# United States Patent [19]

**Ackard et al.**

[11] **3,838,271**

[45] **Sept. 24, 1974**


[54] **FAILURE DETECTION FOR HIGHWAY GRADE CROSSING SIGNAL SYSTEMS**


[75] Inventors: **David A. Ackard**, Claridge; **Donald E. Stark**, Penn Hills Township, Allegheny County, both of Pa.

[73] Assignee: **Westinghouse Air Brake Company**, Swissvale, Pa.



[22] Filed: **Jan. 5, 1973**

[21] Appl. No.: **321,132**

[52] **U.S. Cl.** ..... **246/125**, 246/28 F

[51] **Int. Cl.** ..... **B61d 1/02**

[58] **Field of Search** ..... 246/125, 128, 130, 28 F; 340/214, 410, 411



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,864,805 | 6/1932 | Crago | 246/28 F |
| 3,313,933 | 4/1967 | Sibley | 340/214 |
| 3,390,256 | 6/1968 | Clanton et al. | 246/125 |
| 3,660,652 | 5/1972 | Staples et al. | 246/125 |
| 3,781,542 | 12/1973 | Brockman | 246/125 |



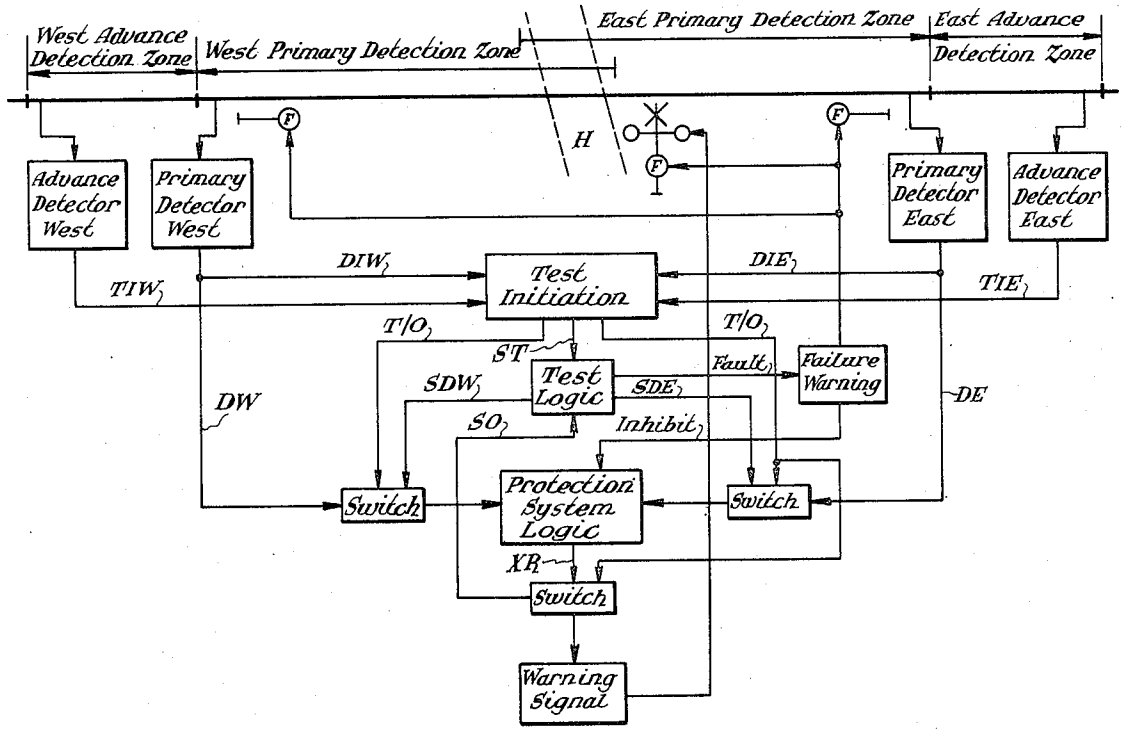
*Primary Examiner*—M. Henson Wood, Jr.
*Assistant Examiner*—George H. Libman
*Attorney, Agent, or Firm*—H. A. Williamson; A. G. Williamson, Jr.



[57] **ABSTRACT**

An advance train detector for each direction of travel is added to a conventional two-direction, overlap highway crossing protection system. Detection of a train, prior to its occupancy of the primary approach warning section, by an advance detector actuates a test logic means to drive the conventional crossing protection control logic through an operational sequence simulating the passage of a train. The test logic monitors the warning signal outputs from the conventional protection logic during this simulated train passage to assure that a proper, safe warning operation is possible for the approaching train. Failure to detect proper warning signal outputs activates a failure warning indication and inhibits response by the crossing logic to occupancy of the approach warning sections by the train.


**5 Claims, 2 Drawing Figures**



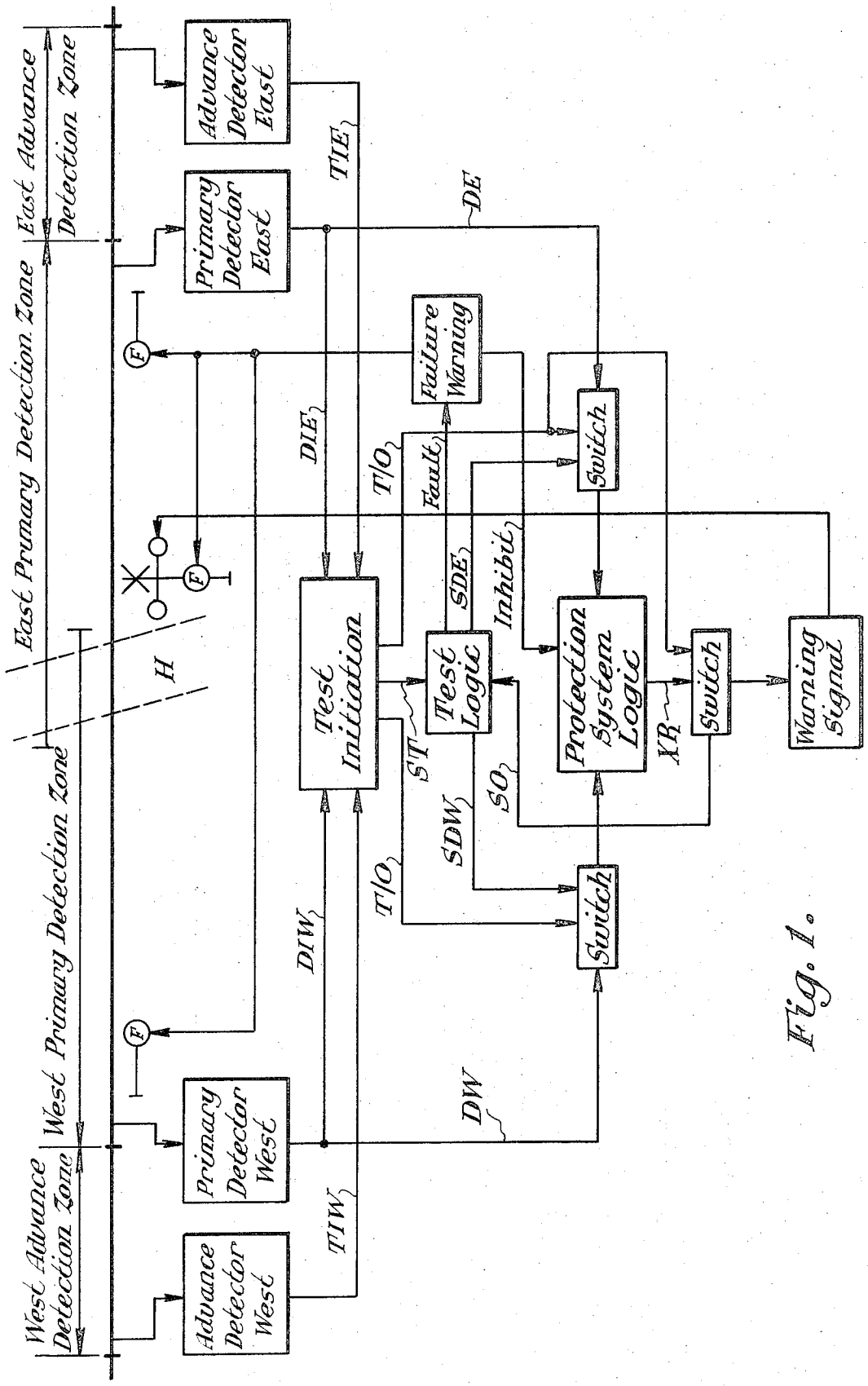

East Primary Detection Zone
East Advance Detection Zone
West Primary Detection Zone
West Advance Detection Zone
H
Advance Detector East
Primary Detector East
Primary Detector West
Advance Detector West
Failure Warning
Switch
Test Initiation
Test Logic
Protection System Logic
Switch
Switch
Warning Signal
TIE
DE
DIE
T/O
Fault
SDE
Inhibit
ST
SDW
SO
XR
DIW
T/O
DW
TIW

Fig. 1.

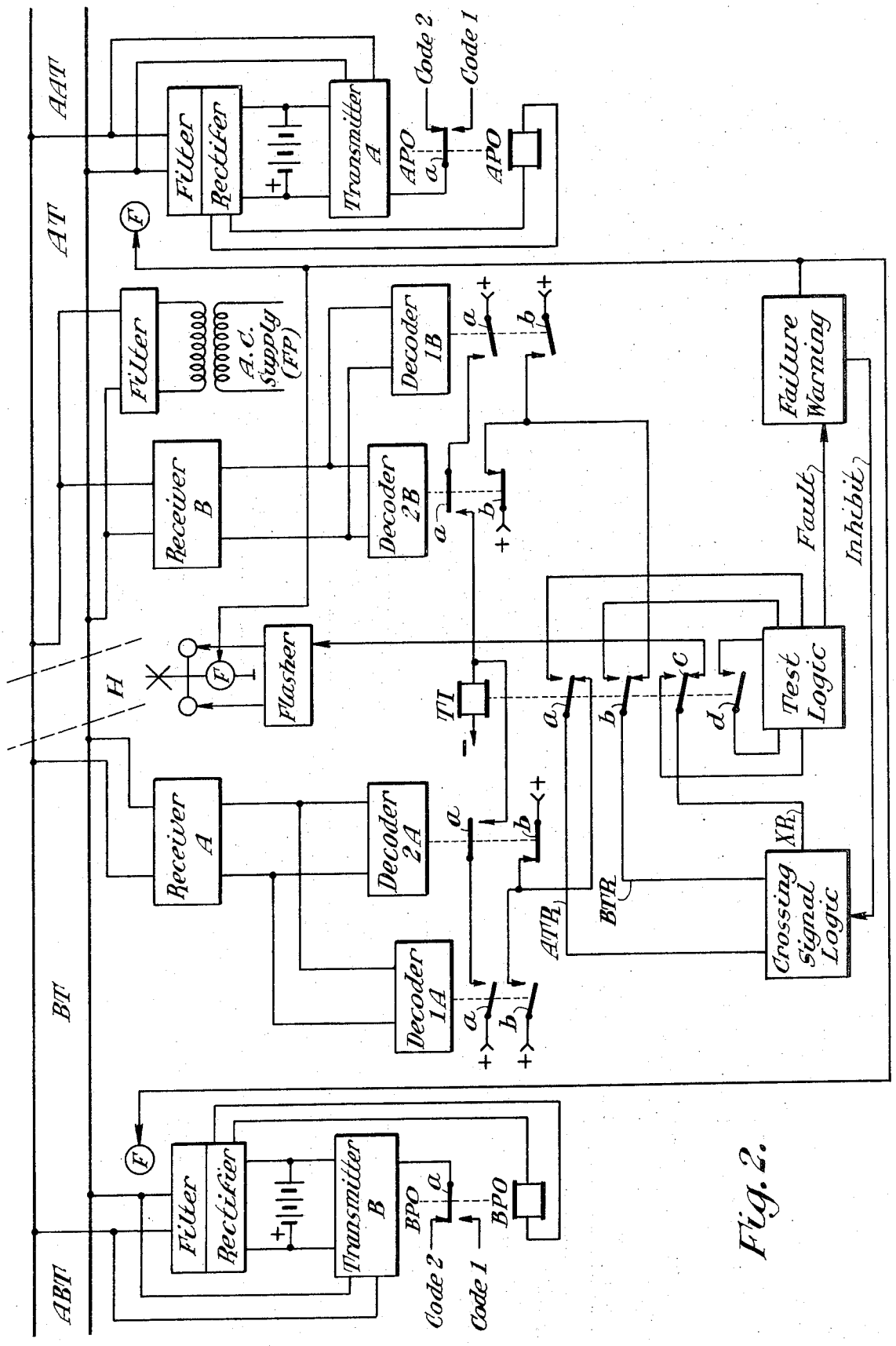

AAIT
AIT
BIT
ABIT
H
Filter
Rectifier
Transmitter A
APO
Code 2
Code 1
Filter
A.C. Supply (FP)
Receiver B
Decoder 1B
Decoder 2B
Flasher
TTI
Receiver A
Decoder 2A
Decoder 1A
Test Logic
Failure Warning
Fault
Inhibit
Crossing Signal Logic
XR
BTR
AITR
Filter
Rectifier
Transmitter B
BPO
Code 2
Code 1

Fig. 2.

# FAILURE DETECTION FOR HIGHWAY GRADE CROSSING SIGNAL SYSTEMS

Our invention relates to a failure detection arrangement for highway grade crossing signal systems. More particularly, the invention pertains to an arrangement for checking or testing highway-railroad grade crossing warning signal and other protection systems for proper operation, prior to a requirement to warn of an approaching train, in order to indicate to highway users and train crews, if a fault condition within the system is detected, that a normal warning signal cannot be provided.

One problem in providing effective protection for highway users at railroad-highway grade crossings is to create confidence in the operation of the protection system and respect for its warnings. A corollary is that the system should indicate to the highway user when proper operation of the warning system is not possible due to an apparatus fault so that the highway user may exercise extra precaution. This requires some form of testing to determine the operability of the warning or protection signaling system. At the same time, it would be well to indicate to the crew of an approaching train that a normal highway warning is not being given and to require the crew under such conditions to inform maintenance personnel of the fault. The conventional train detection portion of such protection systems is already on a fail-safe basis so that any fault or failure actuates a warning signal. However, at the same time, the protection system may include a timing cutout to clear the warning if a normal reset does not occur within a preset time period which, of course, it cannot do if a detector track circuit failure exists. Such timing cutouts eliminate any long continuous warning periods which unnecessarily delay highway traffic but may result in an improper or lack of operation for a subsequent train. Due to the gradual shift from relay to solid state apparatus in the logic portions of such highway warning systems, there is further reason or requirement to provide an operational test of the warning equipment prior to its required use. Although fail-safe solid state circuitry is possible and is used, it is rather expensive and any timing cutout arrangement may reduce or eliminate the fail-safe characteristic. As a convenience then to highway users and to increase railroad crossing safety by reducing accidents, an arrangement is needed to test the warning system immediately prior to a requirement for its operation to warn of an approaching train. Such testing provides additional safety, warns highway users when an inoperable condition exists, and can also inform train crews of the absence of any indication of train approach. Such a testing arrangement will allow the use of fewer vital control circuits and apparatus for the warning signal system by reducing the overall requirement for extra fail-safe characteristics and will allow the use of a timing cutout of a continued warning resulting from a fault condition without eliminating all subsequent warning of approaching trains.

Accordingly, an object of our invention is a failure detection arrangement for highway crossing warning signal systems.

Another object of the invention is to provide apparatus for testing the operation of a highway-railroad crossing signaling system, immediately prior to a requirement for its operation to warn of an approaching train, and for indicating to highway users and the train crew if a fault condition exists.



A further object of our invention is a method of testing highway crossing protection systems for proper operation upon train approach by simulating the passage of a train through the crossing stretch and checking to determine that the proper output signals occur from the crossing logic circuits.

It is also an object of our invention to provide an arrangement for testing the condition of a highway crossing signaling system immediately prior to an operational requirement to determine its ability to properly warn of the approach of a train and to reset upon the departure of that train.

Still another object of our invention is a testing arrangement or apparatus for a highway crossing signal system which detects the approach of a train to the warning area, tests the operable condition of the control apparatus by simulating the passage of a train and checking the output to control warning devices, and actuates a fault indication to the train crew and highway users if the warning signal system fails to respond properly during the simulated train passage.

A further object of the invention is a method of testing highway crossing signaling systems, immediately prior to a required operating period to warn of a train approach, by detecting in advance the approach of a train to the warning section, switching the signaling system to a test mode, simulating the passage of a train through the crossing signal area, registering and checking the system operation during this simulated operation, and actuating an auxiliary signal to warn highway users and the train crew of the failure of the signal system to operate properly, if proper operation does not occur, so that additional precautions may be taken to assure the safety of the highway users.

Other objects, features, and advantages of our invention will become apparent from the following specification when taken in connection with the accompanying drawings and appended claims.

In practicing our invention, the test arrangement is added to a conventional highway crossing signaling system of the two-direction, overlap type using overlay detector track circuits. However, in principle, the arrangement of our invention is usable also in cooperation with newer crossing warning arrangements using other types of train detection and with solid state or integrated logic circuitry. The first feature of the arrangement is the detection of an approaching train prior to the time that it enters the principal detection zone in the approach to the crossing in which a warning signal should be displayed. A plurality of different types of apparatus may be used to accomplish this advance train detection. Wheel detectors, radar, laser or other optical devices, and inductive means are possible arrangements for advance train detection. In the specific showing, a second track circuit is used which also supplies operating power through the rails to the transmitter source of the regular detector track circuit. This advance detection of an approaching train actuates a testing operation. The initiation of the testing mode transfers control of the crossing logic means from the regular train detection means to a test logic means. This test logic means is a cycling apparatus which steps through a predetermined sequence of testing conditions. In effect, the test logic drives the conventional crossing logic apparatus through a simulated passage of a train in the highway crossing area, that is, through its approach and occupancy of the crossing and departure on

the other side. The occupancy of each crossing warning section is simulated in turn. The response of the conventional crossing logic apparatus is checked by the test logic means as to its registry of the simulated occupancy, the output of a warning signal to simulate the actuation of the highway warning signals, its directional lockout as the train clears the crossing in order to eliminate the highway warning as the train recedes on the opposite side, and finally the reset of the crossing signal apparatus.

If the test logic detects any improper operation during this testing cycle, it actuates a failure warning means which can display a warning indication to highway users, directing extreme caution and observance as they approach and use the railroad crossing, and a special signal to inform the crew of an approaching train that the crossing signal is inoperable so that a repair crew can be called. The failure warning also inhibits further operation of the crossing logic apparatus. At the end of the testing period or cycle, if the conventional crossing apparatus operation under test is found to be proper, the test logic means restores the crossing signal apparatus to its normal operating mode, that is, to control by the conventional detector track circuits so that the warning of the approaching train can be actuated and displayed in the normal manner. As the train recedes from the crossing and departs from the conventional detection zone on the departing side, a second test period is actuated as the train passes through the opposite advance approach section. This additional test period, which occurs in a similar manner by sequencing another simulated passage of a train, provides certain checks to determine whether a failure of the conventional train detection apparatus and control logic means for the crossing signal has occurred as the train was receding from the crossing and during which time the warning signal was locked out by the directional stick arrangement. This provides a particularly important check so that the approach of a subsequent train from the opposite direction will not result, due to the fault condition, in the absence of any warning for highway users.

We will now describe in greater detail highway crossing signaling apparatus embodying the features of our invention and then point out the novel features thereof in the appended claims. During the detailed description, reference will be made from time to time to the accompanying drawings in which:

FIG. 1 is a schematic illustration in block diagram form showing a conventional crossing warning signaling system to which have been added features embodying our invention.

FIG. 2 is a diagrammatic illustration, partly in block diagram form and partly a circuit diagram, of a specific highway crossing warning system of a conventional type, such as schematically shown in FIG. 1, to which specific test apparatus embodying the features of our invention has been added.

In each of the figures of the drawings, similar reference characters refer to similar parts of the apparatus.

Referring to FIG. 1, across the top by a conventional single line symbol is illustrated a stretch of railroad track which is intersected by a highway H, shown by the double dashed line symbol at the center. Trains move in either direction along this stretch of track across the highway-railroad grade crossing. This grade crossing is provided with an automatic highway warning signal protection system. The warning signal for highway users is indicated by the obvious symbol positioned in the vicinity of the highway crossing to which has been added a failure warning signal F, which will be discussed later. Although this conventional crossing signal symbol specifically represents the well-known flashing light type, it also here designates all the signal protection units known for such crossing warnings. Specifically, there may be equivalent or duplicate flashing light signals on both sides of the railroad track to provide warning for each direction of highway traffic. Also covered by the representative symbol is automatic gate apparatus which is known and frequently used to provide additional crossing protection. Any of these well-known warning arrangements, as well as those that may be developed or added in the future, would be usable in the test arrangement provided by our invention.

The overall failure detection arrangement of our invention may be configured as shown in this block diagram of FIG. 1. Each of the two track approaches to the crossing is equipped with two train detection arrangements, the outer or more remote serving to initiate a preoccupation test sequence and the inner detection apparatus serving to initiate the conventional crossing protection system operation in a customary manner. The outer or remote detection units are referred to as the Advance Detectors West and East while the inner units are designated as the Primary Detectors West and East. The zone of train detection for each detection apparatus is indicated by conventional arrow symbols setting apart the detection zones covered. Outputs of all train detectors are applied to the test initiation means, shown by a conventional block, which then determines, on the basis of the inputs, whether the overall protection system should be in the test or operate mode. The blocks designated as switches are highly secure or reliable switch apparatus controlled by the test initiation means to connect the system either in its test configuration or in its operate configuration.

The protection system logic means, shown here by a conventional block, performs all the functions normally performed by the highway crossing protection system logic. In normal operation, it actuates the protection or warning signals depending upon the status of the primary detector units. This operation includes the determination of the direction of approach of the train, the actuation of the warning signal, and the discontinuing of the warning when a train has cleared the actual crossing and is receding through the opposite direction primary detection zone. The test logic means issued to check the conventional protection system logic when a test sequence is initiated upon the advance approach detection of a train. This test logic means is a cycling apparatus which provides a predetermined sequence of test conditions to simulate the passage of a train through the stretch. The test logic also checks and verifies the protection system logic outputs during this test cycle. These are the outputs which normally actuate the operation of the highway crossing signal and later cut off its operation as the train recedes.

A successful test sequence completion allows the protection system logic to actuate the warning signals in the normal manner as controlled by the primary train detection apparatus to provide a normal train approach

warning to motorists of the approach of a train. The failure warning means is actuated by the test logic if any abnormal operation of the conventional protection system logic is detected. This in turn activates the display of a failure warning indication to rail and highway traffic and also inhibits operation of the protection system logic in response to the primary detectors. The failure warning indicators are special indicators or signals, illustrated in FIG. 1 by a small circle with an enclosed letter F, operated by the failure warning means when the test logic detects an abnormal operation by the protection system logic. As shown, such special signals F may be positioned to indicate to an approaching train the improper operation of the highway warning signal while others may be positioned so as to warn highway users that extra precaution should be taken since the normal warning arrangement is not operating properly.

We shall now describe the basic operation of our invention with reference to the broad schematic illustration of FIG. 1. Assuming that a train is approaching the highway crossing from the left of the drawing, or from the west, the Advance Detector West provides a test initiation output signal TIW in response to the detection of the train entering the west advance detection zone. This TIW signal actuates the test initiation means to provide outputs on the test/operate signal lines T/O which position the switches to the testing position. Another signal on the start test line ST activates the test logic means. The test logic means is specifically provided with any known cycling apparatus which will rapidly produce a predetermined sequence of output signal to simulate the passage of a train through the crossing stretch. These signals appear and are then removed in this sequence on the simulate detection lines SDW and SDE. The signals simulate the occupancy of the west primary detection zone and the east primary detection zone in that order by the eastbound train. These outputs from the test logic means are applied through the corresponding switches, which are now in their test position, to the protection system logic means. This conventional logic means produces a warning signal output XR during the time that the crossing signal operation should exist to warn of the simulated train movement. The test logic means receives this XR signal through the positioned switch as a simulated output SO, although this signal could be applied direct since its appearance during normal operation will not have any effect on an inactive test logic means. The test logic cycles set up test circuits to assure that signal SO is received at the proper time and then is removed so that there will be no back ringing of the crossing signal as the train recedes. If the crossing protection system logic fails or operates improperly so that no signal XR appears, or appears at the wrong period of time, the test logic means actuates the failure warning apparatus which, in turn, activates the special warning signals F to display a warning to highway traffic that the crossing signals are not operating properly. Under such failure conditions, further operation of the protection system logic means in response to train detection signals from the primary detectors is inhibited by the test logic until the fault is corrected.

When the train reaches the primary or regular detection zone, with no failure warning registered, the primary detector outputs signal the test initiation means to restore the switches to the operate position so that the normal protection operation mode is enabled. The test or simulated operation has completed prior to this time since the test period is on the order of only 3 to 5 seconds duration. Thus, the output signal DIW from the Primary Detector West causes the test initiation means to restore the switches to the operate position and turn off the test logic apparatus. An alternate arrangement could be to have the test logic means, when the test sequence is completed, actuate the restoration of the switches to their operate position. In any event, the outputs from the primary detectors on the DIW and DIE lines inhibit any further test operation while the primary detection zones are occupied.

In the normal operating mode, the protection system logic receives the primary detection signals DW and DE and actuates the operation of the crossing warning signal in a conventional way to provide an indication to the highway users of the approach of a train. The crossing signal operates until the train clears the highway H and then the sole application of the detection signal DE to the protection system logic activates cutout of the signal operation as the train recedes from the crossing. When this train clears the east primary detection zone, the occupancy of the east advance zone actuates another test period, the output on the signal line TIE from the Advance Detector East actuating the test initiation means to enable the test period. The test logic sequence under these conditions may be reversed to simulate the movement of a train in the other direction. In any event, this second test operation is similar to that already described and determines if the system is ready for the next train. If any fault is detected, the special signals F are actuated by the failure warning means to continue to display an indication until the fault can be repaired.

It may be noted that the passage of a train through an advance detection zone, during its approach, may also be used to actuate timing means which determine the relative speed of that train. This measurement can then be used to provide a more uniform operating time for the highway crossing signals, i.e., a relatively equal warning period prior to the arrival at the highway of trains moving at different speeds. A simple arrangement, already known in the art, delays the activation of the crossing signal after the train enters the corresponding primary detection zone for a period selected in accordance with its speed relative to the maximum allowed speed.

Referring now to FIG. 2, we shall describe a specific crossing protection system embodying our test arrangement. Across the top of FIG. 2 is a two-line symbol representing the stretch of track which is intersected by a highway H, designated by the double dashed lines near the center. The East and West Primary Detection zones are represented by the track sections AT and BT, respectively, while the East and West Advance Detection zones are represented by the approach track sections AAT and ABT, respectively. In this specific example, the primary train detectors utilized are jointless overlay track circuits for which power is supplied through the track rails to the transmitter equipment located at the remote or distant end of the crossing approach warning section. This power supply technique provides, in addition to the customary detection signal, a second distinct current in the rails which, with proper treatment, may also be used to provide the advance detection circuits required by this particular failure detection arrange-

ment of our invention. Through the selection of appropriate power transmission frequencies and the selection of appropriate power levels, power supply current can be made to propogate sufficiently beyond the normal track circuit to provide the advance detection zone. A power off detector incorporated into the approach equipment permits the detection of shunting of the power frequency as a train approaches through the advance zone before the primary detection signal is shunted. This power circuit detection functions, therefore, in advance of the normal detection circuit providing for the detection of a train approaching the remote limit of the primary detection zone of the rail powered track circuit.

Thus, in the showing of FIG. **2**, the primary train detection means comprises two alternating current overlay track circuits. Each includes basically a transmitter means connected to the rails at the remote or distant end of the corresponding detection zone and a receiver means connected across the rails at the highway crossing location on the opposite side of the highway from its associated transmitter. For example, for the east primary detection zone or track section AT, an overlay track circuit A is provided which includes a transmitter A, connected to the rails at the east end of section AT, and a receiver A connected to the rails at the highway crossing on the opposite side from transmitter A. Track section BT is provided with a corresponding track circuit including transmitter B and receiver B. Each of these transmitters and receivers may be circuited as disclosed in Letters Patent of the United States No. 3,035,167, issued to Philip H. Luft, on May 15, 1962, for a Railway Track Circuit. However, it will be obvious that other types of transmitters and receivers, including even those designed with integrated type circuits, may be used if they provide similar type operation of the track circuits. It is also to be noted that the transmitters and receivers A and B, shown here, are positioned along the rails and coupled thereto in the manner shown in FIG. **1***a* of the reference patent, except that each receiver is directly connected across the rails as shown in FIG. **1***b* of this reference. The two sets of track circuit apparatus provide an overlap area at the crossing which serves as the island track circuit for positive train detection.

Each of the receiver units is energized by a local direct current source in a conventional manner and thus this operating energy supply is not specifically shown. Each remotely positioned track circuit transmitter receives power through the rails of the track from a central source at the highway location in a manner similar to that shown in Letters Patent of the United States No. 3,069,542, issued Dec. 18, 1962, to Charles W. Failor, for Railway Track Circuits. Here the central source is an alternating current supply source FP having the commercial power frequency although, if necessary to avoid interference with other track circuits in use, a special frequency source may be used. It is also possible, if other track circuits permit, to use a direct current source for this rail power arrangement. Special features necessary to separate battery charging and power off detection at the transmitter location will be apparent to those practicing the art. The alternating current energy supply is transformer coupled through a tuned filter to the rails at the central location. Energy in the form of a track current of the corresponding frequency FP flows in the track both ways from the rail connections and actually beyond the points at which the track circuit transmitters are connected. The extension of the flow of the track current of this frequency FP is in accordance with the frequency used and power levels chosen.

At each transmitter location, a full-wave rectifier is connected across the rails through a filter unit to receive the alternating current power. The purpose of the filters at these locations and at the central supply is to avoid shunting the track currents of the overlay track circuits and of any track circuits in use for a conventional signaling system to control the movement of trains. Each rectifier produces a direct current output to charge a local battery at the same location which, in turn, energizes the associated transmitter unit. Energy from each rectifier-filter means is also provided to a power off relay which may be either an a.c. or a d.c. relay. If of the d.c. type, energy is supplied by a separate rectifier while an a.c. relay is connected across the input to the battery rectifier. These relays are used to detect the a.c. power off condition and thus an approaching train shunt. For example, at the west end of section BT, the rectifier-filter package connected across the rails supplies energy not only to the local battery but to the winding of power off relay BPO so that this relay is normally energized. A similar power off relay APO is provided at the east end of section AT.

The output of each track circuit transmitter A or B is connected directly across the rails at its remote location. However, each transmitter and receiver includes within the designating block symbol the necessary tuned filter for selectively supplying or receiving to or from the rails the track circuit energy of the assigned frequency and, at the same time, preventing the unit circuits from acting as a shunt across the rails for track currents of other frequencies. A modulating signal is applied to each transmitter for modulating its output into the track circuit. This modulation occurs at a first or a second code rate in accordance with the position of the associated power off relay. The specific sources of the modulating code rates 1 and 2 are not shown since they may be supplied by the well-known track coders used in railway signaling arts, or by other known modulation means. Thus, each track circuit transmitter, as long as the associated power off relay is energized, supplies a track circuit current at its assigned frequency and modulated by the code rate 2. When the power off relay is released, closing its back contact *a*, the modulation code rate is shifted to code 1.

Since the supply frequency current applied to the track rails at the central location is received not only by the rectifier but flows also in the advance detection zone more distant from the highway crossing, the approach of a train will cause the release of the power off relay when the power supply current is shunted away from the associated rectifier. For example, relay BPO will release because it is no longer supplied energy from its associated rectifier when a train approaches from the west and occupies the west advance detection zone or track section ABT. Thus, transmitter B applies current at the code rate 2 as long as section ABT is not occupied by a train. As soon as an approaching train shunts away the power current so that relay BPO releases to close its back contact *a*, the modulation code rate of the current supplied by transmitter B is shifted from code 2 to code 1. This provides a means of detect-

ing the advance approach of a train toward the highway crossing. It will be apparent that, instead of coded energy, steady track energy may be supplied by each transmitter when the associated PO relay is released. Under this arrangement, the decoding means associated with each receiver, to be discussed shortly, will be designed to distinguish between coded and steady energy receiver outputs rather than between two code rates. Such modifications in the decoding circuits are well known in the railway signaling field.

At the central or highway location, each track circuit receiver is connected across the rails to receive track circuit current of the assigned frequency from its associated transmitter at the distant location. When track circuit energy is being received, each receiver supplies a modulated or code rate output signal which is applied in multiple to two demodulating or decoder units. For example, when track coders are used to provide the modulation code rates, well-Known tuned decoder units used in railway signaling practice may be provided to demodulate the code rate. Other types of decoding or demodulating devices may also be used. In any event, when the corresponding assigned code rate is being received, each decoder unit controls a pair of associated contacts to close in the upper or front contact position. These contacts may actually be contacts on a decoding relay, which is energized by the decoding unit only when the designated code rate is being received. However, the contacts are here shown as being directly controlled by the corresponding decoder unit. In other words, the contact armature is picked up when the assigned code or modulation rate is received. Since code rate 2 is normally active or transmitted from each transmitter location, decoders 2A and 2B, associated with receivers A and B, respectively, are normally active and hold their armatures picked up so that front contacts are closed and back contacts are open. Under these normal conditions, the contact armatures controlled by decoders 1A and 1B are released, since the decoders are not active, and front contacts are open.

In the arrangement of FIG. 2, the test initiation means is provided by the test initiation relay TI. This relay is provided with a first energizing circuit which extends from the positive terminal of a local direct current energy source over front contact *a* of decoder 1B, back contact *a* of decoder 2B, and through the relay winding to the negative terminal of the source. A second energizing circuit includes front contact *a* of decoder 1A and back contact *a* of decoder 2A. Contacts *a*, *b*, and *c* of relay TI represents the three switch units shown in the schematic arrangement of FIG. 1. In each case, the front contact is closed to enable the test mode for the apparatus. Front contact *d* of relay TI, when closed, actuates the test logic means which is the same as the similarly designated means of FIG. 1. Briefly, it is a cycling apparatus having a predetermined sequence of outputs which simulate different track occupancy conditions in the stretch of track on each side of the highway crossing. This test logic means also receives the simulated warning signal output from the crossing signal logic means during the test mode and determines whether this warning signal occurs at the proper time in the track occupancy sequences. This last means is equivalent to the protection system logic means of FIG. 1.

The crossing signal logic means, designated by the block in the lower left of FIG. 2, may be similar to the relay logic circuitry shown in FIG. 1*a* of the previously cited Luft patent. The inputs to the crossing signal logic means, designated ATR and BTR, will control track relays similar to relays TR25 and TR20, respectively, of the Luft patent. The XR output signal from the crossing signal logic occurs when relay XR, shown in the Luft system, releases to close its back contact. Obviously, other types of logic circuitry, especially using solid state components, may also be used for this device. The flasher means, also designated by a conventional block, represents controls for the crossing signal units and the controls for any associated crossing gates or other warning devices which may be supplied. As is known, the two conventional signal lamps on the crossing signal will be alternately flashed at a preselected rate to indicate a warning condition, that is, a train approaching. The failure warning means, shown also by a conventional block, responds to a fault signal output from the test logic means to actuate the various signal indicators F which provide a warning to highway users and an indication to approaching train crews of the improper operation of the highway warning system under test conditions. An inhibit signal is also applied to the crossing signal logic to interrupt its response to train detection in sections AT and BT when a fault exists.

In describing the operation of the specific arrangement of FIG. 2, it is initially assumed that no trains are in any of the primary or advance detection zones. Since no trains are occupying the track sections shown, energy from the central power alternating current source FP is received at each transmitter location ans is rectified by the rectifier means to maintain the local battery charged and to energize the associated power off relay PO. The local battery, of course, continuously keeps the track circuit transmitter at that location energized and in its operating condition. Since each power off relay is picked up, code 2 modulation is applied to the track circuit transmitters and each track current furnished into the primary detection zone is modulated at this code rate. Thus, at the highway location the currents received by each receiver result in a modulation rate output which maintains the associated decoder 2 active so that its contacts are picked up. Since decoders 2A and 2B are active, the converse rules that decoders 1A and 1B are thus inactive and their contacts are released. Relay TI is deenergized and released since each of its energizing circuits is open. With back contacts *a* and *b* of relay TI closed, energy is supplied over front contacts *b* of decoder 2A and decoder 2B to inputs ATR and BTR of the crossing signal logic means. With each of these inputs energized, the output lead XR from this logic means is deenergized and thus supplies no signal to the flasher means so that the highway crossing signals are inactive. Obviously, the test logic means is also inactive since front contact *d* of relay TI is open.

It is now assumed that a train approaches the crossing from the west, occupying advance detection section ABT. At some point in this advance section, in advance of the rail connections of transmitter B, the train shunt draws sufficient track current from the power source to reduce the voltage supplied to the rectifier-filter to a degree that is insufficient to retain relay BPO energized and this relay releases. Of course, the local battery, being fully charged, maintains transmitter B opera-

tional. The release of relay BPO opens its front contact *a* and closes the corresponding back contact to replace the code 2 modulation with code 1 modulation. At the central location, receiver B thus supplies an output which activates decoder 1B and, at the same time, causes decoder 2B to become inactive. The contacts of decoder 2B are thus released while those of decoder 1B pick up.

A circuit will now exist to energize relay TI which includes front contact *a* of decoder 1B and back contact *a* of decoder 2B. Relay TI, thus energized, picks up and closes its front contact *d* to activate the test logic means. Front contacts *a*, *b*, and *c* of relay TI close to transfer the ATR and BTR inputs and the XR output of the signal logic means to the test logic connections. In other words, the test mode is now enabled. The test logic means, being activated, runs through its cycle of simulated train movement signals. These signals simulate the occupancy of the various track sections and are applied to inputs ATR and BTR of the crossing signal logic in a predetermined sequence to simulate the movement of the train into section BT and thence into section AT and on to the east. During the operation of the crossing signal logic under these simulated input sequences, the test logic means monitors the XR output lead to determine that a warning signal is supplied at the proper time during the simulated occupancy sequence. The failure warning means is actuated by a fault signal output from the test logic if an XR signal does not occur or occurs at the wrong time in the sequence operation. This test logic sequence is completed before the train arrives at the location of transmitter B.

When the train passes the rail connections of transmitter B and occupies section BT, receiver B at the highway location is deenergized since the train shunt interrupts the flow of current through the rails to that receiver. Decoder 1B is now also inactive and releases its contacts. Relay TI is deenergized by the opening of front contact *a* of decoder 1B since the second energizing circuit for this relay is still open. The release of the contacts of relay TI, closing all the back contacts, restores the detection mode to the active condition. With front contacts *b* of both decoders 2B and 1B now open, there is no energy on input lead BTR to the crossing signal logic means. This logic arrangement is thus actuated to initiate the warning signal operation. In other words, an XR signal is applied to the flasher means, over back contact *c* of relay TI, and the flasher means initiates the operation of a warning indication.

As this train proceeds through the track stretch, the crossing signal logic functions in a conventional manner. Briefly, the warning signal operates as the train approaches through section BT and while it is occupying the overlap or island track section which includes the actual highway crossing itself. Operation of the warning signal is halted when the train clears the crossing section and occupies only section AT. This condition remains in effect as the train recedes through section AT on its way to the east.

When this train first occupies section AT, it shunts not only track circuit A but also the power supply to transmitter A from the central source. Relay APO thus releases and remains released even after the train clears section AT and occupies only the near portion of the east advance section AAT. Thus, when this train clears section AT, a second test period is initiated since relay TI is then energized over its second circuit including front contact *a* of decoder 1A and back contact *a* of decoder 2A. This occurs since transmitter A is supplying track circuit energy to receiver A over the now clear track section AT but with the modulation rate at code 1 since relay APO is released. The test logic means is again actuated and another test cycle occurs. Again, a failure warning is actuated is improper XR output signals occur from the crossing signal logic means. The second test period checks certain possible lockup conditions which may occur in the crossing signal logic while the train recedes from the crossing. As during the approach test period, detection of a fault condition causes the test logic to lock out further operation of the warning signals until repairs are made. The second test period ends when relay APO picks up when the train shunt in section AAT becomes so remote that sufficient energy is received by the rectifier to energize relay APO. Although it is not shown specifically, the test logic means could be arranged to restore relay TI, that is, to release the relay, to end the actual test period prior to the pickup of relay APO. Under these conditions, front contact *b* of decoder 1A would then hold the crossing signal logic means inactive, or locked out, as the train recedes until decoder 2A again becomes active upon the energization of relay APO.

While the particular failure detection arrangement described is primarily intended to verify the integrity of system logic, verification of the performance of other hardware within the crossing protection system is also possible. For example, each time the crossing protection system operates normally, performance of the motorist warning signal, i.e., the flasher lights, may be monitored by current sensing devices or light sensitive cells. This would allow immediate detection of a signal lamp failure causing immediate actuation of the failure warning signal. Train detection device failures may be monitored and indicated by the failure warning. This may be accomplished by any of a variety of means depending on the detection device used. For track circuits, approach timing may be used to determine when a track circuit has indicated train presence too long without it occupying adjacent circuits. Other types of detection might supply failure alarms which could directly actuate the failure warning.

The arrangement of our invention thus provides, in a broad sense, means for testing the operability of highway crossing protection arrangements prior to and immediately after each use. Such a test is initiated by the approach of a train to the highway warning zone. Improper operation of the crossing apparatus during the test mode results in a special signal indication warning of the absence of the usual crossing protection. The testing is accomplished with a minimum of additional apparatus to the conventional warning system. The improved arrangement is adaptable to any crossing situation and type of warning apparatus with only the proper selection of train detection and test logic means to match the equipment already in use. The resulting test system or failure detection arrangement is thus efficient and economical in operation and installation.

Although we have herein shown and described but one specific arrangement for detecting the failure of highway crossing apparatus, it is to be understood that various modifications and changes may be made therein within the scope of the appended claims with-

out departing from the spirit and scope of our invention.

Having thus described our invention, what we claim is:

1. A highway crossing signal system, for controlling highway warning signals where the highway is intersected by a stretch of railroad track, comprising in combination,

a. an overlay track circuit, for detecting a train approaching the highway within an approach warning section requiring a warning to highway traffic, comprising,

1. a transmitter means connected to the rails at the distant end of the approach section and operable for supplying output signals to said rails,

2. a receiver means connected to the rails at said crossing on the opposite side of said highway from said transmitter means for receiving signals therefrom through the rails of said approach section when unoccupied by a train;

b. an advance detection means for detecting a train when in approach to said approach warning track section,

c. a modulation source connected to said transmitter means and controlled by said advance detection means for modulating the transmitter output signals by a first or second characteristic as a train is or is not detected, respectively, by said advance detection means,

d. a demodulation means coupled to said receiver means for detecting the reception of said first or second modulation characteristic,

e. a protection control means normally controlled by said track circuit and responsive to the detection of a train within said approach warning section for activating said warning signals to warn highway traffic of the approaching train,

f. a testing means controlled by said demodulation means and coupled to said protection control means when an approaching train is detected only by said advance detection means for simulating the passage of a train through said approach warning section and for monitoring the operation of said protection control means to simulate the proper activation of said warning signals in response to the simulated passage of a train, and

g. a failure warning means controlled by said testing means for registering a fault condition when an improper operation of said protection control means is detected during a simulated train passage test period,

1. said failure warning means operable for displaying an indication to highway traffic that an unsafe condition exists when a fault condition in said protection control means is registered,

2. said failure warning means also coupled for inhibiting further operation of said protection control means in response to the detection of a train by said track circuit when a fault condition exists.

2. A highway crossing signal system as defined in claim 1, for a stretch of track over which trains move in either direction, further comprising,

a. a track circuit for each direction of travel for separately detecting a train occupying the corresponding approach warning track section, each track circuit including,

1. a transmitter means having a distinctive frequency different than the other transmitter means and connected to the rails at the distant end of the corresponding section,

2. a receiver means connected to the rails at said crossing on the opposite side of the highway from, and responsive only to output signals of, the associated transmitter means,

b. an advance detection means for each direction of travel connected for detecting a train approaching the associated approach warning section and also for detecting a train receding from said crossing beyond that approach section,

c. a modulation source separately connected to each transmitter means and controlled by the corresponding advance detection means for modulating the associated transmitter output signals by a first or a second characteristic as a train is or is not detected by the corresponding advance detection means, and

d. a separate demodulation means coupled to each receiver means for detecting the reception of the first or second modulation characteristic by that receiver, and in which,

e. said protection control means includes control logic apparatus initially responsive to the detection of an approaching train by either track circuit for activating said warning devices,

f. said control logic apparatus being further responsive to the detection of the same train by the other track circuit while receding from said crossing in the opposite direction approach warning section for deactivating said warning devices,

g. said testing means is controlled by each demodulation means for actuating a test period when the reception of said first modulation characteristic is detected, and

h. said control logic apparatus is also controlled by each demodulation means for initially activating said warning signal when neither modulation characteristic is received by a first one of said receiver means, for holding said warning signal active when neither modulation characteristic is received by either receiver means, and for deactivating said warning signal when neither modulation characteristic is received by only the other receiver means.

3. A highway crossing signal system as defined in claim 2 in which each advance detection means comprises an open end track circuit including,

a. a power source common with the other advance detection means connected to the rails at the crossing and having a frequency characteristic different from each overlay track circuit,

b. the rails of the corresponding approach warning track section and the rails of an advance track section extending a predetermined distance in approach to said corresponding warning section, and

c. a normally active detector device coupled to the rails in multiple with the transmitter means of the associated overlay track circuit for receiving operating energy from said power source,

d. each detector device responsive to a rail shunt within said predetermined approach distance for registering the occupancy of that advance section by a train,

e. each detector device connected to the modulation source for shifting the modulation of the associated transmitter means from the second to the first characteristic when a train is detected in the corresponding advance track section, and

f. said power source also coupled at the distant end of each approach warning section for supplying operating energy to the associated overlay track circuit transmitter means.

**4.** A highway crossing signal system as defined in claim **3** in which,

a. said modulation source provides a first and a second code rate for selectively modulating a particular transmitter means output to supply signal pulses at the selected code rate to said rails as a train is or is not detected occupying the corresponding advance detection section,

b. each demodulating means includes a first and a second decoder responsive only to received pulses of said first and second code rates, respectively, for operating to an active condition,

c. said control logic apparatus jointly controlled by each pair of decoders for activating said warning signal initially when both decoders of one pair are in the inactive condition, for holding said warning signal activated when all decoders are in the inactive condition, and for deactivating said warning signal when only both decoders of the other pair are subsequently in the inactive condition, said warning signal being normally held inactivated while any one decoder of each pair is in its active condition.

**5.** A highway protection system for controlling warning devices for highway traffic where the highway is intersected by a stretch of railroad track over which trains move in either direction, comprising in combination,

a. an approach warning track section extending a selected distance each direction from said crossing,

b. a source of alternating current energy having a selected frequency coupled to the rails in the vicinity of the highway crossing for supplying track energy to the rails in both directions,

c. an overlay track circuit for each approach warning track section, each including,

**1.** a transmitter means coupled to the rails at the distant end of the corresponding track section for supplying track current of a distinct frequency to the rails,

**2.** a receiver means coupled to the rails at the crossing on the opposite side of said highway from the associated transmitter means and responsive only to track current of the distinct frequency of said associated transmitter means for detecting the absence or presence of a train in the corresponding approach warning section as track current is or is not received,

d. an energy conversion means also coupled to the rails in multiple with the transmitter means at the distant end of each approach warning track section and responsive only to selected frequency track energy from said energy source for supplying operating energy to the associated transmitter means,

e. a train detector means coupled to each energy conversion means and responsive to the reception of energy from said energy source for detecting the absence or presence of a train in a predetermined length of advance track section more distant from the crossing than the associated energy conversion means rail connections,

f. a modulating means connected to each transmitter means and controlled by the associated train detector means for applying a first and a second modulation characteristic to the distinct frequency rail current supplied by the associated transmitter means as a train is or is not detected in the corresponding advance track section,

g. a demodulating means controlled by each receiver means for registering the modulation characteristic of the rail current received from the associated transmitter means,

h. protection control logic apparatus connected for at times activating said warning devices to warn highway traffic of a train approaching within one approach warning section and for deactivating said devices when that train recedes from said highway through the other approach warning section,

i. both demodulating means connected to said control logic apparatus for activating said warning devices when one demodulating means first registers the absence of both modulation characteristics, for holding said warning devices active when both demodulating means register the absence of both modulation characteristics, and for subsequently deactivating said warning devices when said one demodulating means registers a first or second modulation characteristic while the other demodulating means registers the absence of both modulation characteristics,

j. a testing means coupled to said protection control logic apparatus for at times simulating the passage of a train through said stretch and for monitoring the operation of said protection control logic apparatus to simulate the proper operation of said warning devices in response to said simulated train passage,

k. each demodulating means connected to said testing means for actuating a test period when the reception of said first modulation characteristic is registered, for ending a test period when neither modulation characteristic is received, and for retaining said testing means non-actuated when the reception of said second modulation characteristic is registered, and

l. a failure warning means controlled by said testing means for registering a fault condition when an improper operation of said protection control logic apparatus is detected during a simulated train passage test period,

**1.** said failure warning means operable for indicating to highway traffic that an unsafe condition exists when a fault condition in said protection control logic apparatus is registered,

**2.** said failure warning means also coupled for inhibiting further operation of said protection control logic apparatus in response to the detection of a train by said primary detection means when a fault condition exists.

* * * * *