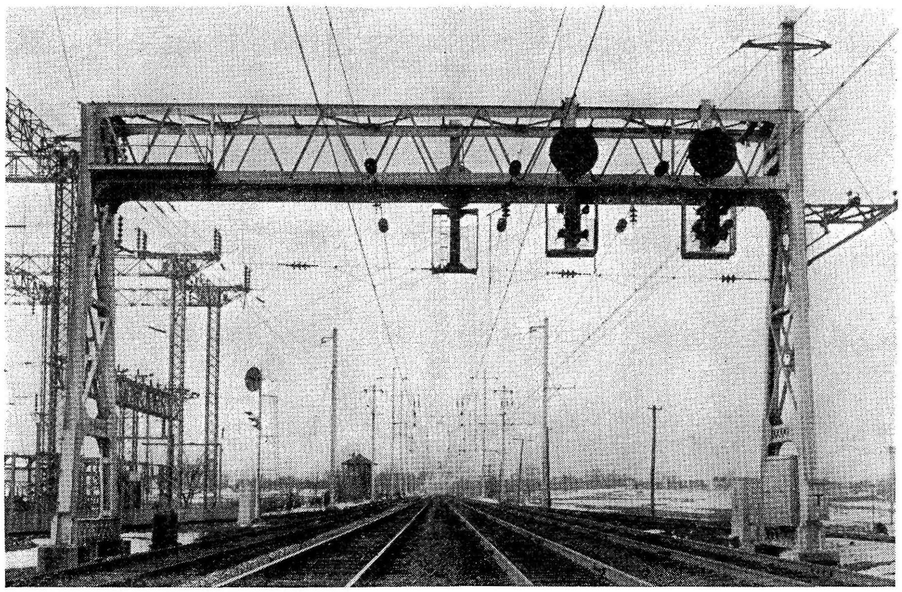
Railway Signaling

Coded Track-Circuit Signaling on the Pennsylvania



Home-signal bridge at Davis interlocking on three-track territory

New system controls wayside automatic signals as well as cab signals without the use of line wires

As A PART of the improvement incident to the electrification of the line between Wilmington, Del., and Washington, D.C., the Pennsylvania not only rearranged the automatic block signal system, using position-light signals spaced for maximum train speeds of 90 miles an hour, but, of special interest, the new coded track-circuit system of control was provided, by means of which the wayside signals, as well as the continuously-controlled cab signals, are controlled without the use of line wires. This new system of control was developed on the Pennsylvania and has been tested in regular service on short sections for more than two years, but the Wilmington-Washington project is the first extensive installation to be placed in service. With the completion of this project in April of this year, the Pennsylvania is equipped for electrical operation of trains between New York and Washington, the entire territory being provided with modern position-light wayside automatic signals and cab signaling.

The line between Wilmington and Washington, 109 miles, consists of sections of two-, three- and four-track railroad, including 314 track miles of signaled main line. Of this track mileage, 18 track miles are signaled for either-direction train operation; for example, between Ragan and Davis there are 9.1 miles of three-track road with the center track signaled for either-direction operation and each of the two outside tracks signaled for one direction.

Interlockings at Junctions

An interlocking is provided at each of the junctions where the track layout changes from a certain number of tracks to another number, a total of 27 interlockings being included in this territory. At some of these plants the turnouts and crossovers were changed to accommodate higher train speeds, thus requiring changes in the interlockings and respacing of the home and distant signals.

The signaling system was replaced practically in its entirety. All semaphores were discarded, but where position-light signals were previously in service these were rehabilitated and used in other locations, so that position-light signals are now provided not only for automatic blocks but also for interlocking signals.

In the new arrangement, the automatic blocks average 8,000 ft. long with some variations to adjust for overall distances between interlockings. This spacing is based on maximum train speeds of 90 m.p.h., using three-aspect, two-block signaling. The intermediate automatic block signals are mounted on the new beam bridges which form a part of the "H" structure for supporting the catenary and for carrying the high-voltage power-distribution circuits for propulsion current and for signal supply. At interlockings, the home signals are mounted on heavy anchor-type bridges which act as anchors for the catenary.

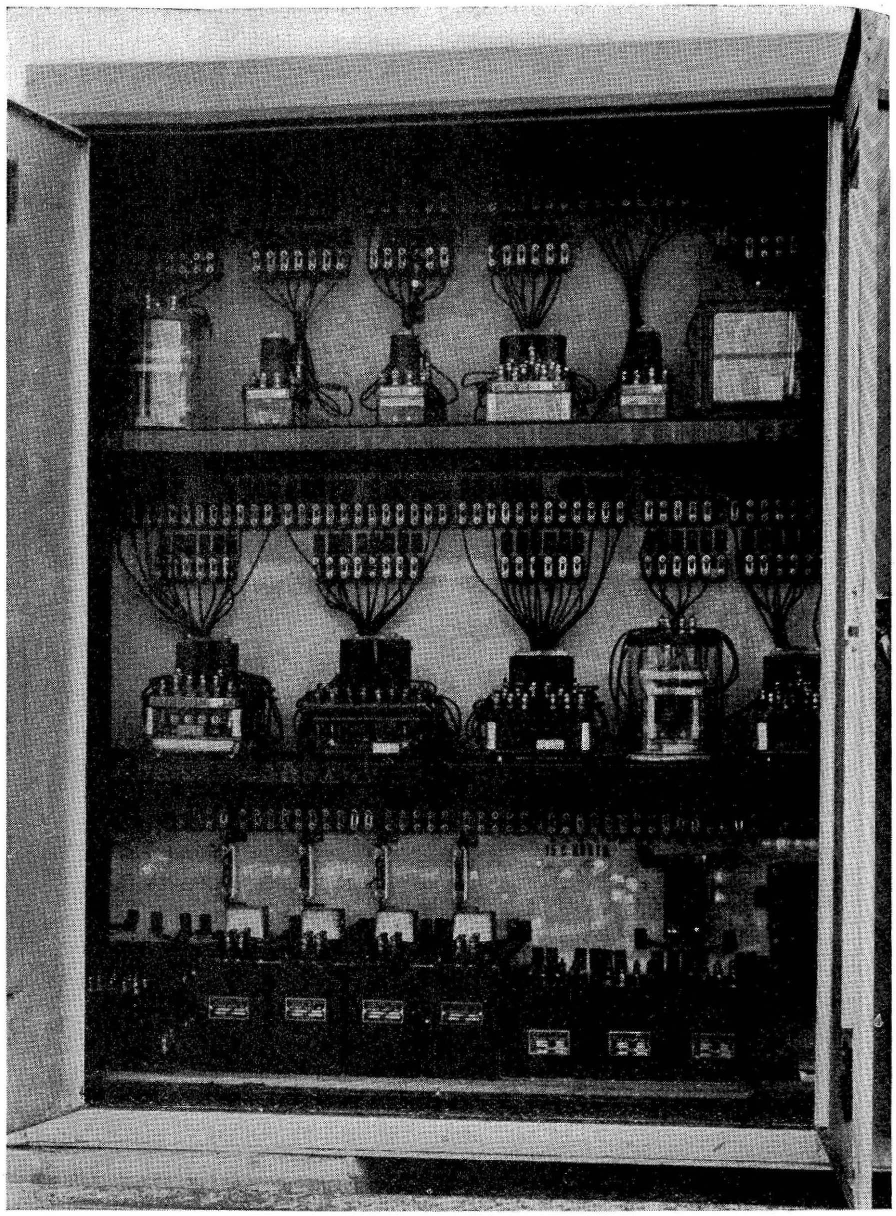
As the propulsion current is 25 cycle, it was necessary to use a different frequency for the signal track circuits in order to prevent any interference. Therefore, 100-cycle current was adopted for the track circuits which, of course, necessitated an entirely new 100-cycle power system for the signaling, separate from the propulsion power supply system. The track circuits are of the double-rail type, using impedance bonds of 200-amp. per rail capacity, with a 4-ohm bond at the feed end and a 1-ohm bond at the relay end. These impedance bonds are so constructed that the 25-cycle propulsion current will flow through but the 100-cycle track circuit current will not. Each impedance bond is housed in a metal case located between the rails, which fits down between the ties at normal tie spacing.

The coded track-circuit control system is an adaptation of the continuously-controlled coded cab-signaling system,* which has been used quite extensively on the Pennsylvania for several years, but on the installation in service prior to the Wilmington-Washington project, a continuously-flowing current was used on the track circuit to control the wayside signals. In the new adaptation of the code control system, the coded impulses, formerly used for the control of the cab signaling only, are now used also for the control of the wayside signals, thus eliminating the extra provisions for a separate circuit, and, of greater importance, eliminating the need for line control circuits, except in the vicinity of interlockings.

Interrupted 100-cycle energy is fed to the track circuit through the code transmitter. This instrument, which operates continuously, includes a synchronous motor, driving a set of gears which operate a shaft at 15 r.p.m. On this shaft is a set of two or three cams, each with a different number of equally spaced depressions in the periphery. Each contact-operating arm bears on one of the cams, and thereby regulates the frequency of impulses transmitted. An impulse frequency of 180 per minute is transmitted to control a "clear" aspect, with 75 for "approach," and, when used, 120 for the "approach restricting" aspect.

Selections of Codes to be Sent

The selection of the code cycles to be sent out at the feed end of a track circuit, to control the respective aspects of the signal in the rear, is effected by circuits controlled through relays, as shown in Fig. 1 which represents the conditions when the 180 code is being sent out. The track transformer is fed by a circuit starting with "110 volt" through the "180" contact on the code transmitter CT and then through front contacts of relays H, BSA and FSA. As will be explained later, the H relay controls the proceed aspect of the signal shown on the diagram, and relays FSA and BSA are slow-acting relays which are normally held in the picked-up position by circuits through the contacts of the code following relay TR.



On the top shelf the code-following relay is at the left end and the code-transmitter at the right end, see page 250 for explanation of other apparatus shown

Code cycles at the rate of 75 per minute are fed to the track transformer and out over the track circuit to the rear when the block protected by the signal shown is occupied; in other words, when the code-following relay ceases to operate, causing relays FSA and BSA to be released. Under this condition, the wayside signal at the location shown indicates "stop and then proceed" but nevertheless the 75 code cycle must be sent out on the track circuit to the rear to control the signal in the rear to display an "approach" aspect, and, likewise, to control the cab signal on an approaching locomotive to give an "approach" indication, while a train is in the block approaching a wayside signal indicating "stop and then proceed."

Regulation of the 100-cycle current used for feeding the code impulses to each track circuit is accomplished by a W-10 transformer and a reactive impedance. The normal voltage of the 100-cycle current on the rails at the feed end ranges from 2 to 10 volts. In order to provide for proper operation of the cab signaling, the track-circuit feed is adjusted to

*For description of coded system of train stop and cab signaling, see page 125 of April, 1928, issue of *Railway Signaling*.

provide about 2.0 amp. minimum axle current, this being the reading when a train first occupies the entering end of the track circuit. This current increases as the train proceeds toward the feed end, the current, of course, being limited by means of the reactive impedance.

Code-Receiving Equipment

On an approaching locomotive, the codes are picked up inductively by the receiving apparatus, and are then amplified, decoded, and utilized in the usual manner to control the cab signals. As previously indicated the new feature of the installation described in this article is that these same code impulses on the rails are used to control also the wayside signals. This result is accomplished by using apparatus of the same general character as that on a locomotive, except that in the case of the wayside, signals the code impulses need not be picked up inductively, but are conducted from the rails at the receiving end of the track circuit by wire connections to a resonate transformer unit which, through a rectifier, feeds an 18.5-ohm d-c. relay TR, known as the code-following track relay, which picks up and drops for each interruption of the code, thus being constantly in operation except when the track circuit is occupied. When no energy is being received by relay TR, its back contacts are held closed by spring pressure.

The circuits in Fig. 1 show the condition of the apparatus when 180 code cycles are being received per minute, thus resulting in the display of a "clear" aspect on the automatic signal. The control relay H is energized, it having been picked up by battery feeding from battery marked "B" through a front point of the second contact arm of relay TR and through a front point of the second contact arm of relay BSA; and after relay H is energized, it is held up by a stick circuit through a front point of its own second contact arm connected to "B."

The energy for feeding the lights in the vertical row of the position-light signal to give a "clear" aspect is fed from +E through the hinge of the third contact of relay H, out at a front point to the hinge of the second contact arm of relay AJ and out on a front point to the signal.

This introduces relay AJ into the control, and its control will now be explained. As will be noted, AJ is fed from the decoding unit 180 DU, consisting of a resonate transformer unit which incorporates a transformer, a capacitor and a set of rectifiers so arranged as to select between 180 and 75 code cycles per minute, relay AJ being energized on 180 code cycles but de-energized when 75 code cycles are being received. Returning now to the feed for the different signal aspects, it will be seen that when relay AJ is energized, a circuit through its second contact arm will feed to the front contact to light the "clear" aspect lamps, but when de-energized the back point feeds to the lamps in the diagonal line, thus giving the "approach" aspect. Relay AJ is not involved in the control of the "stop and then proceed" aspect, these lights being fed through a back point on the third contact arm of relay H, and this relay is de-energized when relay BSA is released. Referring to the sketch of the lamp connections, it will be seen that the marker lamp, mounted below the signal unit, is lighted simultaneously with the lamps in the horizontal row, thus completing the "stop and then proceed" aspect. The lamp in the

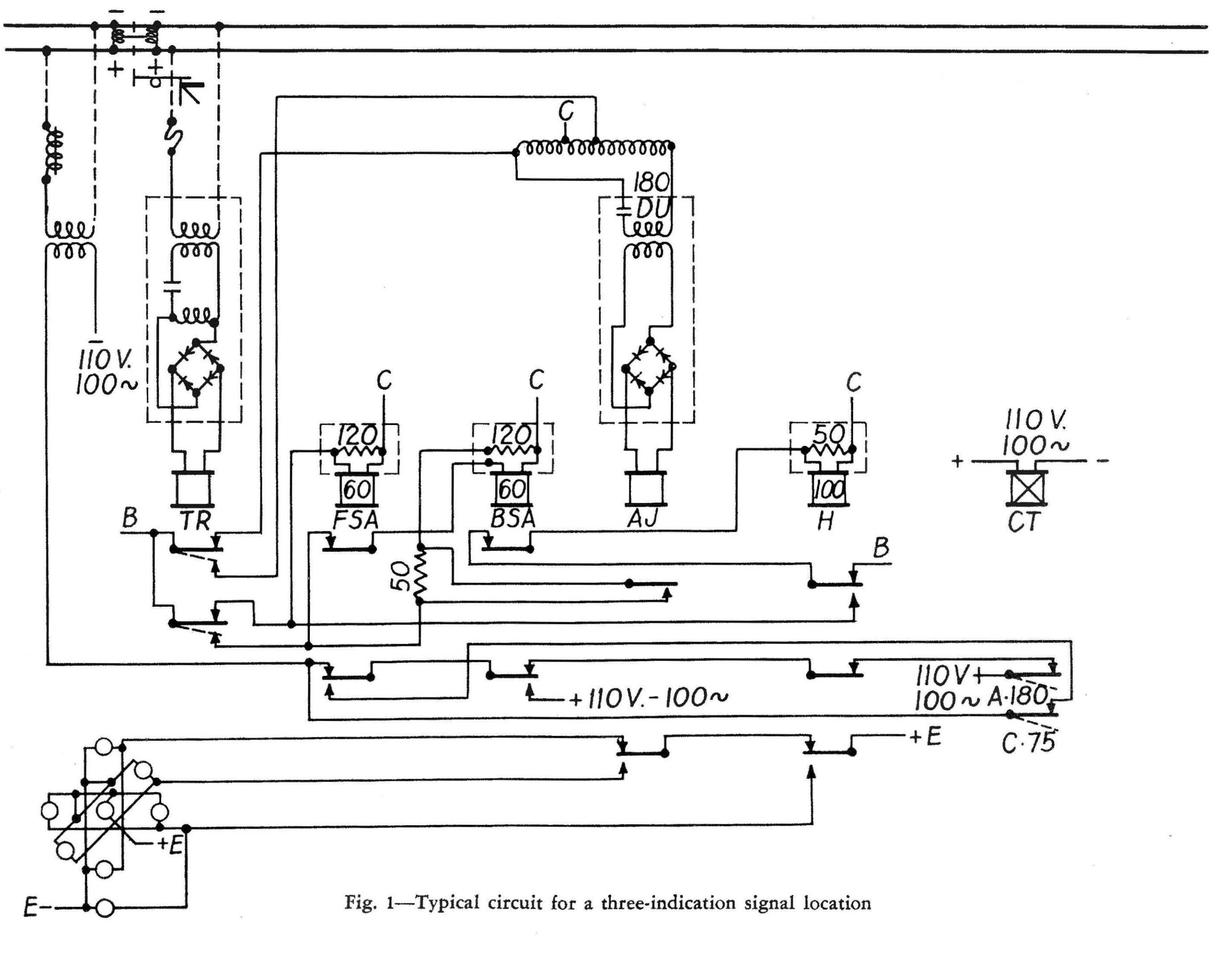


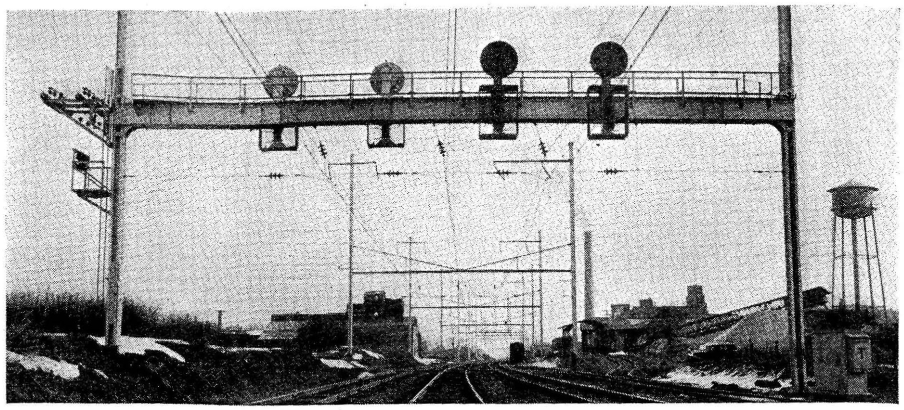
Fig. 1—Typical circuit for a three-indication signal location

central position of the signal unit is lighted constantly.

Receipt of Code Beyond Relay TR

The control of both the BSA and the FSA come from the code-following relay TR, which, as mentioned before, is energized and de-energized to follow the number of code cycles being received. Relay FSA is energized by a circuit through the front point of the second contact arm of relay TR so that the first time that relay TR is energized, relay FSA picks up. However, relay FSA does not drop its contacts while relay TR is released and picked up again to follow the code cycles, because relay FSA has slow-release characteristics which retain it in the energized position to bridge the interruption. Thus the front contacts of relay FSA remain closed as long as the code-following relay operates normally on either 180 or 75 code cycles.

Now referring to relay BSA, it will be seen that it is controlled through a front contact of relay FSA and a back point of the second contact arm of relay TR. Therefore, after relay FSA is energized, the first time that relay TR is de-energized on a code cycle, relay BSA is picked up, and as it has slow-acting release characteristics, by virtue of a resistor snub circuit connected across its coils, its front contact will remain closed as long as the code-following relay operates normally on either 180 or 75 code cycles.



Automatic block signal bridge in three-track territory middle track signaled for both directions

Recapitulating, it will be seen that when either the 180 or the 75 code is being received, the code-following relay TR is operating and relays FSA and BSA are energized. Therefore, relay H is energized and the selection between the "clear" aspect and the "approach" aspect is effected depending on whether relay AJ is energized, it being picked up only when 180 code is being received.

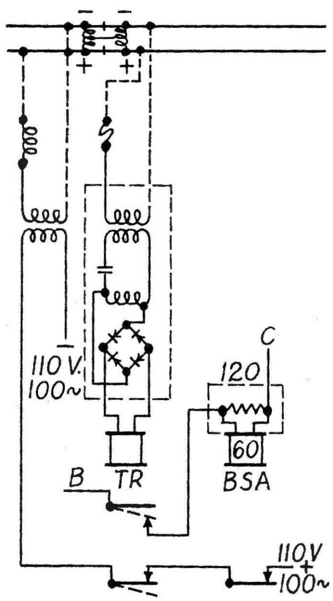


Fig. 2—Circuit plan for an ordinary cut-section location

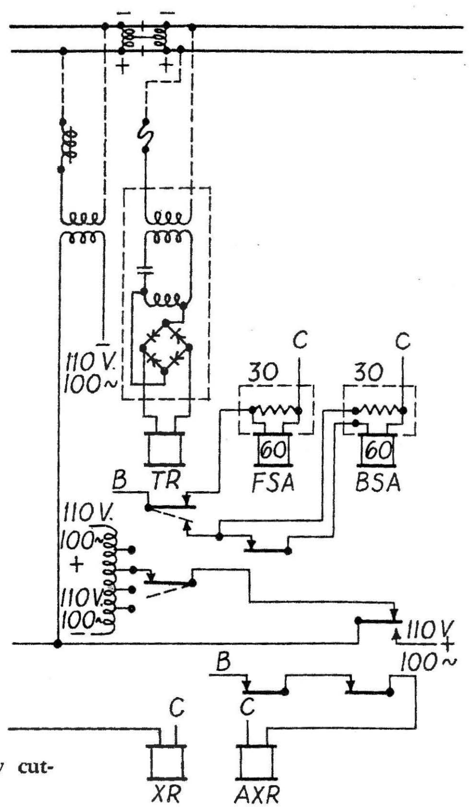


Fig. 3—Steady-energy cut-section for highway crossing signal location XR and AXR are the two units of an interlocking relay

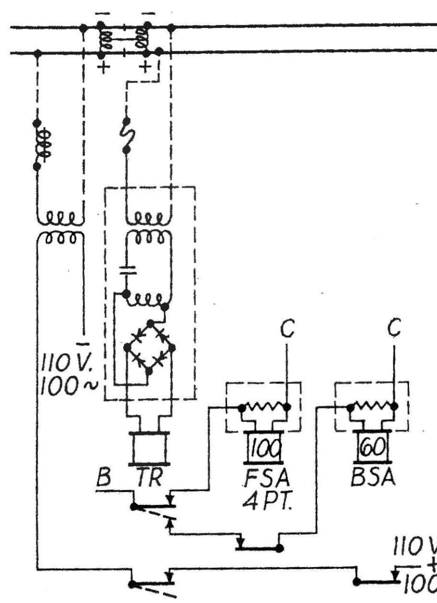


Fig. 4—Cut-section for start of highway-crossing control or for approach locking

Lock-Out or Check Features

Following is the explanation of other functions of the slow-acting relay FSA and BSA in affording protection in case of broken-down insulation in an insulated rail joint or in case steady flowing foreign alternating current is received.

If the operation of the code-following relay TR is stopped with its front contacts closed, relay BSA will be released which, as explained above, will cause relay H to be de-energized, resulting in the display of a "stop and then proceed" aspect. Furthermore, with relay FSA and relay BSA down, steady flowing 100-cycle current is fed to the track transformer feeding out over the track circuit to the rear, thus causing the signal in the rear also to display the "stop and then proceed" aspect.

As a further precaution to assure a prompt release of relay BSA, it will be noted that a 50-ohm resistor in

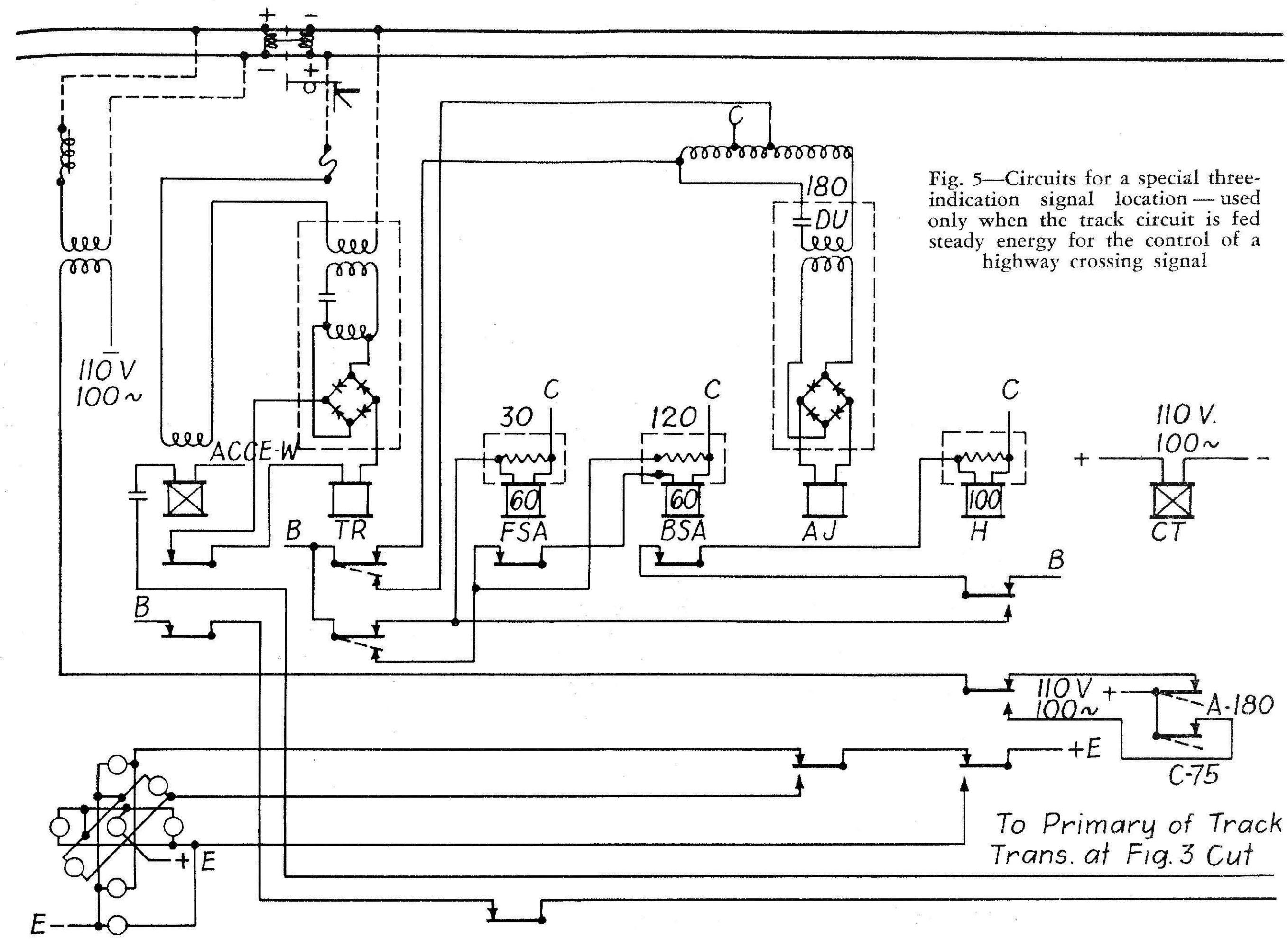


Fig. 5—Circuits for a special three-indication signal location — used only when the track circuit is fed steady energy for the control of a highway crossing signal

series with the snub circuit of BSA is shunted by a back contact of relay AJ. This relay AJ is released at all times except when 180 code cycles is being received. Therefore, by removing the shunt from the 50-ohm resistor when relay AJ picks up, the snubbing resistor of relay BSA is partially shorted, causing it to release more quickly when the 180 code is being received. The relay H, which has its stick circuit controlled through a front contact of relay BSA, has slow-acting characteristics sufficient to effect correct operation.

Use of Cut Sections and Crossing Signal Control

In some instances the track circuits extend the full length of an automatic block, but where the block is more than 6,000 ft. long, or where highway crossing signals are involved, cut-sections are required. At a cut-section, the code-following track relay of the first track circuit merely codes the track-circuit energy feed to the second section. In the diagram, Fig. 2, the resonant transformer operates the relay TR, causing it to open and close according to the number of code cycles being received. Therefore, the second front contact of this relay is used to repeat the number of code cycles to the transformer which feeds the track section to the rear. Slow-acting relay BSA is used to provide protection in case of a broken-down insulated rail joint, as explained previously. However, even if relay BSA were not provided, a steady current holding relay TR energized, would result in a steady current being sent to the track circuit in the rear, which would effect the display of a "stop and then proceed" aspect, as explained before.

Where a highway crossing signal is located in a block in coded track-circuit control territory, a cut section is required, as usual, so that the operation of the highway crossing signal will be stopped after a train has passed the crossing. The track circuit in the rear of the cut-section is supplied with energy which will not give a proceed indication. One means of controlling the highway crossing signal is to feed steady energy to the portion of the block in the rear of the cut-section while the train occupies that portion of the block ahead of the cut. (See Fig. 3.) Steady energy will pick up the code-following track relay at the entrance to the block when the train clears the cut-section and will hold the front contact continuously closed. The steadily-energized code-following track relay will continue to hold the wayside signal at the entrance to the block at "stop and proceed," the same as obtained with a steadily de-energized relay. The circuit arrangement at a cut section for the start of the control of a highway crossing signal or approach locking is shown in Fig. 4, and the typical circuits at a signal location when the track circuit is fed steady energy for the control of a highway crossing signal, are shown in Fig. 5.

Steady energy is used in this manner merely to guarantee that a definite section of track is unoccupied even though the remaining portion of the block may be occupied. This affords a very simple means of operating highway crossing signals in the coded track-circuit control system by what is called "steady-energy" track-circuit detection.

Provision for Future Installation

A considerable number of the crossings of streets and highways with the tracks in this territory were already protected by standard flashing-light crossing signals, and in making the rearrangements of the signaling, either a cut-section or a signal was located at each crossing not now protected so that a minimum expense will be occasioned in case it is necessary to install an automatically-controlled crossing signal at any of these locations.

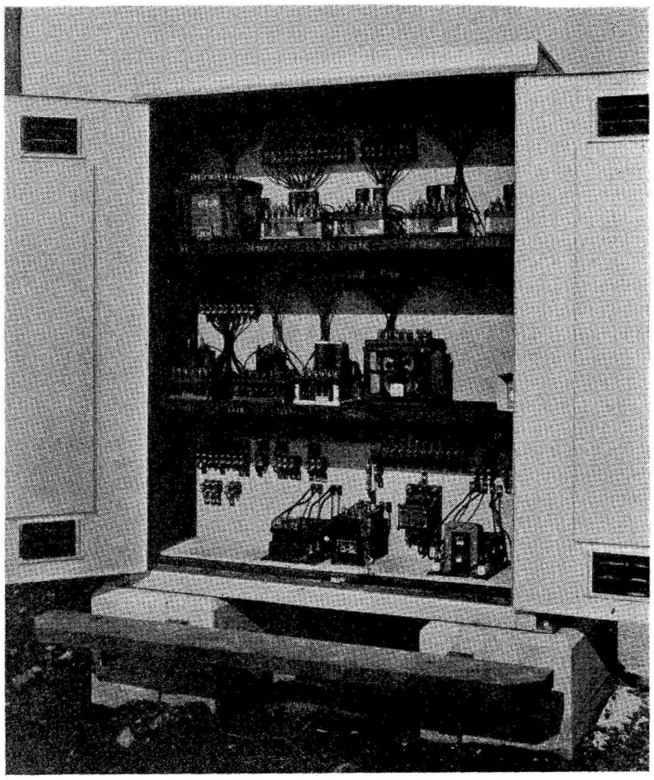
The coded system of control for wayside and cab signaling, as explained in this article, was developed through the co-operation of representatives of the signal department of the Pennsylvania and the Union Switch & Signal Company, the wayside signals, relays and other instruments, as well as the cab-signal apparatus, having been furnished by the Union Company.

Signal Power Distribution

The power for the signal system is distributed at 6,600 volts single-phase on two No. 0 bare hard-drawn copper line wires run on crossarms on the H-fixtures for the catenary supports. At each automatic signal location there is a 1.5 kv.a line transformer to reduce the voltage to 110, and at a cut section a 0.75-kv.a transformer is used. The 110-volt circuit entering the instrument case is run to an automatic circuit breaker, used in lieu of fuses. A 110/17 volt transformer is provided to supply current to the lamps in the position-light signals, a separate 4-ohm adjustable resistance unit being provided to adjust the feed to the lamps for each aspect so as to secure uniform intensity. Each signal lamp is rated at 11.5 volts, 9 watts, and is normally fed at about 11.5 volts. The d-c. relays at each location are fed from a rectifier, an RG-30 rectifier being used at double-track locations and an RG-60 where the demands are greater.

Sheet Metal Instrument Housings

The relays and other instruments at each location are housed in standard welded sheet-metal cases, each of which is 58 in. wide, 20 in. deep and 58 in. high, the top being sloped to the rear. The doors at the front are hinged at the end of the case. The rear of the case is made up of removable panels of sheet metal, held in place by machined stud screws. A wiring space at the rear is formed by setting the false back, made of insulating board, 6 in. from the rear of the case. In the front of the case the shelves are about 14 in. deep. The two top shelves for the relays are made of sheet metal and are covered with rubber matting, while the bottom of the case, where the transformers are located, is floored with a piece of insulating board.



Typical relay cabinet showing foundation and step arrangement

In each shelf space one or two rows of bakelite-based multiple-unit type terminals are mounted on the insulating wall panel and flexible jumpers extend to the relays. The incoming wires are brought up through the wiring space at the rear and each wire is brought out through a separate hole to its terminal, the wire tag being set against the panel above the terminal.

The wires leading to the resonate transformers, track transformers and rectifiers on the bottom shelf are, in most instances, run directly to the terminals on the instruments.

In one of the accompanying illustrations (pg. 246) showing the interior of a case at a location on three-track territory, the tall cylindrically-shaped relay at the left end of the top shelf is a code-following relay, designated TR in the circuit diagrams. The next four relays on this shelf, reading from left to right, are FSA, BSA, H and AJ. As explained previously, these are all d-c. instruments. The large square shaped instrument at the right end of this top shelf is a code transmitter designated as CT in the diagrams.

The relays in the second shelf are of a similar character used for a different signal. In the bottom shelf a rectifier is located at the left end and there are four resonate transformer units and three Type W-10 transformers with two track reactances mounted on the wall.

Each case is set on two concrete foundations, one at each end, and a concrete wall, made to match up with the opening to the wire space at the rear of the case, extends between the two foundations. Pipe conduits, placed in this wall when it was poured, extend from below the ground line up into the bottom of the wiring space. At the front of the case, an angle iron, extending from each foundation, supports a plank platform for a man to stand on when inspecting the instruments.

The circuits coming into each case are all in parkway cable which is brought up through the pipe conduits. The outer protection on each cable is removed, and the end of this protection sealed, the openings around the cables in the pipes being cemented.

As a part of the electrification improvements, the wayside pole lines were eliminated and a six-way tile duct-line, encased in concrete, was constructed along the entire territory to carry the cables for the telegraph and telephone circuits, as well as signal circuits, where used in the vicinity of interlockings. For a description of the construction of the duct line, see page 215 of *Railway Signaling* for June, 1931.

The connections between the instrument cases and the rails are in parkway cable, a four-conductor cable used for four adjacent rail ends extending to an iron junction box located near one joint. This box is mounted on a two-inch pipe about two feet

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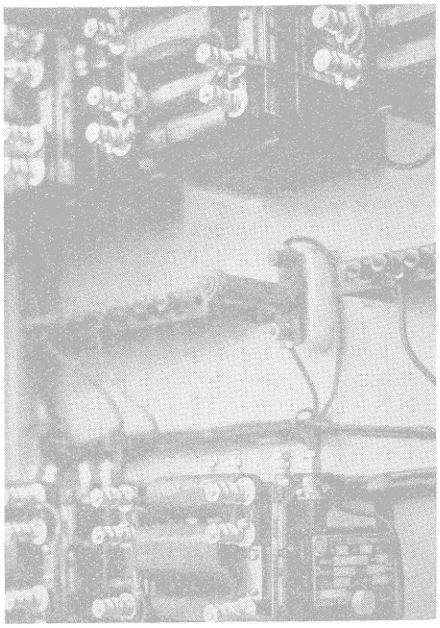


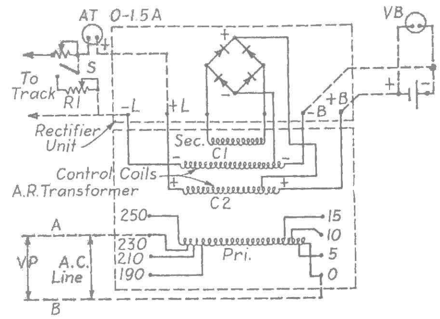
Closeup of rectifiers and fittings

stand in the "stop" position so that the only current normally required is for the line control circuit. The signal mechanisms are of the semaphore type and in clearing from zero to 90 deg. with 8 volts across the motor terminals the current input to the signal is about 2.35 amp. of which 2.25 amp. comes from the eight cells connected to the rectifier and 0.10 amp. from the rectifier. The other 8 cells discharge at the rate of 2.35 amperes while the signal is clearing. While the signal is in the clear position, the hold-clear coils take 19 m.a. with 14 volts at the coil terminals, the reading at the battery being 14.2 volts, 12 m.a., and 7.2 volts, 7 m.a. at the rectifier.

At each of the six operative signals electric lamps were provided to replace the oil lamps, a General Railway Signal lighting transformer being installed. Each lamp is rated at 10 watts, 10 volts. The lamps are lighted constantly. No standby energy supply is provided for the lights.

Battery Life Increased

During the three years that this plant was operated directly from primary battery, the average life of three cells of track battery on each track circuit was five months, the 16 cells on each signal about 7 months, and the 8-cell control battery at the central point 12 months. The a-c. primary system of power supply has not been in service a sufficient length of time to determine the life of the battery but for comparison the track cells are now normally supplying 7 m.a., contrasted with 135 m.a. before

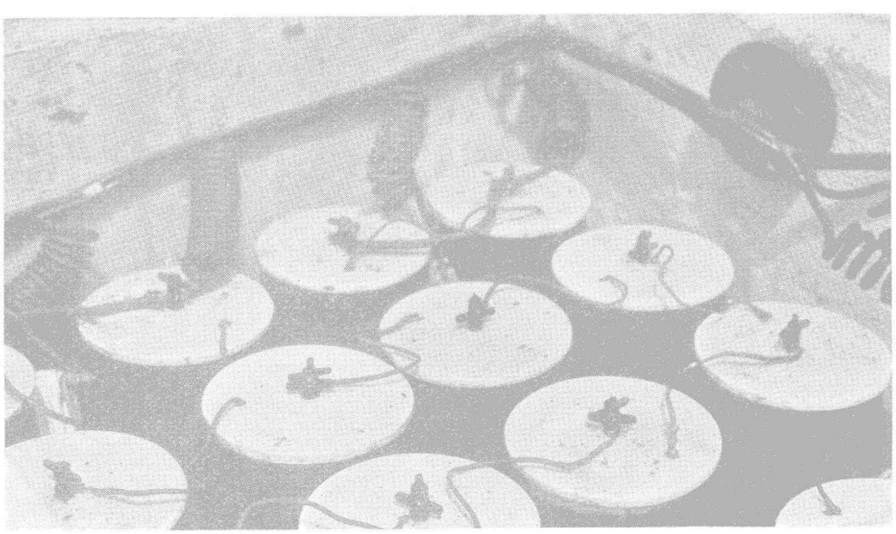


Rectifier setup for track circuit

the recent installation was made, and the entire train-shunt load is now carried by the rectifier.

In November, 1934, the changeover to the a-c. primary system was completed. This changeover cost $1,450 complete and it is estimated that the total savings will amount to at least 25 per cent of the total investment.

The construction of this interlocking, as well as the change in power-supply system, was planned and installed by signal forces of the Missouri Pacific.



One of the 16-cell batteries housed in a concrete box

Code Signal System

(Continued from page 250)

long with a flanged base at the bottom to support it, and also to eliminate sharp edges which might injure the cable covering. In the junction box, the four-conductor cable terminates on four standard terminals. From one of these terminals, a standard flexible track connection extends to the rail. From each of the other three terminals, a single-conductor parkway cable is run to an elastic bootleg riser at each of the other three rail ends, dossert connectors being used to connect the cable conductor to the stranded connection which extends to the rail. In each instance, the outer protection of the cable is removed only a short space, and the connection is pushed back down in the riser, and, when complete, the extra space in the riser is filled with sand.

The parkway cables extending from the instrument case to the signals and line transformers are run in brackets in the channel of the legs of the catenary structures.

The Wilmington to Washington electrification program, including the new signaling and interlocking changes, was financed as a Federal Government, P.W.A. project, being handled by Pennsylvania railroad forces but by an organization assembled especially for this purpose. Practically all of the men employed on this project were furloughed Pennsylvania employees from all parts of the system, as many as 2,243 men having been employed in the signal and communication, engineering and construction forces during the peak.

The installation of the duct line and other preliminary work was started early in 1933. Practically all of the foundations for instrument cases were poured in place from mixers on work trains. The instrument cases were wired at central locations and distributed by work trains, the instruments being set in place later.

The mounting of the signals and the installation of cables had to be co-ordinated with the progress of the electrification program, and all changeovers, from the old signaling system to the new, had to be carried on under heavy traffic. A crew of 12 to 20 men or more was assigned to a territory of six to eight miles. When everything was complete, ready for the cut over, a separate testing crew made a complete inspection and test of all the apparatus and its operation. Then the section was cut in service and turned over to the maintenance forces.