

Pennsylvania installation on 110 miles of double track with position-light automatic block signals has no line control circuits and is fed from batteries, thus being immune from the effects of an a-c. power outage



## 11,000-Ft. Coded Track Circuits

THE Pennsylvania Railroad has installed automatic block signaling on 110 miles of double-track main line between Bradford, Ohio, and Anoka Junction, Ind. (Logansport), the interesting feature of this project being the use of coded track circuit controls, thus eliminating line control circuits and obviating foreign current trouble. The coded track circuits are of the direct-current type, and the control system as a whole operates from batteries, thus being immune from the effects of a-c. power outages. Furthermore, this type of d-c. coded track circuit operates successfully on track circuits up to 11,000 ft. in length, so that the number of track circuits is minimized.

### Track Layout and Traffic

The main east-and-west line of the Pennsylvania between Pittsburgh, Pa., and St. Louis, Mo., extends through Columbus, Ohio, and Indianapolis, Ind. On this line at Bradford, Ohio, 83 miles west of Columbus, a double-track line extends northwest through Marion, Ind., and Anoka Junction to Logansport for connections to various points including Chicago. This line handles two local passenger trains in each direction daily, a local freight train in each direction daily except Sunday, a

turn-around run between Logansport and Ridgeville daily, and from 5 to 7 through freight trains daily in each direction. These through freight trains handle merchandise and perishable traffic, and, therefore, are operated on fast schedules. The train movements are bunched during certain periods of the day, as, for example, eastward traffic leaving Chicago in the morning is handled over this territory between 11 a.m. and 2 p.m.

The grade of this line is undulating, with a maximum of 0.3 per cent. The line includes long sections of tangent, with only 14 curves, none of which exceeds 1 deg. 20 min. in the entire 110 miles of territory. The maximum permissible speed for passenger trains is 55 m.p.h. and for freights 45 m.p.h.

### Signaling Arrangement

In determining the lengths of the automatic blocks, consideration was given first to the fact that the home signals at the interlockings were fixed points, one interlocking being located at the east end, Bradford, one at the west end, Anoka Junction, and one at each of six intermediate points, Meeker, Union City, Ridgeville, Redkey, Kent, and Bunker Hill. The approach signal for each interlocking home signal is located about two miles from its corresponding home signal.

The intervening distance to the next interlocking is divided into blocks of approximately equal lengths so that the automatic blocks range in length from about three to a maximum of about four miles.

With this layout of blocks, using 11,000-ft. track circuits, each two-mile block is handled by one track circuit, and each block ranging between two and four miles in length is handled by two track circuits. Where two track circuits are included in a block, the code control is repeated through a cut section, thus requiring no line wires for the control of the automatic block signals. Where highway-railroad crossing protection is involved, track circuits approximately 3,600 ft. in length are required for the approach control of the crossing signals.

### Variations in Types of Power Supply

At the interlockings and at the highway crossing protection installations, a-c. power for charging storage batteries was already available. At these locations, the storage batteries for operating crossing signals and controls were continued in service, and storage batteries were installed in these territories for the new track circuits and automatic signals. Where an extension of an existing a-c. power

circuit for about two thousand feet would take in a new automatic block signal, such an extension was made, and storage batteries were provided at such locations. On the remaining sections of the new automatic signaling project, primary batteries were provided to feed track circuits as well as signals.

### Local Battery

At each signal location, a 12-volt battery feeds the local control relays. This battery consists of 6 cells of 180-a.h. lead storage battery, at locations when a-c. power is available for charging. At locations where a-c. power is not available, the local 12-volt battery, for each signal and the operation of local relays, consists of 20 cells of 1,000-a.h. high-ampereage type primary battery. This battery also feeds the signal lamps on approach control. At locations where the signal for the eastward track is opposite that for the westward track,

cold weather showed an average temperature inside the box of 20 to 30 deg. higher than outside temperatures.

### Signal Lighting Controls

At all signals, either interlocking or automatic block, where a-c. power is available with storage battery, the Type PL-1 position-light signals are used with lamps rated at 12 volts, 9 watts, and at such locations, the lamp feed is normally from a transformer fed from the a-c. power line. A power-off relay is used to switch the lamp feed circuit to the storage battery in case of an a-c. power outage. At the signal location where no a-c. power is available and primary battery is used, Type PL-3 position-light signals are used with lamps rated at 12 volts, 6 watts, the combined load of the three lamps in an aspect of a position-light signal being 1.6 amp. with 11 volts at the signal.

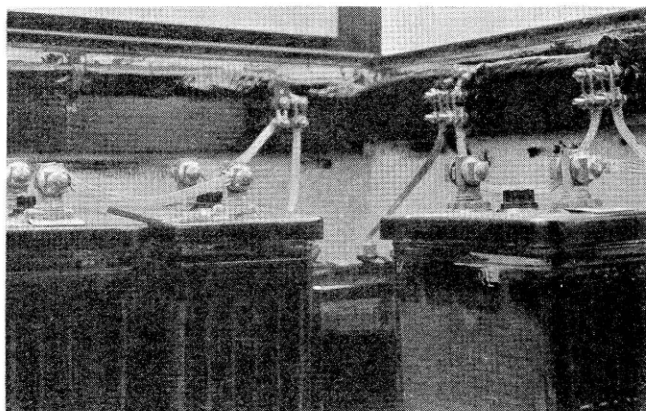
The interlocking home and distant signals are lighted constantly,

pulse, controls various signal control relays, depending on the code being received, and thus indirectly causes different aspects to be displayed. Code at the rate of 180 per minute results in the display of the Clear aspect, 75 code results in the Approach aspect. The most restrictive aspect of an automatic signal, i.e., Stop-and-Proceed, will result unless properly coded d-c. energy of the correct polarity is present in the track circuit. Protection is, therefore, afforded against foreign current. The code-following track relays are polar biased, in other words, they will not operate unless the polarity of the incoming energy is correct, and, by staggering the polarity in adjacent track circuits, protection is provided to prevent improper operation if the insulated rail joints are defective.

A coded d-c. track circuit has better train shunting characteristics than a conventional d-c. track circuit using steady-flowing energy, because, with a coded track circuit, the energy is cut off from the code-following track relay during each off-period of the code, and the relay must release to close its back contacts and continue in operation in accordance with code in order to effect the controls. The higher pick-up values, rather than the lower release values, therefore, determine the shunting sensitivity. For this reason, such circuits 11,000 ft. in length can be operated successfully where the minimum ballast resistance is not less than 3 ohms per thousand feet, and where the rail joints are bonded to capacity. On the Bradford-Anoka Junction project, the rail is of 100-lb. and 130-lb. section, and each joint is bonded to the current carrying capacity of the rail section by a rail-head, plug-type, mechanically applied bond. The ties are in good condition and the track is ballasted with gravel.

### Use of Reverse Code and Steady Current

In addition to the use of code fed into a track circuit in the direction against the current of traffic to control the aspects of wayside signals, impulses of reverse code sent in the opposite direction during the off periods of the control code, are utilized to control approach annunciators and approach locking at interlockings so that no line wires are required for these purposes. This same type of reverse code is used, on the section approaching the Bradford interlocking, to affect approach control of d-c. operated tuned alternators which feed cab signal energy to the track for operating cab signals in accordance



The storage as well as the primary cells are housed in insulated battery boxes

which is true in the majority of instances, the two sets of 20 cells each are connected in multiple.

As no signals are located at cut sections, 2.5-volt battery is used to feed the local relays. As a-c. is not available at any cut section, this 2.5-volt local battery consists of primary cells connected in series. Each track circuit is fed either by one cell of storage battery on floating charge or by a battery of three cells of primary in multiple.

Both the conventional concrete and the insulated types of battery boxes were used on the project. A test of the temperature conditions existing with insulated boxes was made by using recording thermometers. While the outside temperature varied from 104 deg. to 47 deg., the temperature inside the box varied from 100 deg. to 79 deg., with temperature of the electrolyte from 90 deg. to 83 deg. This indicates that, with sudden changes of outside temperatures, a gradual temperature change occurs inside the box. Tests recorded during

being fed normally from the a-c. supply but, in case of an a-c. power outage, are switched by power-off relays to feed from storage batteries. The lamps in the remaining signals are normally extinguished, approach control being used to light the signals before a train approaches to within 4,000 ft. of a signal. Where primary battery is used to feed a track circuit, the approach-lighting relay is in series with the track battery feed, but where storage battery is used to feed a track circuit, the approach-lighting relay is in multiple with the track feed. These circuits will be explained later.

### Principle of Coded Track Circuits

The coded track circuit control system includes an arrangement to interrupt the feed to a track circuit a certain number of times each minute, for example, 75 or 180 times, while, at the other end of the track circuit, a code-following relay, which is energized and released with each code im-

with the aspects being displayed by wayside signals. With the exception of the track sections approaching the Bradford interlocking, wayside equipment for cab signaling control is not provided on the Bradford-Anoka Junction territory. Preliminary arrangements have been made, however, so that cab signaling can be added later with a minimum of alterations.

Another feature of the system is the use of steady-flowing d-c. track circuit energy to accomplish cut-out control of highway-crossing protection, and, at the same time, maintain proper control of wayside signals, as will be explained later.

### How the Code is Transmitted

The devices identified by 75CT or 180CT at Signal 2 are code transmit-

ters at the top end of the pendulum, operate contacts which code the feeds to the track circuits. Each code transmitter has two front and two back contacts, therefore, where an eastward signal is opposite a westward signal, one 75CT and one 180CT serve for both tracks.

### Diagrams on Insert

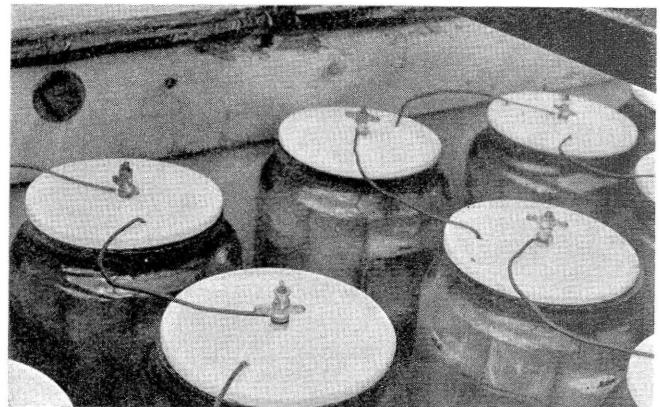
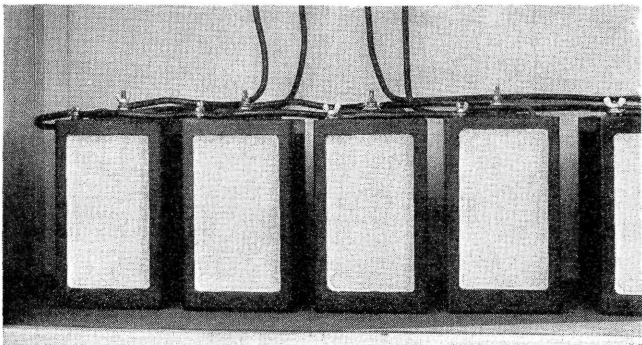
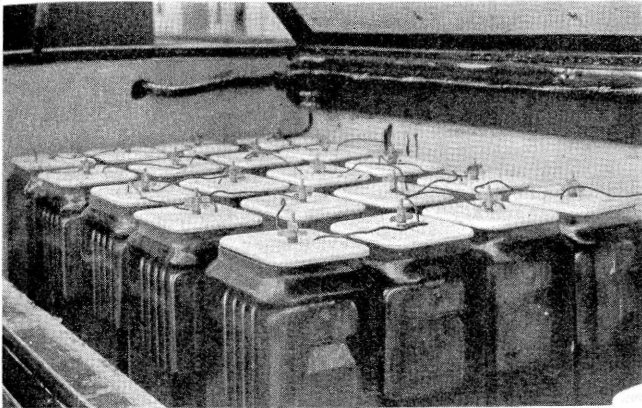
Referring to Diagram 1 on the folded insert following page 434, when the block controlling Signal 2 is occupied, controls are established to cause that signal to display the Stop-and-Proceed aspect, and 75 code must be fed westward from that signal to cause Signal 1 to display the Approach aspect. As this situation exists only for short periods of time, when a train is occupying the block, the

battery. Thus energy from the track battery, coded 75 times per minute, is sent out westward on track circuit X1B.

If the block controlling Signal 2 is unoccupied and the block ahead of that is occupied, Signal 2 displays the Approach aspect, while if two or more blocks are unoccupied, the controls are effective to display a Clear aspect. With the controls set up for either an Approach or a Clear aspect for Signal 2, the 180 code must be fed westward from Signal 2 to Signal 1 so that the Clear aspect can be displayed on Signal 1.

### Feed for the Track Circuits

With the block controlling Signal 2 unoccupied, relay AH is energized as previously explained. Positive track battery B (X1B) feeds through multiple front contacts of 180CT, through multiple front contacts of relay AH to the wire extending to the north rail of track circuit X1B as explained previously in discussing the 75 code and



Three different types of primary battery cells are used on this signaling installation

ters which are required only at signal locations, because, at each cut-section location, the incoming track code is repeated through the code-following track relay to the next track circuit.

Each of these code transmitters is provided with a pendulum type armature arranged to swing in a vertical plane. An electro-magnet, fed from the 12-volt battery, is so mounted and controlled that the pendulum is given a slight pull each time it swings back and forth. By using pendulums of different weights, the cycle of swings can be regulated to exactly 75 or 180 per minute. Normal variations in the voltage of the battery do not cause undesirable variations in the operation of the pendulum. Connections, from

75CT need not be operated continuously.

With the block controlling signal 2 occupied, the control relay AH will be de-energized. Positive 12-volt battery B is fed through a finger and back contact point of relay AH to the 75 code transmitter 75CT, which then starts and operates 75 times per minute. A connection from the positive side of a track battery B (X1B) is fed through parallel front contacts of this code transmitter, through parallel back contacts of relay AH and to a wire extending to the south rail of track circuit X1B at Signal 2. A connection from the north rail extends through an adjustable resistor RX to the negative C (X1B) of the track

the return is through the resistor RX to the negative side of the track battery. The 180 code is, therefore, in effect on track circuit X1B.

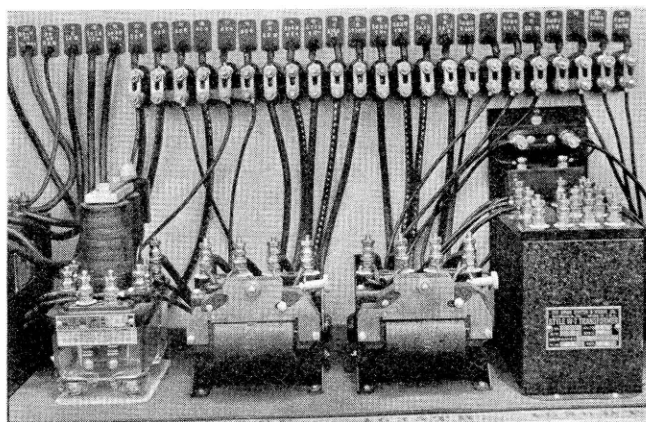
The 75-code transmitter is fed and operated only when relay AH is released, and when the approach control is in effect. Although the 180-code transmitter operates all the time, the output cannot connect with the track circuit when relay AH is de-energized, therefore, the 75 and the 180 codes cannot interfere. The wire marked "shunt", extending from the left-hand terminal of approach-lighting relay X1BVR to the back contacts of the code transmitters, provides a means of shunting the track circuit each time a code transmitter closes its back contacts, thus draining off any "storage" action of energy which might tend to maintain a code-following track relay energized longer than desired. Furthermore, by shunting the track circuit with each code operation, the shunting sensitivity of the



track circuit depends on the pick-up value of the relay rather than the release value, as previously discussed.

### Code at the Cut-Section

With code being fed to track circuit X1B at Signal 2, as explained above, the relay X1BR at the cut-section will pick up and release 75 times each minute to follow the code. At the cut-section positive 2-volt battery B feeds through a back contact of relay X1BR



A power-off relay, two rectifiers and a lighting transformer

to the coils of code-following repeater relay X1BM and to the negative side of the battery. A connection from the positive side of track battery, extends through front contacts of code-following repeater track relay X1BM to the north rail connection of track circuit X1A, and a connection from the south rail extends to the negative side of the track battery. Thus, whatever code, either 75 or 180, is effective in track circuit X1B, is repeated to feed westward on track circuit X1A. As relay X1BM is a back contact repeater of X1BR, and as the track battery for section X1A is coded over front contacts of X1BM, the "on" period of the code in section X1A occurs during the "off" period of the code in X1B. This is known as a back-contact repeating cut section. During the "off" period of the code in track circuit X1A, that track circuit is shunted in a manner similar to that described for the signal location.

At the west end of track circuit X1A, i.e., at Signal 1, the 75 code causes the Approach aspect to be displayed, and the 180 code causes the Clear aspect to be displayed, as will be explained later.

### Code-Following Track Relay and Repeater

With the block controlling Signal 1 unoccupied, but with the block controlling Signal 2 occupied, Signal 1 would be displaying the Approach aspect. Under this condition, code-following track relay X1AR at Signal 1 would

be receiving 75 code impulses per minute, and would be energized and released the same number of times per minutes. With two blocks ahead of Signal 1 unoccupied, 180 code would be received by relay X1AR.

For long track circuits, X1AR is a highly sensitive code-following relay which has only one contact finger with a front and a back contact. This highly-sensitive relay, X1AR, is known as a pilot code-following relay because it controls a larger 12-volt,

code-following repeater relay X1AM, with four non-independent front and back contacts. The X1AM relay is controlled by a circuit through a front contact of the pilot relay X1AR, and, therefore, the X1AM relay will be energized when X1AR is picked up, and X1AM will be released when X1AR is released, thus X1AM repeats the incoming code.

The combination of a very sensitive track relay with coded track circuit energy is safe because any interference of foreign current (whether that foreign current comes from some d-c. trolley system or from storage or primary battery action in the track circuits) will cause the code-following pilot relay to be either continuously energized or continuously de-energized, either of which will produce a "Stop" indication.

### Control Circuits for Primary Battery Territory

Relay 1AH is used to control the lamps in the Approach aspect on Signal 1, and an explanation will now be given to show how the operation of code-following relay X1AM causes relay 1AH to be energized. Referring to Diagram 1, the primary winding of the H transformer is fed 12-volt battery of one polarity when the front contacts of relay X1AM are closed, and battery of the opposite polarity when the back contacts are closed. The flux in the core of the transformer is, therefore, reversed each time the contacts of relay X1AM change posi-

tion, and, as a result, the secondary feeds low-frequency alternating current to a rectifier, which feeds unidirectional impulses of direct current to the coils of relay 1AH, which is a direct-current relay with slow pick-up and slow-release characteristics so adjusted that it will pick up and remain energized on d-c. impulses at the rate of 75 or more per minute. Therefore, this relay is energized when either the 75 or the 180 code is being received on track circuit X1A. Energization of this relay 1AH will close contacts to complete a circuit to light the Approach aspect on Signal 1, providing a train is approaching to affect the approach control. If track circuit X1A is shunted by a train, the pilot track relay X1AR will be continuously de-energized and its repeater X1AM will be continuously de-energized so that the flux in the H transformer remains constant and no alternating current energy is induced in its secondary winding. Consequently relay 1AH will be de-energized. The same is true in case foreign current should continuously energize the code-following pilot relay. As this circuit is in no way tuned, relay 1AH will be energized when track circuit X1A is receiving 75 or 180 code. As the H transformer receives energy from the 12-volt primary battery source of supply, a small type of highly efficient transformer is used.

### Control of Clear Aspect

If two automatic blocks ahead of Signal 1 are unoccupied, the 180 code is being fed to track circuit X1A, and code-following relay X1AR and its repeater X1AM are operating 180 times per minute. This causes relay 1AH to be energized as explained previously, and also causes relay 1AJ, which controls the clear aspect of Signal 1, to be energized, as will now be explained.

The second decoding transformer is larger than the H transformer. As the signal lighting is on approach control, there is no need to energize the decoding transformer or relay 1AJ until a train is approaching and primary battery energy can be conserved. As a train approaches Signal 1 at a distance of not less than 4,000 ft., the relay VM (the operation of which will be described in detail later) closes its front contact to energize the decoding transformer. When the code-following repeater track relay X1AM has its front contact closed, battery flows through the upper half of the primary winding to common. When relay X1AM has its back contact closed, battery flows in the opposite direction through the lower half of



the primary winding to common. Thus the flux in the core of decoding transformer is likewise reversed upon each operation of relay X1AM. The reversal of flux in the core of this decoding transformer likewise induces a low-frequency alternating current in its secondary windings and in its auto winding. In this circuit, the two secondary windings are not used but the induced alternating current energy in the auto winding of this transformer is used to feed the 180 decoding unit which, in turn, supplies energy to relay 1AJ. The 180 decoding unit, 180 D.U., is electrically tuned so that it will pass only alternating current of 180 cycles per minute or 3 cycles per second. It includes a rectifier unit so that the 3-cycle alternating current which is passed by the filter element of this unit is rectified to energize the d-c. relay 1AJ. In case track circuit X1A is receiving 75 code energy when a train approaches Signal 1, relay 1AH alone will be energized because the lower frequency alternating current energy induced in the auto winding of decoding transformer 20 will not pass the filter unit of the 180 decoding unit.

When a train has passed Signal 1, the battery connected to the decoding transformer is broken by the front contact of relay 1AH so that the relatively large amount of power taken by this larger decoding transformer is taken from the 12-volt local primary battery only when necessary to display the Clear aspect on Signal 1.

### How Approach Lighting Is Controlled in Primary Battery Territory

Referring to Signal 2 on Diagram 1, which applies where primary battery is used, track battery energy flows through current-limiting resistor RX. Approach relay X1BVR is connected in series with adjustable resistor RV, and in multiple with current-limiting resistor RX. When a train approaches Signal 2, relay X1BVR will receive sufficient energy in its track winding to cause this relay to be energized during each "on" period of the code when the train has approached to a point not less than 4,000 ft. from the signal. Relay X1BVM with its resistor snub attached, is a slow-acting repeater of the front contact of relay X1BVR. When relay X1BVM is energized, as previously described, it applies battery energy to the lighting circuits for approach lighting Signal 2.

As soon as the leading wheels of the train pass Signal 2 to shunt the track circuit, the Stop-and-Proceed aspect is lighted until the rear of the train passes the signal, at which time relays

X1BVR and X1BVM are released and all lamps are extinguished. With the traffic now being handled, a 4,000 ft. track section is occupied about 25 min. daily. Where 6-watt lamps are used and fed from primary battery, the discharge for a three-lamp aspect is 1.6 amp. with 11 volts at the lamps or a total of 0.66 ampere hours daily under the examples cited above. The normal drain on the 12-volt battery for energizing relays X1AM and AH and operating the 180 code transmitter, totals 65 m.a. Energization of relays X1BVM and AJ as well as operation of the 75 code transmitter, during certain periods, causes additional loads on the 12-volt battery.

### Signal Control Circuits Where Storage Battery Is Used

Where storage battery on floating charge from a rectifier is used, a different arrangement of transformer and controls for relays 1AH and 1AJ is necessary. The storage battery might be disconnected or become dry, in which case the pulsations on the double-wave rectified energy from the

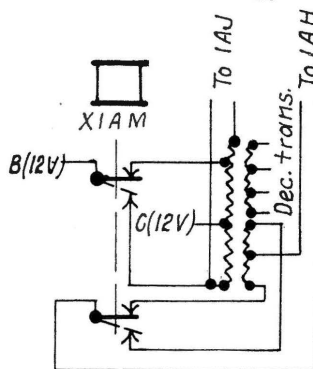


Diagram 1A

trickle charging rectifier might induce sufficient energy in the secondary winding of the decoding transformer to energize relay 1AH, even though the code-following track-repeater relay is not in operation. For this reason, where storage battery energy supplies the decoding transformer, the mechanically-rectified relay control circuit, as shown on Diagram 1A, is used. With this arrangement, one side of the coil of relay 1AH is connected to the center tap of the secondary of the transformer and the other side of the relay coil is connected to a contact finger in relay X1AM, while the front and back points are connected to the end taps of the transformer secondary. Therefore, as the relay finger operates up and down, when following code, the output of the secondary is mechanically rectified by the relay action, thus producing unidirectional impulses in the coil of relay 1AH, which is sufficiently slow acting to remain

picked up when the impulses are at the rate of 75 or more per minute. If relay X1AM is either energized or de-energized, energy from battery or from a rectifier fed to the primary of the transformer may induce a current in the secondary, but in view of the fact that relay X1AM is not operating to rectify this energy, relay 1AH cannot be energized. The control of relay 1AJ is the same as in Diagram 1, as previously explained.

### Approach Lighting Control Where Storage Battery Is Used

In the Diagram 1B for application where storage battery is used for feeding coded track battery energy to track section X1B, the approach relay X1BVR is connected in mul-

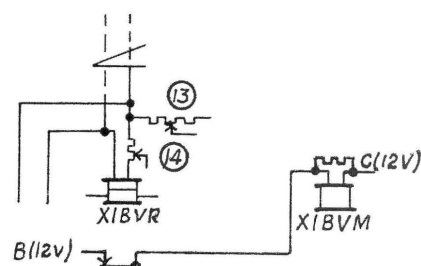


Diagram 1B

multiple with the track battery leads. In this case, resistor item 13 is the track limiting resistor while resistor item 14 adjusts the amount of energy taken by the track winding of relay X1BVR. When the approach relay is thus connected in multiple with the track circuit, it normally follows the code. As a train approaches, reducing the voltage on the rails, relay X1BVM ceases to operate. Thus where storage battery is used, the approach repeater relay X1BVM is normally energized so that the approach lighting is carried over back contacts of this relay. This arrangement gives a minimum approach-lighting distance of 4,000 ft.

### Use of Coded Reverse Circuit Approaching Interlockings

To avoid the use of line wires for approach locking the interlockings, a coded reverse circuit is used in the two-mile track circuit normally used between the distant and the home signals at interlockings and in the first track circuit in approach to the distant signal. This coded reverse circuit feeds a short impulse of energy in the reverse direction through the track circuit during the normal "off" periods of the control code. The coded reverse circuit is relayed at the distant signal location so that as soon as a train passes the cut section in approach to the distant signal, the coded

reverse circuit is cut off up to the home signal, and the relays responding to the coded reverse circuit are de-energized at that time. The relays responding to the coded reverse circuit control the ordinary approach locking relay.

Referring to Diagram 2, on the folded insert, the code-following pilot track relay X1BR and its repeating relay X1BM are connected in the same manner as the cut section shown on Diagram 1, and repeat coded energy to the track circuit X1C in the same manner, this again being a back-contact repeating point. Relay X1BM, however, is made a four-contact repeater relay. Relay X1BR normally receives track battery energy over two back contacts on relay X1BIR connected in multiple.

Each time that relay X1BR is de-energized at the end of an "on" period of the control code in track circuit X1B, this relay closes its back contact to energize relay X1BM. For a very brief interval, while the back contact of relay X1BR is closed and the back contact of relay X1BM is closed, energy is applied to relay X1BIR. While this relay is energized, it connects battery over its front contact to feed the reverse pulse or reverse code to track circuit X1B. Because relay X1BIR is energized for only a very brief period, its front contacts are closed for only a short period. The winding of this relay is so proportioned that its front contacts are closed for a period of time which is always less than the shortest "off" period of a control code so that its back contacts are again closed to allow relay X1BR to again be energized as soon as the

"on" period of the next code cycle in track circuit X1B starts.

Referring again to Diagram 2, it will be noted that coded battery energy is fed to track circuit X1B in the same manner as shown on Diagram 1. During the "off" interval of the control code, however, track circuit X1B is not short-circuited but while the back contacts of the 180 or 75 code transmitters are closed, as selected by relay 1DH, the track wind-

but when the code transmitters are de-energized, closing their back contacts, X1BVR is energized by the reverse code impulse. It will be noted that the local winding of relay X1BVR is here used to stick this relay energized during the entire "off" period of the code, that is, when relay X1BVR has been momentarily energized by the reverse code impulse in its track winding. Energy from the track battery which normally feeds

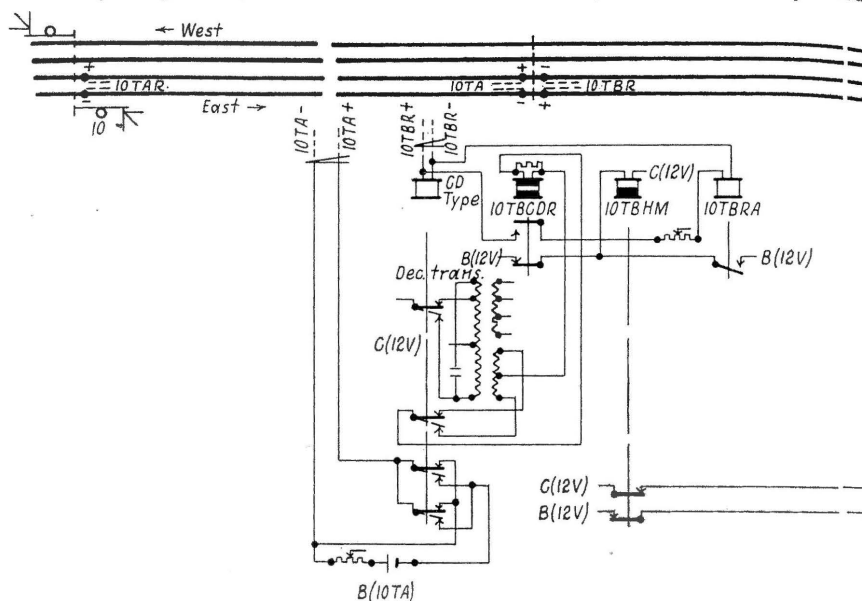
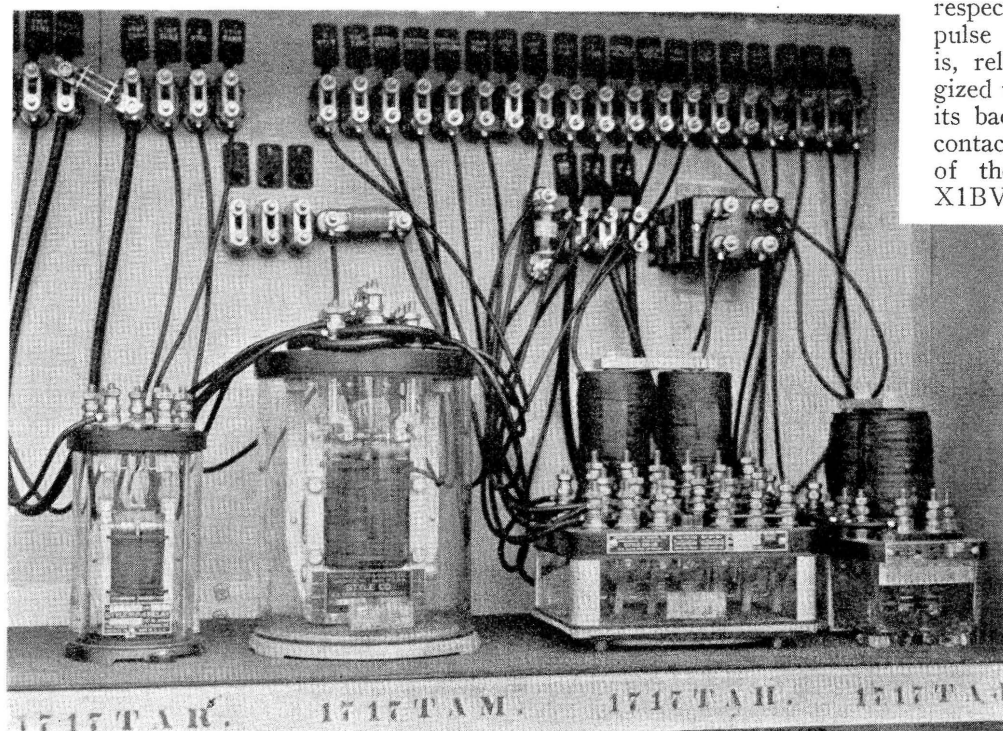


Diagram 3 showing circuits for normal

ing of relay X1BVR is connected to the track circuit to receive the reverse pulse produced at the cut section to the rear. Thus, when the code transmitters are energized, relay X1BVR is disconnected from the track circuit, and battery is fed to the track circuit,

track circuit X1B is connected over a back contact of the code transmitter through the winding of relay X1BVM through the local winding of relay X1BVR and over a front contact of that relay to the negative side of the track battery. This insures that irrespective of how short the reverse pulse received from the track circuit is, relay X1BVR will remain energized until the coder unit again opens its back contact and closes its front contact to apply the next "on" period of the normal code. When relay X1BVR is then de-energized, energy



Typical set of relays including from left to right a pilot code-following track relay, a code-following track repeater, an AH control, and an AJ control relay

from the same track battery is connected over a back contact of that relay over a front contact of relay X1BVM to the winding of relay X1BVMM to the positive terminal of the track battery. Relays X1BVM and X1BVMM insure that relay X1BVMM can be energized only when the code-following approach relay X1BVR is responding to coded reverse current.

The coded reverse current feed to

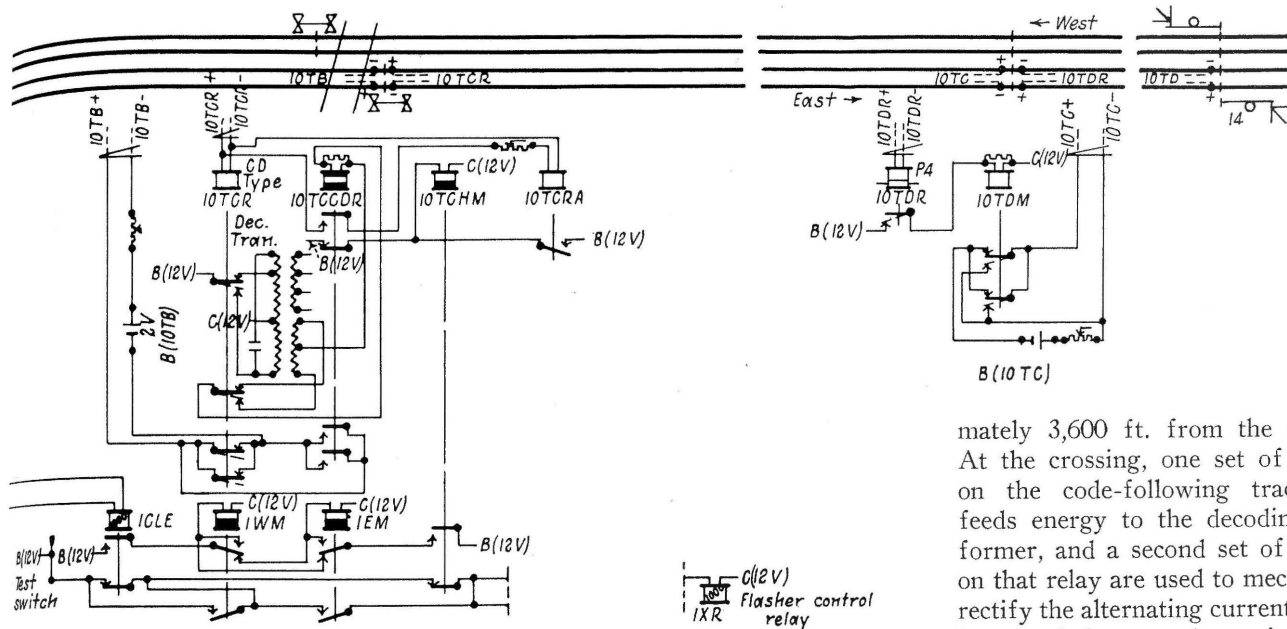
back contact repeater of the code-following approach relay may be omitted.

### Steady Flowing Track Circuit Energy for Control of Highway Crossing Protection

The controls for the highway crossing protection are arranged to control this protection for trains operated in either direction on either track, and

are accomplished by using steady flowing d-c. track circuit energy.

Referring to Diagram 3, it will be noted that track relay 10TCR at the crossing and relay 10TBR at the cut section in approach are code-following track relays. It is unnecessary, where storage battery is used for track circuits, to use a pilot code-following track relay for these track circuits because they are short, the normal starting point being approxi-



code and steady current at crossing protection

track circuit X1AR is identically the same as that described for the cut section except that relay X1AIR is controlled over a front contact of relay X1BVMM so that the presence of a train in track section X1B cuts off the reverse code normally fed to track section X1A.

The code approach relay X1AVR at signal 8L is controlled in a similar manner to the code approach relay X1BVR at signal 1D, the only difference here being that the track circuit energy fed to track section X1A is coded directly by a code repeating relay X1ACTM which, in turn, receives either 180 code or 75 code as selected by the H relay for Signal 8LA. Also the front contact repeater X1AVM and the back contact repeater X1AVMM are controlled the same as the front and back contact repeater relays just described.

As both home and distant signals are normally lighted, the coded approach circuits are used only to control the approach relay at the interlocking. It will be obvious that the coded approach circuit may be used as shown for any safety control purpose and may be also used for approach lighting. Where used for a non-safety purpose such as approach lighting, the

the starting track circuit sections are about 3,600 ft. long.

As explained previously, the normal signal control code is fed to the rails at the leaving end of a block and is repeated through cut sections to control the signal of that block. As a train passes through a block, the track circuits are shunted and no code exists in the track circuits of a block to the rear of a train.

At a highway crossing protection installation, when the rear of a train passes the crossing, in other words, clears the approach track circuit, some means must be provided to detect this circumstance in order to stop the operation of the crossing protection. Likewise when the train has departed from the receding section for approach control of the crossing protection for trains which may run in the opposite direction on that track, non-occupancy of that approach section must be checked. Furthermore, due to the fact that the normal control code is shunted out behind a train, some other type of energy must be made available in both these crossing protection approach control sections as a means of controlling the crossing protection in case a second train entered these sections. All these results

are accomplished by using steady flowing d-c. track circuit energy. At the crossing, one set of contacts on the code-following track relay feeds energy to the decoding transformer, and a second set of contacts on that relay are used to mechanically rectify the alternating current induced in one of the secondary windings of that decoding transformer to energize relay 10TCCR. This latter relay is of the same type as is used for relay 1AH on Diagram 1. Relay 10TCCR is the code-detector relay at this location which will be energized only if the track sections between the highway crossing cut and the next signal in advance are unoccupied.

The coded track circuit energy in track circuit 10TC is normally repeated to track circuit 10TB over front contacts of code-following track relay 10TCR. This is a front contact coding location. As an eastbound train moving from left to right past the highway crossing clears track circuit 10TB, it is necessary to use some form of track circuit energy in track circuit 10TB to determine that that track circuit has been cleared in order to stop the operation of the highway crossing signals. Steady non-coded energy is used for this purpose. It will be noted that the de-energization of relay 10TCCR applies non-coded track battery energy to track circuit 10TB. As long as track circuit 10TC or any other track circuits in advance up to the next signal location are occupied, relay 10TCCR will be de-energized to apply non-coded battery energy to track circuit 10TB.

The track battery fed to track cir-



cuit 10TC at the cut section to the right will apply steady non-coded energy to track circuit 10TC when track circuit 10TD is occupied. Because track circuit 10TC may be fed either coded or non-coded energy, it is necessary to use both a code-detecting relay 10TCCDR and a steady-energy detecting relay which is 10TCRA. This latter relay is a standard type track relay which, it will be noted, is connected in multiple with code-following track relay 10TCR over a back contact of relay 10TCCDR. This is done merely to prevent the steady-energy detecting relay from normally following code. Relay 10TCHM is a slow-acting type of relay which simply repeats the code-detecting relay 10TCCDR or the steady-energy detecting relay 10TCRA. Thus relay 10TCHM is energized when track circuit 10TC is receiving either code or steady energy. This relay is used to directly control the highway crossing signal in conjunction with directional stick relays.

Track circuit 10TB may receive either coded or non-coded track energy. The track relay equipment for track circuit 10TB, therefore, consists of identically the same equipment as described for track circuit 10TC, namely: a 4-point code-following track relay, a decoding transformer to energize the code detecting relay 10TBCCR, a steady-energy detector relay 10TBRA and a slow-acting repeater 10TBHM to repeat either the code-detecting or the steady-energy detecting relay. Relay 10TBHM determines whether or not track circuit 10TB is occupied. Relay 1CLE, at the crossing is a direct repeater of relay 10TBHM at the cut section and is controlled over line wire.

As track circuit 10TA does not enter into the control of the highway crossing, the track energy fed to this circuit need be coded energy only. The code in track circuit 10TD is simply repeated to track circuit 10TC. For this purpose back contact coding is used. Back contact coding is an advantage at this point for two reasons.

Should a train back into track circuit 10TD, the use of back contact coding will insure that steady energy is applied immediately to track circuit 10TC and, because of the front contact coding at the crossing this will also insure that steady energy is immediately applied to track circuit 10TB. This eliminates the necessity of a CDR relay for track circuit 10TD and avoids the necessity of waiting for relay 10TCCDR to release in order to apply steady energy to track circuit 10TB, which, in turn, eliminates any possibility of momentary operation of the highway crossing

protection. Where there are two or more track circuits in a block, back contact coding is used on every other track circuit to correct code displacement due to relay action. If there is a gain in the "on" time on the code due to over-energization of the track relays when the ballast is dry the use of back contact coding shortens the "on" period of the code applied to the second section.

The gain which is due to over-energization in the second section, will make the code received at the signal location approximately the same as that fed to the first track section. Likewise, should there be a loss of "on" period of the code in the first section due to under-energization of the track relay, the use of back contact coding will increase the length of the "on" period fed to the second section so that the code received at the far end of the second section will be approximately the same as that fed to the first section. Where the cut sections are uneven, as in blocks containing crossing protection, one back contact coding cut section will assist in correcting code distortion.

This signaling was installed by the construction forces of the Pennsylvania, during February and March, 1940. The instrument cases were wired complete with terminals, jumpers, etc., in place in a large building at Logansport storehouse, and the signal masts, ladders and signal heads

were assembled in a yard nearby. The instrument cases, signals, sectional precast concrete foundations, etc., were then loaded on cars and assembled in work trains, with two power-operated cranes. One crane was equipped with a clam-shell bucket which was used to dig the holes for the foundations, this operation being done successfully in spite of the fact that the ground was frozen to depths of 18 in. or more. After each hole was dug to the proper depth, the bottom was leveled by hand shovels. The foundation was then set and the hole back-filled, while the signal was set in place and bolted. Instrument cases and their foundations were set in a similar manner. Relays in packing cartons and batteries were handled by hand and set in the cases. On the average, a complete double signal location was handled in less than an hour. The bonding, installation of underground cable, the connecting of the relays, setting up batteries, etc., was handled by separate crews which progressed from one end of the territory to the other, the work being co-ordinated so that the new system could be placed in service in sections of about 20 miles each. As a part of the signaling project, a hand-operated switch and lock mechanism equipped with a point detector was installed to replace the old conventional type switch stands on all hand-operated main line switches.

Interior of a typical instrument case at a double-signal location where storage battery supply is used

