depending on the distance. The control for signals is arranged to give a double approach indication for opposing trains approaching a passing track in either direction. The clear control of the head-in signal located a few feet in approach of the passing track switches and the next signal in approach thereto extends to the same point for following moves which is one block in advance of the absolute signal. Where passing tracks are close, one set of intermediate signals are used and are located opposite each other. At such locations the clear control of the opposing absolute signals extends to the center or far end of the passing siding, so that two approaching opposing trains will receive approach indications before passing the absolute signal on entering the block. Where passing sidings are some distance apart, one set of intermediate signals are placed double braking distance apart, in which case the clear control of the absolute signal extends only to its opposing absolute signal.

At the ends of passing tracks the absolute signal, governing the entrance to a block, is located opposite the fouling point, while the head-in signal governing movements into the passing track, is located a few feet in approach of the passing track switch. At yards and junction points where switching is done on the main track, the absolute signals are located outside the yard limits.

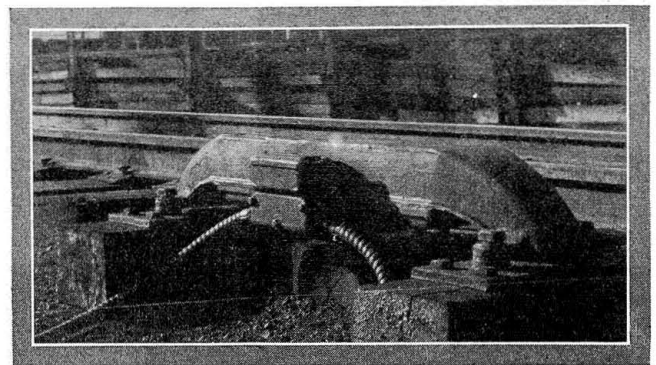
An absolute signal and an automatic signal both mounted on ground masts are shown in an illustration. Each automatic color-light stop and proceed signal has a number plate attached to the mast, while each absolute signal is equipped with a red marker light below the block indication aspect.

Two-indication, color-light dwarf signals are installed at the ends of all passing tracks where absolute signals are installed, and govern train movements from the siding to the main track. At the ends of certain other passing tracks where there are no absolute signals and the distance to the next signal in advance is more than 2,500 ft., an unwound inductor has been installed instead of a dwarf signal. The head-in signals at the entrance of passing tracks are provided with a single-unit light mounted on the mast below the regular signal aspect which gives "yellow under red" indication for train movements into the passing track when the switch is reversed. An absolute signal is also located at the west approach of Blue Ridge tunnel, which is for the purpose of preventing more than one train entering the tunnel at any one time.

Train order signals are in use throughout the train control territory, but they are in no way connected into the train control or automatic signal system.

Two Methods of Power Supply Used

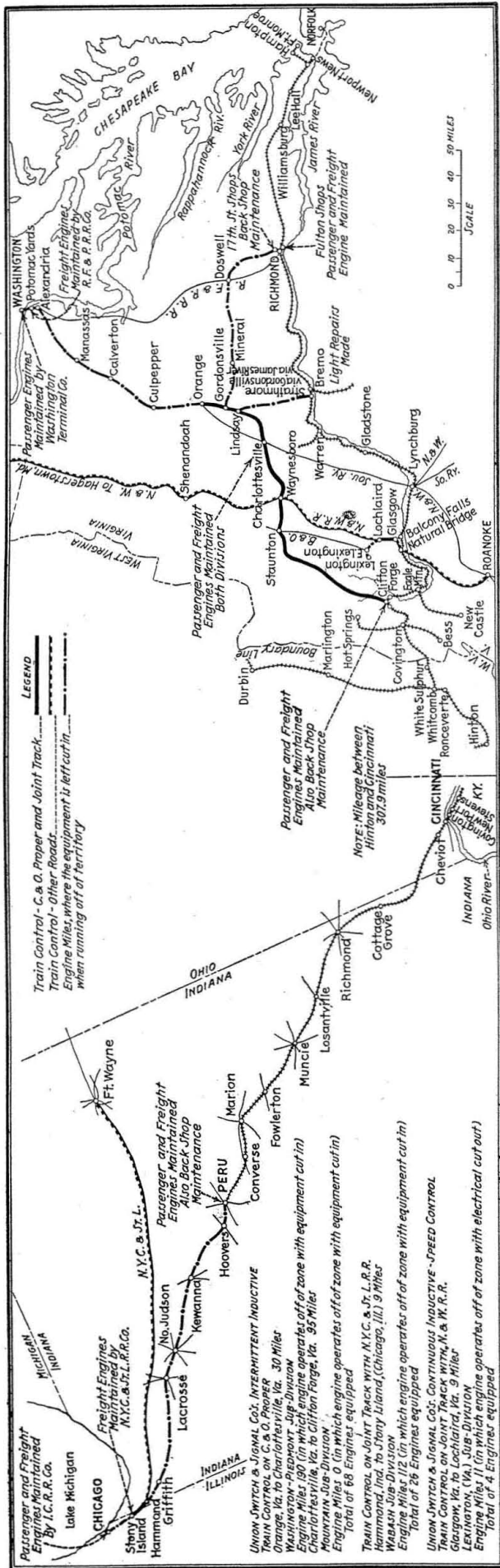
The signals are operated by low voltage d-c. polarized line and neutral track circuits. The signal units are illuminated by 10-volt, 18-watt lamp bulbs operated between 8 to 9 volts. There are, however, some signals located on sharp curves, in which 10-volt 30-watt lamps



Wayside inductor showing flexible conduit connections to junction box

are used with an auxiliary outer lens and a deflecting prism to spread the beam around the curves. The energy for the control relays for the signals, on the 30-mile section Orange to Charlottesville, is supplied from primary batteries, which are also used as standby batteries for the normally a-c. lighted signals, except at some of the interlocking signal locations where a-c. floating charged storage batteries are used. The batteries are housed in concrete battery wells. The track circuits for this section are also operated by primary batteries.

The energy for the control relays for the signals on the 95-mile section, Charlottesville to Clifton Forge, is

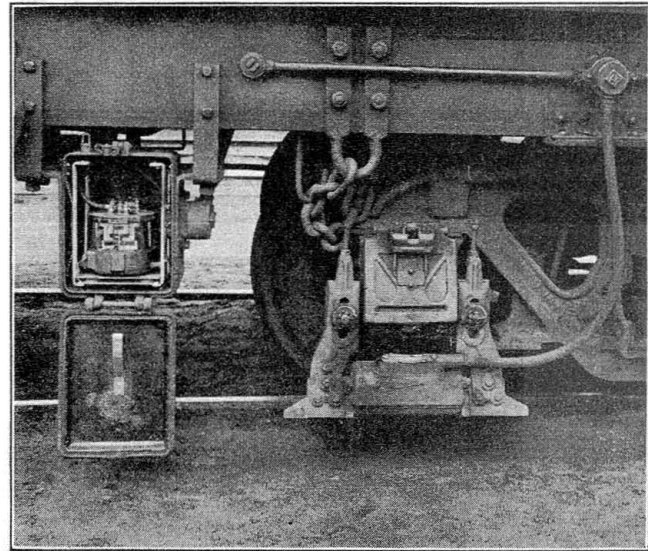


supplied from a-c. floating charged 10-volt storage batteries, which are also used as standby battery for the normally lighted a-c. signals. The storage batteries on this section are housed in metal instrument cases either supporting the signal mast or located on separate foundations adjacent to the signal location. The track circuits on this section are energized by storage battery or primary battery, the primary battery being used for center-fed track circuits only, and are housed in concrete battery wells.

The signals over the whole installation are normally illuminated by a-c. current through "power-off" relays, which automatically connect direct current from either the storage battery or primary battery to the signal lamps when the supply of alternating current fails. The track and line storage batteries on the section west of Charlottesville are charged by mechanical rectifiers. The alternating current for illuminating the signals and charging the batteries is supplied from commercial sources at convenient points along the company's right-of-way, and is distributed by either the single-phase 440-volt line carried on the Western Union pole line, or a single or three-phase 6,600-volt line supported on separate poles, there being about 46 miles of the 6,600-volt line and 79 miles of the 440-volt line.

Special Protection at Switches

Switch indicators are not used. Derails are provided on industrial and certain passing tracks where the grade



Train control relay and engine receiver—Road shocks are nullified by spring suspension for relay

descends towards the main track. At intermediate switches, the switch protection consists of the usual fouling circuits extending to the clearance point, with a shunt box connected to the switch point and derails where used. At ends of passing tracks, the switches and derails are equipped with polarizing switch circuit controllers through which polarized switch repeating relays are controlled. The main line absolute signal is controlled through a neutral and normal polar contact of the relay, while the dwarf signal which governs movements off the passing track, is controlled through a neutral and reverse polar contact of the relay. This arrangement provides the proper selection of the indications of the signals depending on the position of the switch. Where derails are used, whether hand-thrown or pipe-connected to the main track switch, the switch repeating circuits are also controlled through the derail,

to insure that the position of the derail corresponds with the position of the main track switch.

General Description of Train Stop

The Union intermittent inductive train stop system was developed after the Interstate Commerce Commission restored the permissive clause in the specifications on July 18, 1924. After a period of development in the shop and laboratory, an initial installation was made on 20.6 miles of the Chicago division of the New York, Chicago & St. Louis, as described in an article in *Railway Signaling* for May, 1926, page 181. Modifications have since been made, resulting in simplification of, and improvements to the engine device. Installations of this device have also been made on the Pittsburgh & Lake Erie, and the initial installation of the New York, Chicago & St. Louis has been extended over the entire Chicago division.

The roadside element is of the type requiring no roadside energy, and is connected to the signal system to receive the block indication which is transmitted to the engine apparatus.

Roadside Apparatus

The roadside apparatus consists merely of the inert inductor with the necessary wires to connect its coil into the signal system through contacts of the signal relay. No additional relay is required to connect the train stop system into the signal system. The terminals of the inductor coil are connected to the signal control relays in the relay case with No. 9 steel taped cable buried two feet deep in the earth and spaced 7.75 in. apart and so connected through the relay controlling the clear indication of the signal, that it will permit the clear passage of the train when the relay indicates an unoccupied track. No battery or other energy is required for the track element. An illustration shows

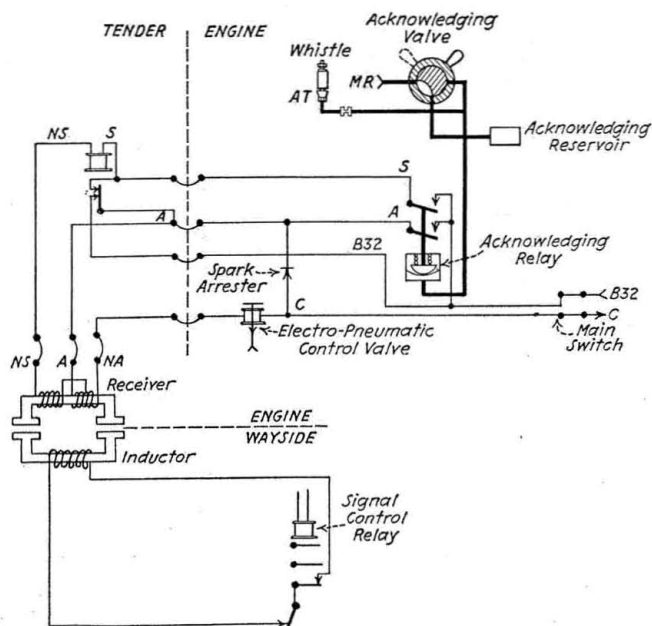


Fig. 1—Wiring diagram of engine equipment

the inductor mounted on the ties with cable connections to the inductor.

The inductor is composed of a series of iron laminations generally U-shaped, but with short legs and large pole pieces. A large coil is formed around the horizontal section which connects the vertical legs of the U. The whole apparatus is protected by a non-magnetic casting having inclined ends forming a structure of a

turtle back section along its longitudinal axis. The complete assembly is 48 in. long over all, 7 in. wide and 7.25 in. high, is placed parallel to the rail on the ends of two long ties with its center 20.75 in. from the gage, and is located approximately 90 ft. in approach of the signal. Substantial iron plates are placed on the ties under the inductor and fastened to the ties by four lag screws. The inductor is bolted to the iron plates. Necessary washers are used to raise it so that the plane of the face of the pole pieces is 2.5 in. above the top of the rail.

Locomotive Apparatus

The engine carries one relay, controlled by circuits through the receiver which is rigidly but adjustably mounted on the trailing journal box of the forward tender truck on the right hand side and so located as to register with the track indicator with a magnetic clearance of 2 in. The brake-applying apparatus comprises special features embodied in a specially-designed engineman's brake valve. The installation is made in such a manner that a stop is produced or the forestalling act required by the enginemen at signals indicating caution, as well as stop. No automatic control is exercised over the train after forestalling, or after the release has been made following the automatic stop, which is in accordance with clause "1b" of the commission's requirements. Some of the locomotives are equipped with additional apparatus to produce a split reduction during a train stop application of the brakes.

The principal elements of the locomotive apparatus are as follows:

- Receiver, installed on the tender truck journal box.
- Modified engineman's brake valve.
- Forestalling valve, reservoir, relay and whistle.
- Split reduction portion.
- Release cock.
- Electro-pneumatic valve.
- Train control relay.
- Spark arrester.
- Source of energy.
- Wiring and piping.

The receiver consists of two coils, one being designated as the primary and the other as the secondary, mounted on a laminated iron bar with pole pieces fastened to each and extending downward. The pole pieces are of the same spacing as those of the track inductor, and register with them when passing above. The windings are incased in a cast aluminum housing, provided with proper outlet for the wires. The receiver attached to the journal box can be adjusted vertically to regulate the height above the track inductor. The bracket carrying the receiver is inclined outward so that the receiver extends slightly beyond the journal box. The standard clearance above the inductor is 2 in., which makes it 4½ in. above the top of the rail.

The engineman's brake valve with automatic braking portions incorporated consists of a modified E.T. brake valve manufactured by the Westinghouse Air Brake Company, known as the H.S.2 brake valve and is applicable to all types of train control manufactured by the Union Switch & Signal Company. Other valves for train control purposes consist of one application valve for controlling the automatic application, one cut-off valve for blanking the brake pipe passage and preventing a manual release during an automatic application, a vent valve which enables the engineman to make a manual quick-action application following an automatic application at any time, or on the second engine of a double-header, and cut-out cock for cutting out the train stop apparatus.

The electro-pneumatic valve is the point of connection between the electrical and the pneumatic apparatus

and is similar in design to that used in railway signaling for many years. It consists of a magnet controlling a poppet valve with a spring to hold it open when the magnet is de-energized. When the device is in the clear position, current from the headlight generator energizes the magnet and closes the poppet valve against the spring pressure, preventing main reservoir pressure from escaping to atmosphere from the faces of the piston controlling the application slide valve. It is located on the rear cab wall at the right of the forestalling relay.

The train control relay is for the purpose of controlling the engine circuits and for initiating the brake application on passing an open track inductor. It is of special construction, with an arrangement of contacts on a single armature designed to control the circuits so as to prevent improper forestalling. Its windings are in series with the windings on the receiver coils and with the winding of the valve magnet, so that any interruption of this circuit tends to cause the relay coils to be de-energized, resulting in an opening of the circuits. After the coil is de-energized, the contact is held open by a spring, until the pick-up circuit is closed by the operation of the forestalling valve. The normal control circuit for this relay is arranged on the "stick principle." The tension of the spring, which opens the relay contact, can be varied by an adjusting screw which is sealed after the final adjustment has been made.

The spark arrester is a special piece of the electrical apparatus connected in the engine circuit to prevent burning the engine relay contact, when the relay is opened, by offering a path of high resistance to current flow in one direction, but a path of low resistance in the other direction. It is connected in parallel with the primary coil of the receiver and mounted in a housing inside the rear cab wall.

The source of energy supply is the headlight turbo-generator located in front of the cab, slightly to the right of the center of the boiler. Current is supplied at 32 volts through a double-pole switch located in the conduit line on the rear cab wall over the gang-way near the forestalling relay and electro-pneumatic valve. No current regulating device is used.

Description of Locomotive Circuits

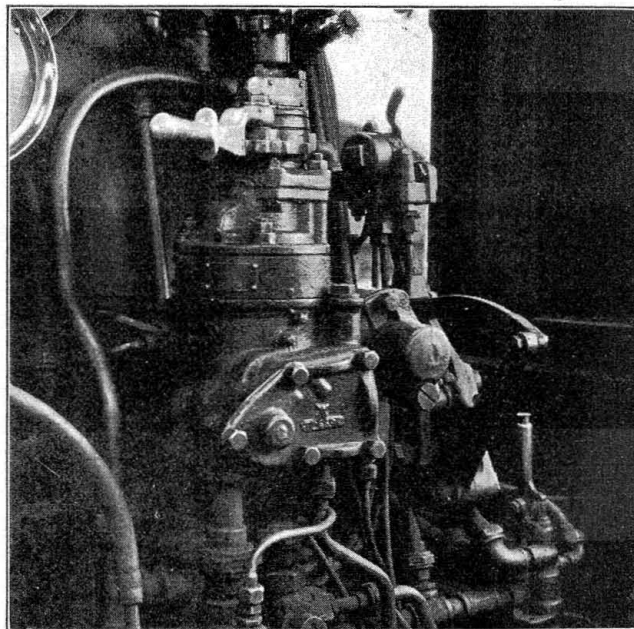
The engine circuits may be divided into two distinct classes; first, those used in retaining the apparatus in its normal or clear position, enabling the engineman to proceed without interruption, and, second, those for the purpose of restoring the engine apparatus to normal position after the brake application has been initiated, or to prevent, by the use of the forestalling valve and relay, a brake application, when one is about to be received as indicated by a signal in the caution or stop position.

Referring to the diagram shown in Fig. 1, the current for the primary circuit flows from *B-32* to one contact point of the stick relay contact arm, to wire *A*, primary winding of the receiver through wire *NA* to electro-pneumatic control valve, to the negative side of battery or common. This is the low resistance or primary circuit and magnetizes the engine receiver.

The secondary circuit is through the upper contact of the stick relay to wire *S*, thence through the operating winding of the stick relay through wire *NS*, through secondary winding of the receiver and part of the primary winding of the receiver to the electro-pneumatic control valve magnet, thence to common. This branch circuit holds the stick relay in the normally energized position shown. It is of high resistance so that the

magnetizing effect of the stick relay current on the receiver is negligible.

The magnetic flux caused by the primary winding is normally constant, but when a receiver passes over a stop inductor, that is, an open-circuited inductor, the receiver flux is offered a path of considerably lower reluctance through the iron inductor core, and the flux rapidly increases as the receiver approaches, and decreases as it recedes, from the inductor. This includes a complete cycle or two alternations of e.m.f. in the receiver secondary through the following circuit. The first half-cycle operating in the direction traced; wire *NS*, operating coil of stick relay, wire *S*, contact of stick relay, wire *A*, part of the primary receiver coil and all of the secondary winding. The induced voltage is high enough to neutralize or to reverse the current through the stick relay causing it to open its contacts. The opening of these contacts de-energizes the receiver primary and the automatic brake valve magnet, and also opens the operating circuit of the stick relay itself. This relay can only be re-energized by operating the acknowledging circuit controller to temporarily connect energy to the operating coil of the relay via wire *S*. The greater the rate of train movement, the greater will be the induced voltage for de-energizing the stick relay.



The Type HS-2 engineman's brake valve is used
Note acknowledging lever at right of valve head

At speeds less than 1.25 miles an hour the relay may not open.

When a receiver passes a closed circuited inductor magnetic action is similar except that current induced in the short circuited inductor winding opposes a change of flux in the magnetic circuit consisting of the inductor and receiver, to such an extent that the voltage induced in the receiver secondary winding is too small to open the stick relay.

Operation of System

When passing an inductor whose coil winding is closed through the relay of the signal, as would be the case when the block is clear, the counter-electromotive force generated in the secondary of the engine circuit is so slight that the train control relay will not open, and the train will proceed without interruption. When passing an inductor whose coil winding is open on account of the signal being at stop or from any

other cause, the counter-electromotive force generated in the secondary circuit is sufficient to cause the relay to open, thus opening the circuit to the electro-pneumatic valve.

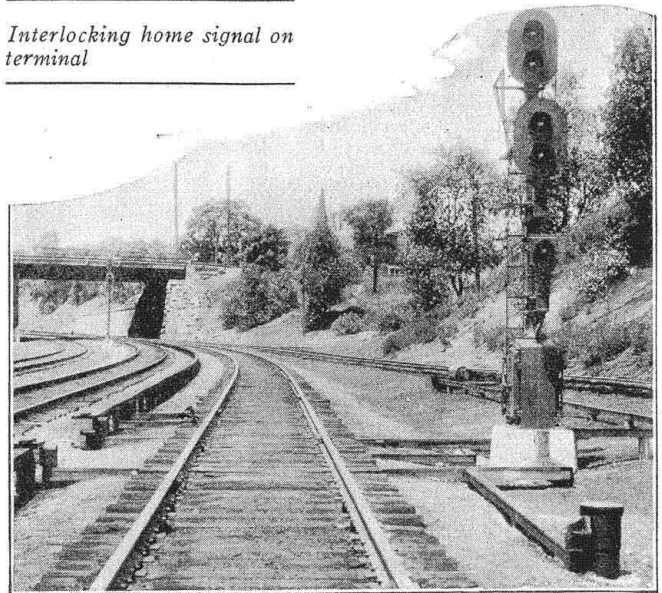
When the train has stopped, in order to effect a release of the device, it is necessary, first, to place the brake valve in lap position, second, to move the forestalling valve to the forestalling position, which restores the electrical part of the apparatus to normal, picking up the electro-pneumatic valve and third, to get out on the ground to operate the release cock to the reset position, allowing it to remain there for several seconds, after which time the pressure is restored to the face of the piston of the application slide valve, moving it to the normal position and restoring the device to normal. The release cock may then be placed normal, after which the brakes may be released in the usual manner and the train proceed without restriction. If the reset cock is left, by design or neglect, in the reverse position, the face of the piston controlling the application valve will be again vented to atmosphere when the brake valve handle is moved to the running or release positions so that the apparatus will not assume the clear position.

If the engine man is alert, and desires to avoid an automatic stop at a signal displaying an "approach" or "stop then proceed" indication, he may operate the forestalling valve which permits air to pass from the forestalling reservoirs to the diaphragms of the pneumatic forestalling relay. In this way the contacts of this relay are closed, and as there is a timing element of about 15 sec. on this relay, it will remain closed for that period, giving ample time to forestall when approaching an open-circuited inductor. While the engine relay will always be opened when passing a track inductor in the open-circuited condition, it closes in a very short interval, less than the period of time required for the action of the electro-pneumatic valve, and there will be no brake application initiated.

Maintenance and Inspection

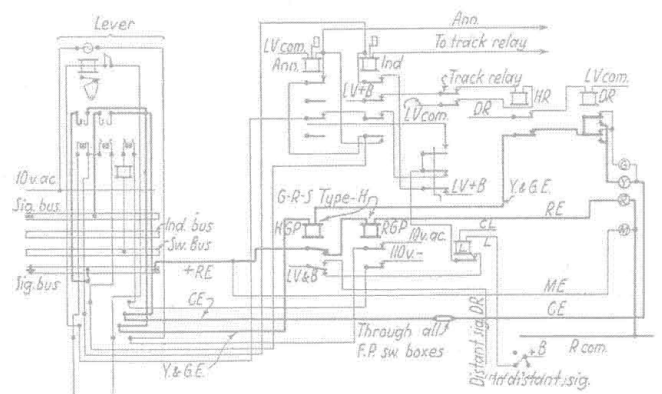
The roadside apparatus is maintained and inspected by the regular signal department forces. On the 30-mile section east of Charlottesville it is taken care of by two maintainers and two helpers; on the 95-mile section west of Charlottesville, there are five maintainers and four helpers. The roadside inspection and tests consist of gaging the inductors for proper gage and alignment semi-monthly, testing the integrity of the inductor circuits with a meter and portable dry cell once each month, and testing the insulation resistance of the inductor circuits to ground every three months, and making a monthly service test on each inductor. In making the monthly service test, a car equipped with train control apparatus is attached to one of the regular express trains. An observer rides in the car, which is usually located near the end of the train, and observes the operation of the apparatus when passing over each inductor. Reports of the results of these tests are forwarded to the supervisor and a copy is sent to the superintendent of telegraph and signals for his information and record.

Interlocking home signal on terminal



G. N. Replaces Semaphores With Color-Light Signals

DURING 1927, the Great Northern replaced all of the semaphore signaling on its four-track line between St. Paul, Minn., and Minneapolis with color-light signals. Two of these tracks are used normally for freight service and the other two for passenger service. The passenger tracks provide the most direct connection between the Union stations in the two cities and, in addition to the Great Northern, are used by the Northern Pacific, the Chicago & North Western, the Chicago, St. Paul, Minneapolis & Omaha, the Chicago Great Western and the Chicago, Burlington & Quincy. There are five electrical and one mechanical interlocking plants within the



Interlocking signal control circuit showing special lamp indicating relays and control in heavy lines

ten-mile section, these plants governing all four tracks. The passenger tracks only are equipped with automatic signals.

The signaling installed in 1908 was all of the semaphore type, these automatic signals being among the first to be operated with the three-position upper-quadrant aspect. The new color-light signal heads were mounted on the old semaphore signal masts. Clearance restrictions made it impossible to mount these signal heads at the standard height of 12 ft.



Interlocking tower at Jacksonville, Fla.