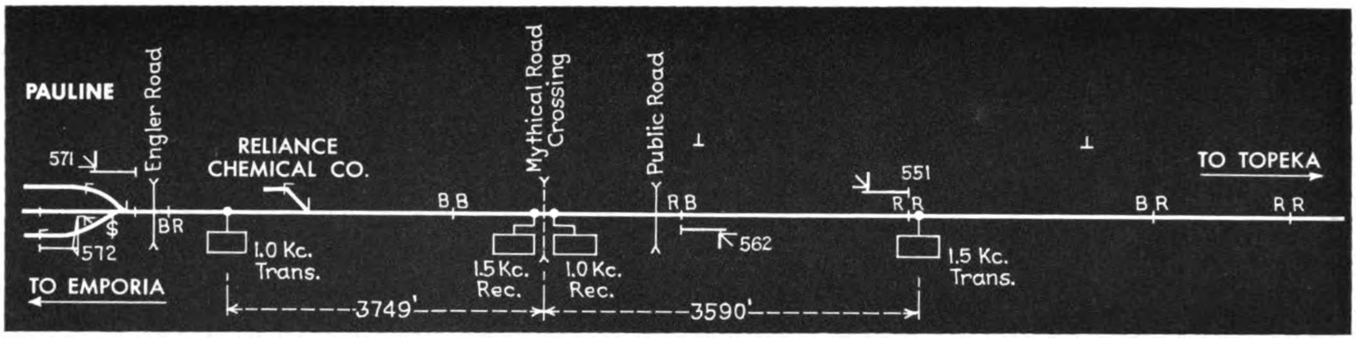


Santa Fe Tests AF Track Circuits

For controls of crossing protection, these audio frequency overlay circuits are superimposed on existing conventional signal track circuits, with no interference, some of the advantages being that no insulated rail joints are required

AN EXTENDED TEST of audio frequency track circuits, for control of highway crossing protection, has been conducted by the Santa Fe signal department. This test was at Pauline, Kan., on the single-track main line from Kansas City to Emporia via Topeka, which handles eight through passenger trains and several local freights daily.

How AFO Works

Application of audio frequency track circuits is based on the fact that frequencies in the range of 1.0 to 2.0 kilocycles per second can be connected to rails to feed definite distances, either short distances, such as 30 to 40 ft; or longer ones ranging up to 4,500 ft or more. This is done without the use of insulated rail joints to limit the lengths of these track circuits. This is important where continuous welded rail is used. Aside from the consideration of insulated joints, avoidance of the cost for cut-sections, when installing crossing protection, will be an important saving.

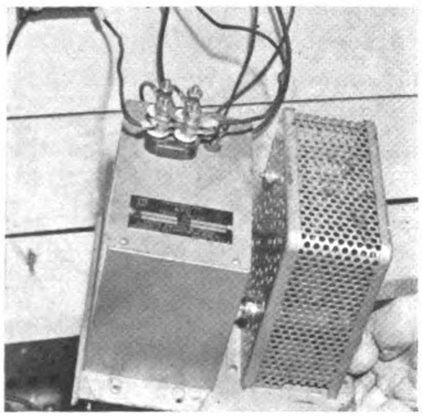
Frequencies in the range of 1.0 kc to 3.0 kc will not interfere with, or be affected by, conventional d.c. or a.c. track circuits of either the steady energy or coded types. Furthermore, these audio frequencies, separated by as much as 0.5 kc, will not interfere with each other.

The electronic equipment at both the transmitter and receiving ends of each AFO track circuit uses hermetically sealed junction transistors. This eliminates all vacuum tubes, thereby giving a long period of service with no outages due to filament failures.

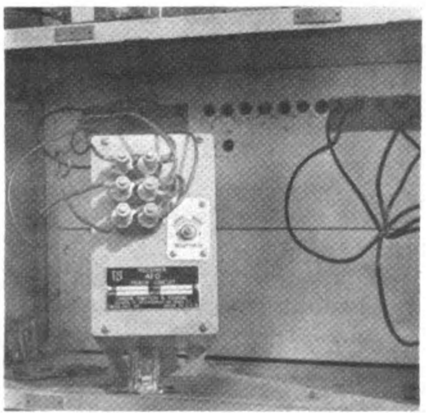
This test of AFO track circuits was made on a section of main track which had no grade crossing or crossing signals. However, a mythical crossing location was established with all control circuits and relays for crossing signals.

This test section (see plan) is equipped with automatic block signaling, including conventional d.c. track circuits, which require insulated rail joints at the signals and at cut-section locations. At these locations, a transformer-type jumper with series condenser, known as a track coupling unit, was connected around each insulated rail joint to carry the audio frequency around the joint, but to prevent flow of the conventional d.c. track circuit.

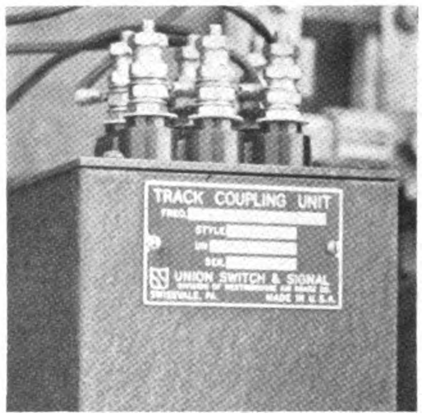
No track coupling is applied to the insulated rail joint in the turnout rail between the main track rails, at the spur for Reliance Chemical Company. Therefore, the audio frequency will not feed



AFO transmitter (2T) is near signal 551. 1.5-kc rail current is fed to crossing



AFO receiver (1R) operates at 1.0 kc and is located at right of mythical crossing



Track coupling unit at signal 551 is 75 ft west of transmitter toward crossing

through this insulated rail joint.

No insulated rail joints are used at the mythical crossing, or at the feed end of each AFO track circuit such as at "E", which is the feed end of the eastward approach control track circuit for the crossing protection.

A frequency of 1.0 kc is used for the eastward crossing protection approach control track circuit, and 1.5 kc for the westward. The 1.0-kc transmitter is connected to the rails 3,749 ft west of the crossing at the location marked "E", at which there are no insulated rail joints.

No insulated rail joints are used at the mythical crossing. The 1.0-kc receiver for this eastward approach track circuit is connected to the rails just east of the crossing, so that, for an eastbound train, the protection will not cut out until after the rear of the train clears the crossing.

Similarly, the receiver for the westward approach track circuit is connected to the rails just west of the crossing. The transmitter for this westward approach control track circuit is connected to the rails 3,590 ft east of the crossing, at a point 100 ft east of signal 551, so that track coupling units are required to feed the audio frequency around the insulated rail joints at this signal.

Each AFO transmitter is fed d.c. current from a 10-volt battery. The normal current requirement is 0.5 amp. Each AFO receiver is fed d.c. current from a 10-volt battery. The normal current requirement is 0.050 amp. On the 3,749 ft eastward circuit, the voltage on the rails at the feed end was adjusted to approximately 3.0 volts at 1.5 kc. The rail is 112 lb section, 39-ft rails, with conventional railhead pin-type bonds.

Shunting Characteristics

In no instance did the AFO track circuits fail to shunt for a train. These AFO track circuits can be adjusted so that an approaching train will shunt the circuit when the leading wheels are within a range of 100 to 150 ft of the transmitter rail connections. Changes in ballast conditions, due to moisture, may vary the exact shunting point within a range of 100 ft. This variation, however, is not objectionable because the approach control section is always several hundred feet longer than that required for the minimum 20 seconds warning time. Pickup of the AFO track circuit, when the rear of a train passes the crossing, is almost as precise as it would be with a conventional d.c. track circuit. Therefore, there is no objectionable "ring-by."

Stick Relay or Interlocking Relay

Each AFO receiver includes an amplifier and power unit with an output of 8.5 volts d.c. for operation of a conventional d.c. relay such as used in ordinary signaling.

During the first several months of the test the Santa Fe used the double-stick relay scheme for cut-out of the crossing protection. Later in the tests, the stick relay scheme was replaced by interlocking relay scheme. Both schemes operated correctly with the AFO track circuits.

All these tests included the use of an Esterline Angus moving-chart recorder, which recorded not only when trains entered and departed from each track circuit, but also operation of the relays in the control of the crossing protection. The recorder was normally at rest. Operation was started by controls through other track circuits, so that the recorder started before trains entered the AFO track circuits. Also, the recorder continued to run for 6 min. after each train departed. The reason for this 6-min. interval was to separate, on the chart, the recordings for different trains.

A conclusion is that, as applied in these tests, audio frequency overlay track circuits can be used with safety and efficiency for the control of highway crossing protection. These tests were installed and conducted by Santa Fe signal forces under the jurisdiction of V. O. Smeltzer, Superintendent of Signals, System, and under the immediate supervision of R. C. Foster, Assistant to Superintendent Signals, System. The apparatus was made by the Union Switch & Signal Division of Westinghouse Air Brake Company.

Circuit Plans →

AFO: What it is and what it does

Designed especially for longer track circuits and greater safety required for control of highway crossings, Union Audio Frequency Overlay (AFO) equipment eliminates the need for and, therefore, the initial and maintenance costs of line wires, insulated joints and impedance bonds. The significance of these factors is obvious in welded rail and electrified territories. Furthermore, fail-safe design provides highway crossing protection (except in electrified territory) without the need for coding.

With this equipment, similar in principle of operation to conventional AFO equipment, approach circuits long enough (4,000 ft) to give 20 sec warning in advance of a train traveling 136 mph may be operated.

Completely transistorized and designed to operate from a nominal 10 or 12-volt battery, this equipment has been tested on the basis of a minimum a.c. ballast resistance of three ohms per 1,000 ft, a minimum shunting sensitivity of 0.06 ohms and a maximum receding ringing distance of 100 ft.

Composed primarily of a transmitter, receiver and associated relay, the equipment can be arranged for control of a typical single-track, two-direction-running highway crossing, as illustrated in Fig. 1. The transmitters, each of a different frequency, are located at the starting points. Each

(*Continued on page 36*)

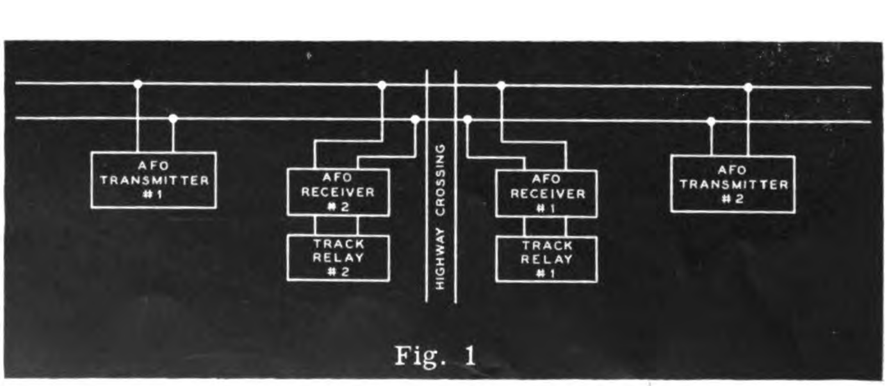
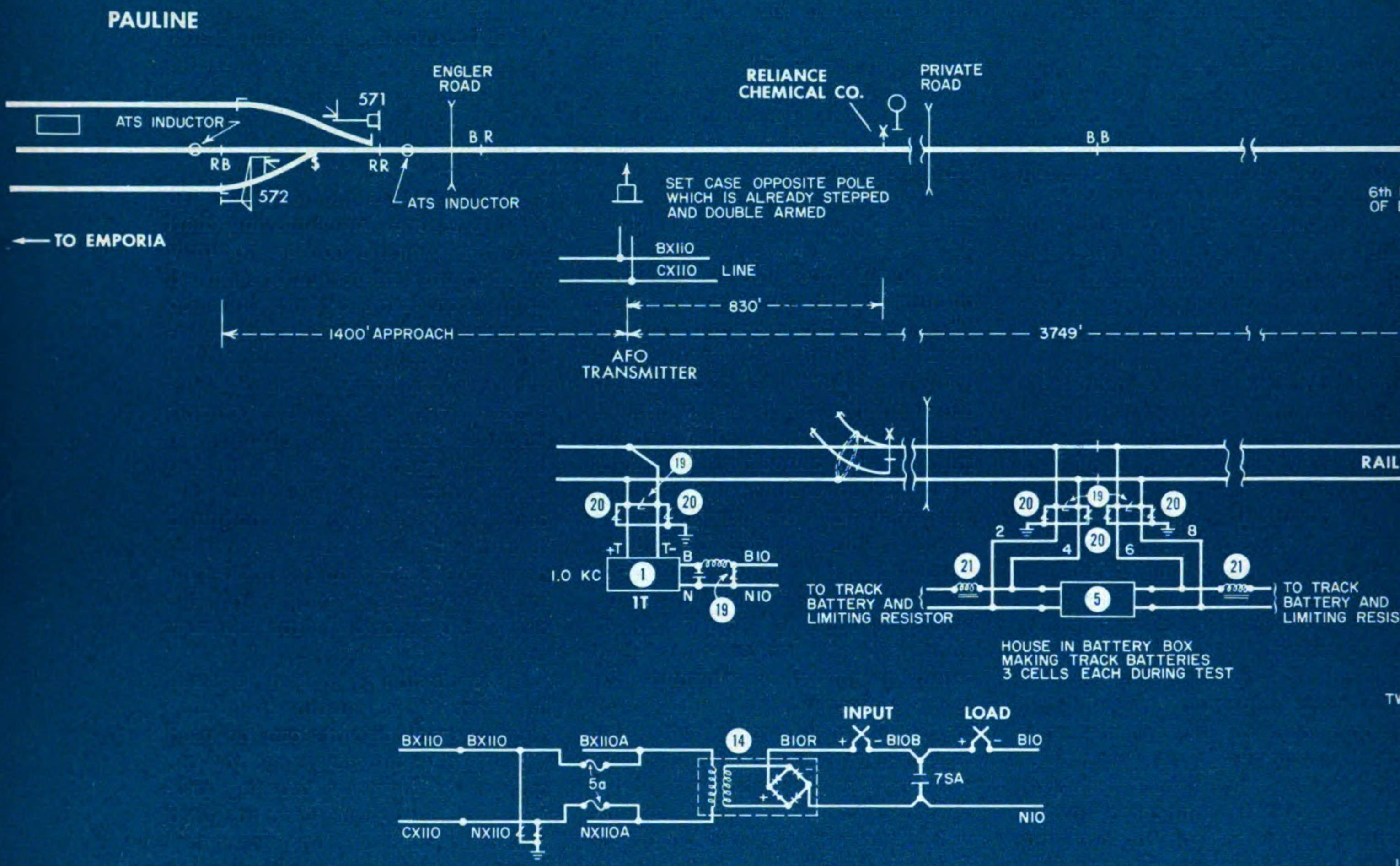
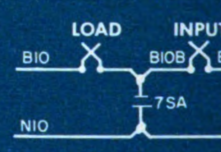
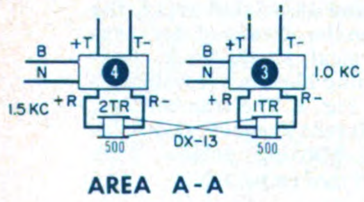


Fig. 1

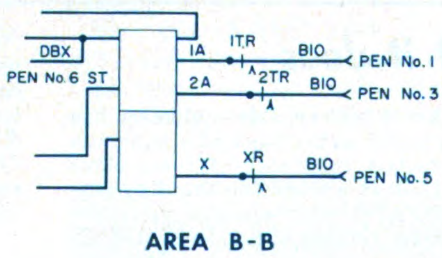




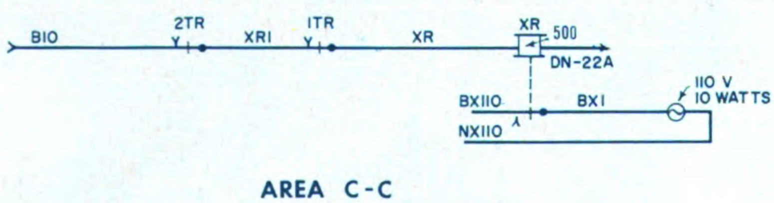
AFO WITH INTERLOCKING RELAY



AREA A-A



AREA B-B

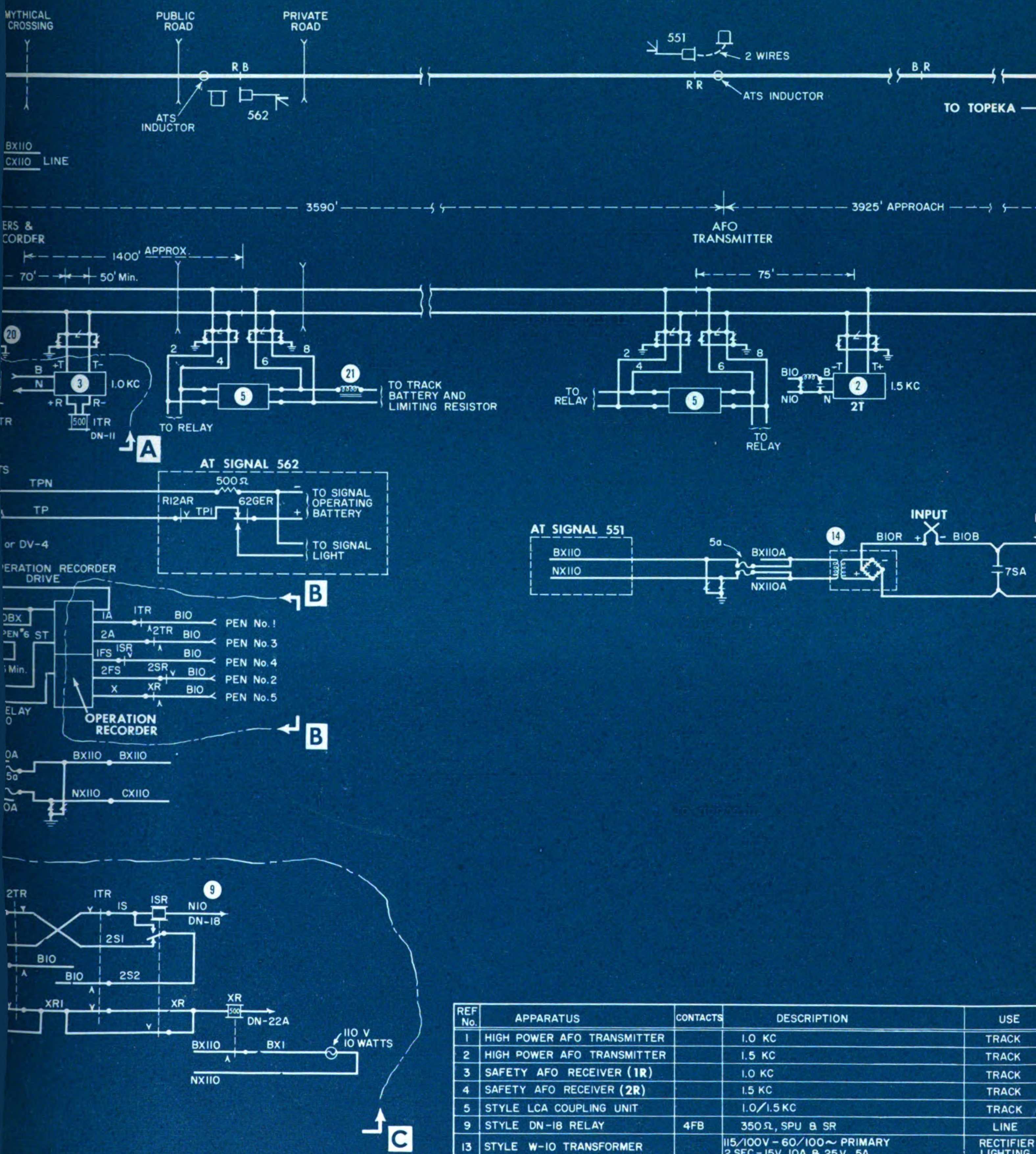


AREA C-C

NOTE:

CIRCUIT CHANGES REQUIRED FOR INTERLOCKING RELAY OPERATION

INTERLOCKING RELAY



REF No.	APPARATUS	CONTACTS	DESCRIPTION	USE
1	HIGH POWER AFO TRANSMITTER		1.0 KC	TRACK
2	HIGH POWER AFO TRANSMITTER		1.5 KC	TRACK
3	SAFETY AFO RECEIVER (1R)		1.0 KC	TRACK
4	SAFETY AFO RECEIVER (2R)		1.5 KC	TRACK
5	STYLE LCA COUPLING UNIT		1.0/1.5 KC	TRACK
9	STYLE DN-18 RELAY	4FB	350 Ω, SPU & SR	LINE
13	STYLE W-10 TRANSFORMER		115/100V - 60/100 ~ PRIMARY 2 SEC - 15V 10A & 25V 5A	RECTIFIER LIGHTING
14	STYLE RT-11 RECTIFIER		110V - 60/100 ~ A.C. 13.5V - 0.9A. D.C.	BATTERY CHARGER
15	STYLE RX-21 RECTIFIER		20V - 60/100 ~ A.C. 13.5 V - 1.7A. D.C.	BATTERY CHARGER
19	STYLE USG LIGHTNING ARRESTER		SHUNT GAP ARRESTER	TRACK SHUN
20	STYLE USG LIGHTNING ARRESTER		SERIES LINE ARRESTER	TRACK SERI
21	TRACK REACTOR			

AFO continued

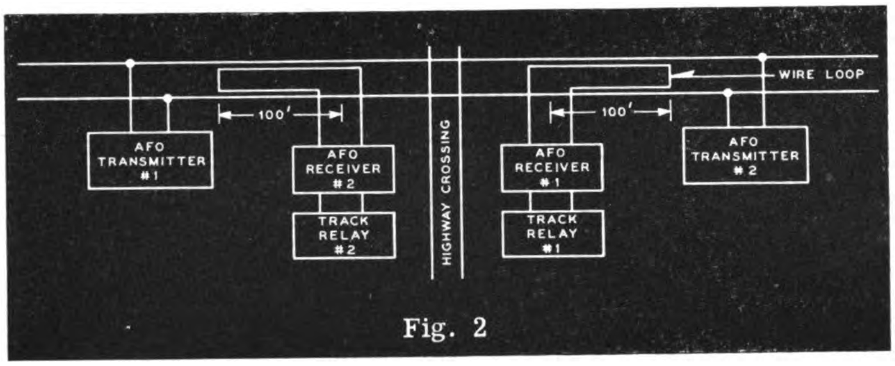


Fig. 2

(*Continued from page 33*)

receiver, also of a correspondingly different frequency, is located on the opposite side of the crossing from its associated transmitter. **Overlapping the two AFO circuits creates the equivalent of an "island" track circuit. Receding movements will normally permit energization of the AFO relay on the far side of the crossing when the last axle is less than 100 ft beyond the crossing.**

If the length of the approach circuit does not exceed 2,500 ft (20 sec warning time at 85 mph), the receiver may be connected to the rail in the usual rail-to-rail or multiple arrangement, as shown in Fig. 1.

For a 2,500 to 4,000-ft approach warning distance, the receiver must be inductively connected to the track with a 100-ft wire loop laid parallel to and between the rails, as shown in Fig. 2. This is necessary to insure a shunting sensitivity of at least 0.06 ohms throughout the entire length of the approach circuit. With the circuit shown (Fig. 2), the input to the receiver is obtained from the voltage induced into the loop by AFO current in the rails. With infinite ballast resistance and an unoccupied track, AFO current is only that which flows through the output circuit of the transmitter for opposite direction of traffic. The receiver is so adjusted that even this small amount of residual AFO current will hold the AFO relay up.

The loop circuit conductor may be uninsulated wire, such as stranded fouling bond wire stapled to the top of the ties approximately 6 in. from the inside base of the rails. If a shorter loop is desired, multiconductor insulated cable may be used. Thus, if the desired loop length is 50 ft, a two-turn loop must be used.

The shorter multi-turn loop can be used to reduce the receding ringing distance, however, only as the length of the approach is reduced below 4,000 ft.

Transmitter

Two styles of transmitters have been developed for highway crossing protection to be utilized for the approach circuit lengths desired.

For those circuits which do not exceed 2,500 ft, the transmitter is similar in size, power output level and appearance to those employed in switch lock releasing circuits.

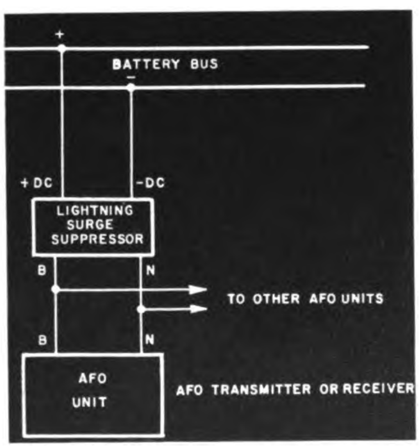
If the desired circuit length is between 2,500 and 4,000 ft, a larger transmitter having a power output capacity approximately ten times that of the conventional transmitter is required. To accommodate the additional power output, this transmitter is equipped with a ventilating case for heat dissipation.

Both models, however, consist of an audio frequency oscillator followed by a Class A amplifier stage and a push-pull Class B output stage. A series-tuned filter in the output stage allows the transmitter to be connected across the rails without interference from or to conventional signal circuits.

Standard transmitter frequencies are 1.0 kc and 1.5 kc for the higher-power transmitter and 1.0 kc, 1.5 kc and 1.95 kc for the lower-power model. However, provision for other frequencies can be made if required.

Receiver

Because highway crossing control circuits are vital, the AFO receiver utilized for this purpose has been designed for fail-safe operation. Derangement, of any kind that could falsely energize the associated relay immediately renders the receiver inoperative. This reliability is achieved by incorporating into the receiver self-checking design features, including four turned circuits arranged in cascade.



All AFO track units require adequate lightning protection. For protection against surges entering through battery terminals of AFO units, connect a lightning surge suppressor between battery and AFO units. Only one suppressor is required to protect all AFO units in one instrument case

The input circuit of this unit includes a filter which, while blocking all other a.c. frequencies and direct current, passes only the AFO tone. A two-stage transistor amplifier stage follows the filter. The output stage is a push-pull Class B transistor amplifier. A rectifier converts the signal from the output stage to direct current. This voltage is then fed to the receiver output terminals for connection to the control relay.

The receiver includes two output voltage adjustments. Coarse adjustments to take care of wide differences in track circuit length are made by shifting jumper straps on four external terminals. The receiver output increases when resistance is shorted. The three jumper straps are all installed for the longer approach distances. As the approach distance becomes appreciably shorter, one or more of the jumpers may be removed. A slotted shaft potentiometer mounted in the top of the receiver case provides for line output adjustment.

Lead Specifications

Lead resistance should not exceed the following values: (1) transmitter to rails, 0.15 ohms; (2) receiver to rails, 0.15 ohms; (3) receiver to relay, 25.0 ohms; (4) battery to receiver, 0.5 ohms.

Track leads should be arranged for minimum series inductance. Two-conductor cable is preferred, but a single conductor may be used if the wires to each unit are twisted together. If metallic-sheathed cable is used, it must be two conductor with both wires in the cable connected to the same unit.

Receiver Relay

In order to hold the receding ringing distance to a minimum on non-code circuits, the receiver relay must be a Style DN-22BH or PN-150-BH relay.

In electrified territory, the input to the AFO transmitter should be coded at 180 code and the code following receiver relay should be a Style CD-F with tuned (180 code) decoding contact.

Power Requirements

Both the transmitter and receiver are designed to operate from a nominal 10-volt or 12-volt d.c. source.

Power consumption at 10 volts for the high and low-power transmitters is 5.5 and 0.3 watts, respectively.

Receiver power consumption at 10 volts is 0.3 watts. This unit and the low-power transmitter may be operated either from primary cells or storage batteries.