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[54] **HIGHWAY CROSSING SIGNAL SYSTEM**

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[52] **U.S. Cl.** **246/125**
[51] **Int. Cl.** **B61l 1/06**
[58] **Field of Search** 246/125, 126, 128, 129, 130

[56] **References Cited**

UNITED STATES PATENTS

2,133,171 10/1938 Lay 246/130
3,268,723 8/1966 Failor et al. ....246/125 X

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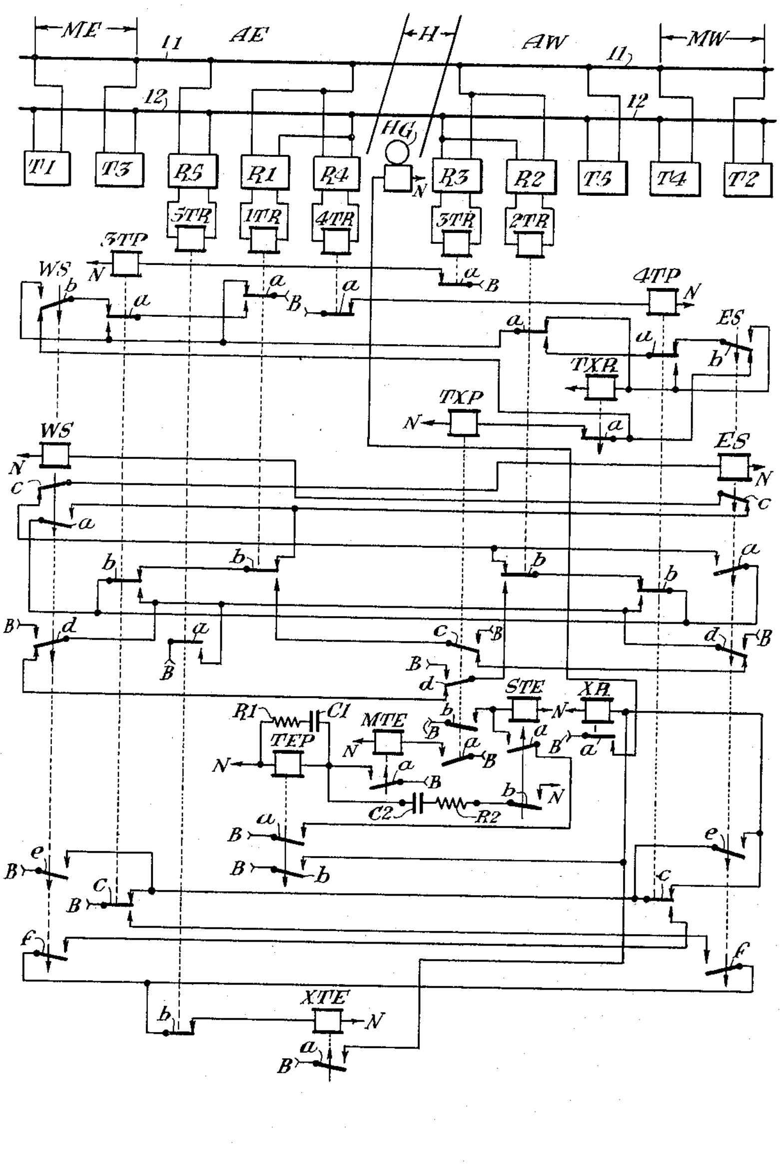
[57] **ABSTRACT**

Two overlay track circuits without insulated joints are installed in the track approaching the highway crossing, overlapped to provide a speed measuring section at the distant end of the approach track and an approach control section extending to the crossing, but with all apparatus except track transmitters at the crossing. Detection of a train only in the measuring section actuates a set of timing relays, one for each selected speed range slower than maximum speed. Completion of the shortest timing period energizes a repeater relay having a basic slow release period which is extended by the successive completion of other timing periods. Entry of a maximum speed train into the approach control section immediately actuates the warning signal but operation is delayed for the established release period of the repeater relay for slower trains to obtain relatively uniform warning times. Two direction train operation doubles the required track circuits but uses only one set of timing relays when the same speed ranges are applicable.

7 Claims, 3 Drawing Figures



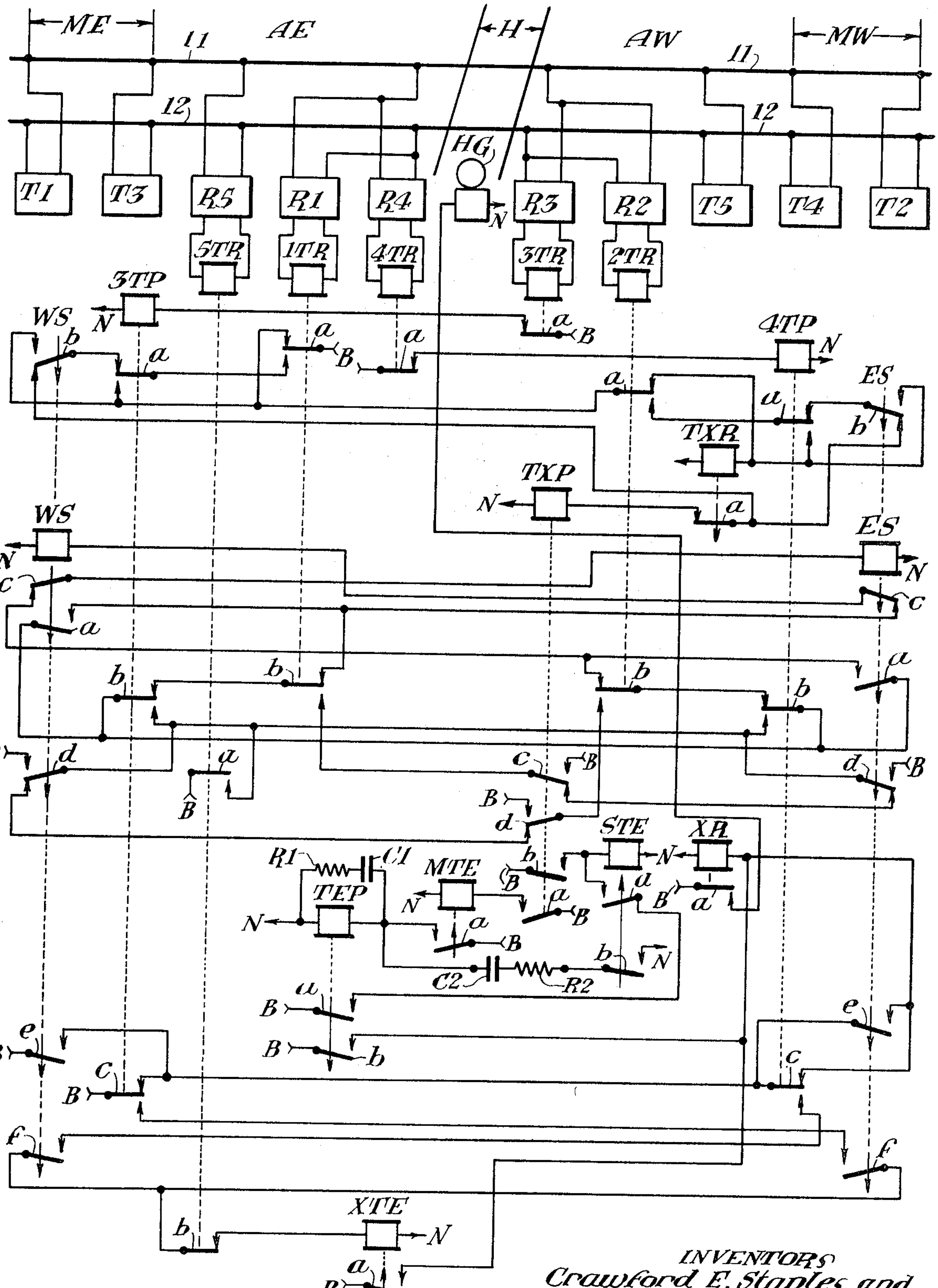


Fig.1.

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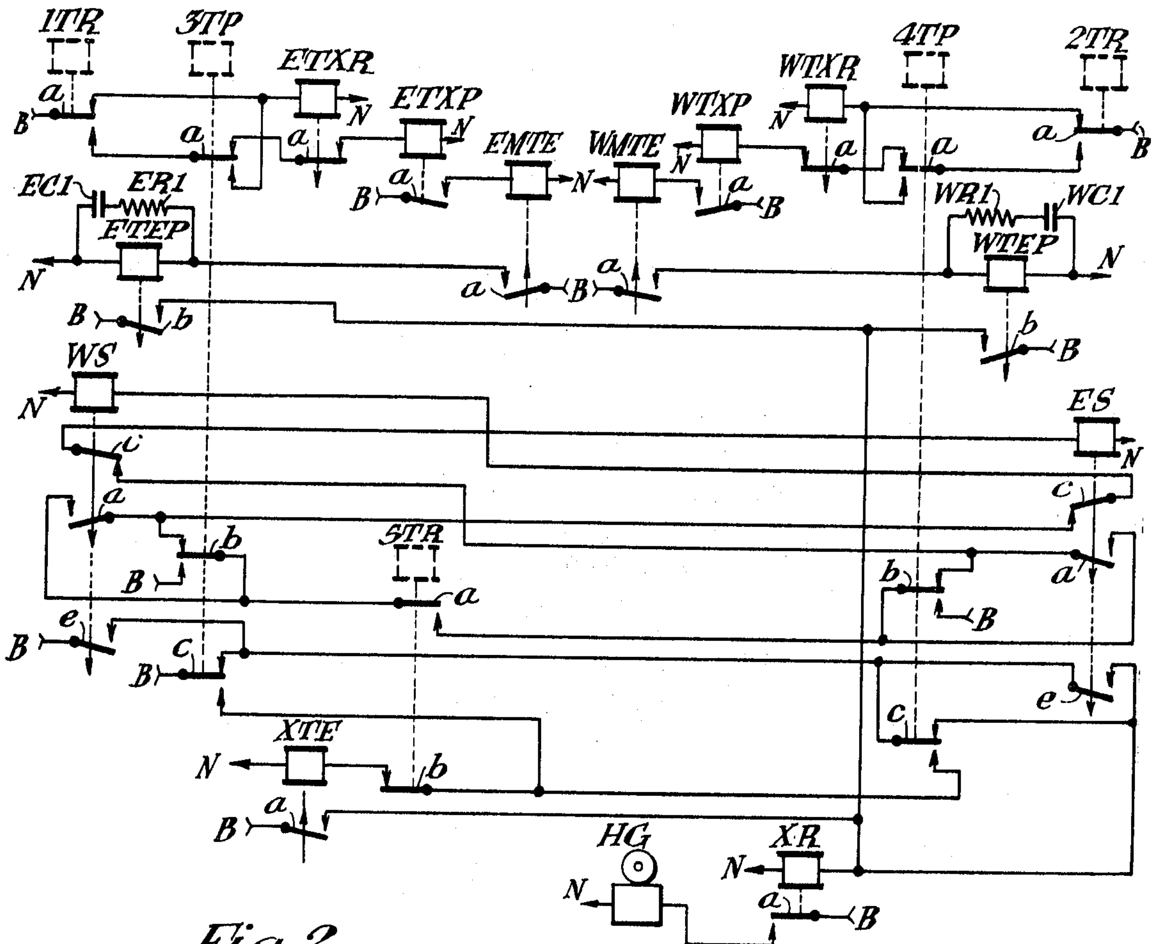

Fig. 2.

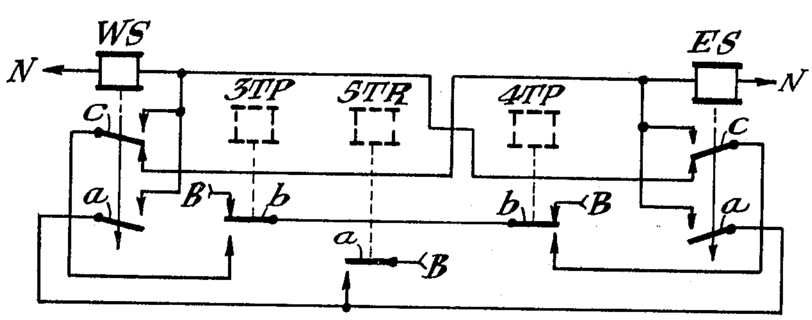

Fig. 3.

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HIGHWAY CROSSING SIGNAL SYSTEM

Our invention pertains to a highway crossing signal system for use on a railroad to warn the users of a highway intersecting the track of the approach of a train. More specifically, this invention pertains to a control arrangement for the warning signal at a highway and railroad crossing which provides relatively uniform operating time of the warning signal for different speeds of the approaching trains.

Signaling systems for highway railroad crossings are well known and the prior art arrangements have included various arrangements to obtain a uniform operating time of the warning signal prior to the arrival of trains having different approach speeds. Such uniform operating time is particularly advantageous in that it encourages immediate obedience of the warning signal by highway users and also reduces road traffic delays when slower trains are approaching. Such prior arrangements for uniform operating time, which are also called graduated warning systems, have normally required several short insulated track sections along the approach track to the highway crossing or along both approaches for two direction train operation. The control apparatus, and thus the power sources therefor, have been scattered at the many section locations along the approach to the crossing. Such arrangements require extra housing or protection for the apparatus and additional power sources for its operation. Of more importance in the prior art systems have been the numerous insulated joints, each of which requires additional installation and maintenance effort. Each insulated joint is also a potential fault location which, even though the system is fail-safe, may cause delays and annoyances. Obviously, these extra joints are a disadvantage and are an additional expense, both at installation and during maintenance operations. Added costs also result from the additional housing required for the apparatus and the plurality of power supply sources. Thus an advantage accrues to a highway crossing graduated warning signal system which both eliminates the requirement for insulated joints and reduces the number of apparatus locations along the approach track. Since many potential causes of failure are also eliminated, such a system operates at a higher efficiency.

Accordingly, an object of our invention is a highway crossing signal control arrangement providing uniform operating times for the warning signal which does not require insulated track sections in the approach track stretches.

Another object of our invention is to provide a graduated warning system for highway crossing signals which does not require insulated track sections along the approach stretches and in which nearly all of the operational apparatus is concentrated at one location.

A further object of the invention is a highway crossing signal system using overlay track circuits for approach control to avoid insulated joints, with an overlap of the track circuits to provide a train speed measuring section so that uniform operating time of the warning signal may be achieved.

Still another object of the invention is a uniform operating time crossing signal control system using overlay type track circuits without insulated joints, so overlapped as to provide a speed measuring, an approach control, and a crossing track section within each approach track stretch, with the majority of the apparatus concentrated at the crossing location.

Also an object of our invention is a control arrangement for a warning signal at a railroad-highway crossing providing relatively uniform operating time of the warning signal for different speeds of approaching trains, and using overlay track circuits so arranged as to eliminate insulated joints, provide detection of approaching trains through the crossing section and measurement of the speed of the approaching trains, and permitting the concentration of the majority of the apparatus at the crossing location.

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, we provide a pair of overlay type track circuits in the stretch of track for each direction by which trains normally approach a highway intersecting that railroad track. These track circuits require no insulated joints, each having a different frequency assignment. Four frequencies are needed for a single track if two direction operation of the trains is the normal practice on that particular track. The track circuit receivers, the corresponding track relay devices, and other associated control apparatus are located at the crossing location so that it may be mounted in a single housing unit for protection. For each direction of train approach, the two receiver units are connected to the rails on opposite sides of the crossing. This provides a crossing or island control track section to maintain the warning signal operation while trains are actually occupying the highway crossing. The track circuit transmitter units are located together, that is, in a single weather protecting case at the distant end of the approach track stretch. The rail connections of these two transmitters are separated in order to provide a short track section of adequate length to time, or measure the speed of, trains approaching the crossing. The length of rail between these transmitter connections thus will vary in accordance with the maximum authorized speed of trains in the particular track. The most distant connected transmitter unit is associated with the receiver on the same side of the crossing section. The connections of the second transmitter to the rails mark the beginning of the approach control track section for the crossing and thus this transmitter is associated with the receiver that is connected on the opposite side of the actual highway crossing. If two direction train operation is in effect on that particular track, directional control relays and circuits are provided in order that the so-called " back ringing" of the crossing signal will be avoided. In other words, these directional control circuits assure that the operation of the crossing signal in a warning condition will cease during the period that a particular train is receding from the crossing.

Our invention adds, to the control system, time element or timing relays, one for each speed range for which a time delay in the operation of the warning signal is to be provided. These time element relays are controlled by the track relays in response to the detection of an approaching train. Each time element relay is activated by the track relay circuitry while the train occupies only the measuring track section, that is, the timing section at the distant end of the approach track stretch. If two direction operation is in effect, the same set of timing relays may be used for each direction of operation, with different basic control circuits, as long as the trains in each direction travel at the same speed ranges. The timing relays are set to measure different and successively longer time periods. The operation of the timing relay having the shortest selected time period energizes a repeater relay which is provided with slow release characteristics. The operation of additional timing relays, as successively longer time periods occur during the passage of a train through the timing section, adds to the slow release period of the repeater relay by the connection of multiple timing units to the slow release circuits. Obviously, the time element relays are so adjusted in their timing periods that a train moving at the maximum speed traverses the measuring track section prior to operation of these relays so that no operation of the slow release time element repeater occurs.

Normally the operation of the crossing signal is actuated by a maximum speed train entering the approach control track section. The length of this approach section is predetermined to give the desired warning time. For slower speed trains, the time element repeater relay delays the operation of the signal control means for the established slow release timing period. By careful selection of the slow release period and the timing periods of the time element relays, the actual warning time provided for a more slowly moving train thus approximates the same time interval as for a maximum speed train. In other words, the slow release times for the time element repeater relay are varied in accordance with the number of timing periods measured and thus in accordance with the measured speed of the train so that relatively equal operatimg times result. The system embodying this invention also provides a cut-out feature, using another timing relay, operable if the approaching train stops within the approach control section. This feature requires also a restart means, provided by an additional overlay track circuit which actuates the restart of the signal operation when the initial period of operation has been halted by the cut-out timing relay. The track circuit apparatus for this additional section is also located at the crossing since the restarting distances involved are relatively short.

We shall now describe in more detail two arrangements embodying the invention in connection with the accompanying drawings and shall then point out the novelty in the appended claims.

FIG. 1 of the drawings is a partly schematic, partly diagrammatic illustration of the apparatus and circuit arrangement embodying one form of our invention.

FIG. 2 is a circuit diagram of an arrangement embodying a second form of our invention.

FIG. 3 shows an alternate directional stick relay arrangement which may be used in the second form of our invention shown in FIG. 2.

In each of the drawings, similar reference characters refer to similar parts of the apparatus. Further, standard symbols are used to designate the various relays and their contact structure. Contacts may be shown above or below the operating winding but in either case the armature symbol moves upward in the drawing when the relay is energized and picks up. The contacts of each relay are designated by lower case letter references unique within the set of contacts of any one relay. Where similar or equivalent relays are used in the different circuit arrangements, contacts of such relays used for similar or equivalent purposes are designated by the same letter references. Slow acting characteristics of relays, whether inherent in the relay construction or added by external means, are designated by an arrow drawn through the movable armature portion of each contact of such slow acting relays. The arrow points downward for a slow release characteristic and upward if the relay is slow to pick up. A direct current source of energy is provided for relay operation. This energy source is not shown, since such use is conventional and any type of direct current power source may be used. The positive and negative terminals of this source are designated by the reference characters B and N, respectively, and the appearance of these references in the drawings designates a connection at that point to the corresponding terminal of the source.

Referring now to FIG. 1, across the top of the drawing is illustrated a stretch of railroad track, each rail shown by a conventional single line representation, the two rails being designated by the references 11 and 12. Each rail is assumed to be electrically continuous in the stretch shown. As such, each rail may thus be welded or may have bonded rail lengths, but no insulated joints are installed. Trains are assumed to operate in each direction over the stretch shown, with trains moving to the right traveling in the eastbound direction and those to the left, westbound. This two direction operation of the trains is not a requirement for the employment of the system of our invention. Rather, the arrangement may be modified, in a manner which will become apparent later, for single direction operation of the trains. The stretch of track is intersected by a highway H at a crossing location shown near the center of the drawing. A crossing signal HG is positioned at highway H and the purpose of our inventive system is to provide operation of this signal to warn the users of the highway of the approach of trains. Signal HG is illustrated as an electric bell only for convenience in the drawing, as any well known crossing signal or warning device may be used. For example, the warning device may be the conventional flashing light arrangement with or without automatic gates associated therewith. The warning signal will be located, in accordance with the type used, to provide a conventional warning to the users of the highway. The system of our invention merely provides the control energy to actuate the warning device and the type specifically used is not a novel part of the arrangement illustrated.

Immediately below the track rails are shown the symbols designating the transmitters and receivers which provide the overlay track circuits for detection of approaching trains, that is, detection of the occupancy of the track stretch. The transmitters are designated by the reference T with a distinguishing suffix numeral, while the receivers are designated by the reference R, also with a distinguishing suffix numeral. Similar numerical suffixes denote associated units of the same track circuit. It will be shortly explained how these transmitters and receivers are connected to the rails in order to establish timing, approach control, and an island track section of the non-insulated type. The transmitter and receiver units are shown by conventional block as any type of apparatus can be used which will provide rail current of selected frequencies from the transmitters for transmission to the corresponding receivers, each set having the same suffix numeral being tuned to the same selected frequency. Preferably, the frequency selections will be in the audio range but this is not a specific requirement of our inventive system. The only requirement of the frequency range selection is that it provide track circuits of sufficient length for system operation. Also, the power supplies for these transmitter and receiver units are not shown as the supply of operating power thereto is conventional and will be of the type suitable to the actual units used. Such overlay track circuits are well known in the signaling art and additional details of the apparatus are not necessary herein for an understanding of our invention.

Although the approach transmitter rail connections are at separated points along the track, each set of transmitter units are at the same location, that is, within the same protective case. The distance between the transmitter rail connections at these points establishes the speed measuring track sections or timing sections designated as sections ME, for eastbound trains, and MW, for westbound trains. The length of these measuring sections will be normally such that trains traveling at the maximum authorized speed within the stretch will traverse the section in between 3 to 4 seconds. The corresponding receivers for the track circuits are connected in the vicinity of the highway crossing, that is, on each side of the crossing. It is to be noted that receiver R1, associated with the most distantly connected transmitter T1 for eastbound moves, is connected to the rails on the same side of the highway crossing while receiver R3, associated with transmitter T3 connected closer to the highway crossing, is connected to the rails on the opposite side of the highway. The same conditions apply for receivers R2 and R4 associated respectively with the approach transmitters T2 and T4 for westbound train moves. The distance between the nearer transmitter connections and the highway crossing establishes an approach control track section between the measuring section and the highway crossing. For example, approach control section AE exists for eastbound trains between section ME and highway H, while the approach control section for westbound trains is section AW. The spacing of the receiver connections on opposite sides of the highway for a particular direction of train movement establishes what is known in the art as an island track section so that operation of the warning signal will continue until the train actually clears the highway in eaCh direction of movement. Regardless of the point of their rail connections, receivers R1 through R4 are mounted in the same housing unit at the crossing location.

A fifth track circuit, for restart purposes after a signal cut-out, is provided by transmitter T5 and receiver R5. The use of this track circuit will be explained later. However, connections for these two units are a selected distance on each side of highway H in accordance with the start-up speed of trains that have stopped within the approach sections. For example, transmitter T5 and receiver R5 may each be connected from 100 to 150 feet away from the actual highway itself on the basis that a train, having stopped for example within section AE, will approach the crossing location at less than 5 miles per hour. Both the units 5 are also mounted in the housing at the crossing location. Likewise, all of the relays shown in the drawing figure are mounted in this same housing. Thus, except for a small case at each distant or approach transmitter location, only a single housing unit is required for the arrangement of our invention. A small capacity power source will serve at each distant transmitter location while a single, larger capacity power source at the crossing can be included within the protective housing and may also supply power for the operation of crossing signal HG.

Each receiver unit controls a track relay, shown connected to the associated receiver by conventional connections and designated by the general reference TR with a prefix number the same as the associated receiver unit's suffix number. Each track relay TR is energized and thus in a picked up condition when no train occupies any portion of the track rails between the corresponding transmitter and receiver units of that track circuit. Track relays **3TR** and **4TR** are each provided with a front contact repeater relay, respectively designated **3TP** and **4TP**. Each relay TP is normally energized over a circuit between terminals B and N including front contact *a* of the corresponding track relay TR.

A timing crossing relay TXR normally repeats the energized position or condition of track relays **1TR** and **2TR**. This normal energizing circuit extends from terminal B over front contact *a* of relay **1TR** and front contact *a* of relay **2TR** through the winding of relay TXR to terminal N. A second type of energizing circuit for relay TXR includes back contacts of the associated TR and TP relays for one direction of train approach. For example, another circuit for relay TXR includes back contacts *a* of relays **1TR** and **3TP** and then front contact *a* of relay **2TR**. A second circuit of this type extends over front contact *a* of relay **1TR** and thence over back contacts *a* of relays **2TR** and **4TP**. A third type of circuit for relay TXR includes a back contact of a track relay TR and a contact closed with the opposite directional stick relay picked up. For example, a circuit may exist over back contact *a* of relay **1TR**, front contact *a* of relay **3TP**, and front contact *b* of directional relay WS and thence over front contact *a* of relay **2TR** to the relay winding. All of these various types of energizing circuits for relay TXR are for the purpose of retaining this relay normally energized, although the relay is provided with inherent slow release characteristics so that it remains picked up for some period even though energy has been removed from its winding. For example, the slow release period of relay TXR may be on the order of 15 seconds, obtained by any known method of the art. Thus it will release only if one of the measuring or timing track circuits has failed so that the associated TR relay only remains released. This is a safety precaution and the resulting operations will be described hereinafter.

The timing crossing repeater relay TXP repeats the successive operation of the track relays, as long as relay TXR remains picked up, and controls the timing relays later described. Two circuits are provided for relay TXP, one for each direction of train operation. For example, for eastbound trains, a circuit exists for relay TXP, when the train occupies timing section ME, extending from terminal B over back contact *a* of relay **1TR**, front contact *a* of relay **3TP**, back contact *b* of relay WS, front contact *a* of relay TXR, and the winding of relay TXP to terminal N. The circuit for a westbound movement includes front contact *a* of relay **1TR**, back contact *a* of relay **2TR**, front contact *a* of **4TP**, back contact *b* of relay ES, and the same front contact *a* of relay TXR. The front contact *a* of relay **1TR** on this second circuit is merely so that contacts may be saved on track relays **1TR** and **2TR**. Specifically, contact *a* of relay **2TR** is being used for two different purposes in the circuit arrangement so that a less expensive track relay may be used. For similar reasons, various other contacts of relays **1TR** and **2TR**, **3TP** and **4TP**, and ES and WS may be used for more than one purpose and thus seemingly are redundant in some of the circuits. In the two circuits for relay TXP, the back contact of the opposite directional stick relay assures that relay TXP is not again energized as that particular train recedes from the crossing since such directional stick relays, as will be shortly explained, are normally energized and picked up during this receding movement. It is to be noted also that relay TXP cannot be energized if relay TXR, for any reason, releases to open its front contact *a*.

The specific embodiment of our invention illustrated in FIG. **1** assumes that the crossing signal system requires the timing of three speed ranges for the approaching trains and, incidentally, that identical speeds are effective for each direction of travel. These may be defined as the maximum authorized speed, a medium speed possibly designated as maximum for a different class of trains, and a slow or approach speed at times designated or required by the wayside signaling system. Also as will be described in detail later, a cut-out timing arrangement is provided for trains that stop along the approach or that are moving at what may be described as a creeping or very slow speed. Thus the uniform timing arrangement here shown requires a medium speed time element relay MTE, a slow speed time element relay STE, and a time element repeater relay TEP. The cut-out or crossing time element relay for very slow trains is the crossing time element relay XTE. Each of the relays TE is of a slow pick up type, that is, one in which the front contacts are not closed for a preselected time after the relay winding is energized, as is designated by the upward pointing arrow drawn through the movable portion of the relay contacts. These relays have a variable pick up timing, which may be preset to a single value in the range from at least 3 to 30 seconds and for relay XTE an even longer period possibly exceeding 60 seconds. Relays of this type are well known in the art and any available form may be used. They may even be a solid state device providing equivalent operation.

Relay TEP is a slow release relay in which the slow release is obtained principally by snubs connected in multiple with the relay winding. The snubbing circuits are shown as series resistance-capacitance circuit paths with a first such path, including resistor **R1** and capacitor **C1**, permanently connected in multiple with the relay winding. As will be described, similar R–C circuit paths may be additionally connected in multiple with the relay winding to obtain additional slow release timing. With proper selection of the relay winding and the resistance and capacitance of the snubbing circuits, it is possible to vary the release of these relays in the range from 5 to 60 seconds, as may be desired.

Simple energizing circuits for relays MTE and STE are provided, respectively, over front contacts *a* and *b* of relay TXP. Each relay picks up to close its front contacts at the end of its preset timing period after the winding is energized, relay MTE having a shorter period than relay STE since it is for a higher speed timing arrangement. Relay STE is provided with a stick circuit which includes its own front contact *a*, closed at the end of the timing period, and front contact *a* of relay TEP. The energizing circuit for relay TEP includes only front contact *a* of relay MTE so that relay TEP is energized and picks up at the end of the timing period preset for relay MTE. As explained, the winding of relay TEP is permanently snubbed by the series circuit including resistor **R1** and capacitor **C1** which provides a slow release period for this relay associated with the medium speed timing delay required for the system operation. A second snubbing circuit is connected in multiple with the first circuit when front contact *b* of relay STE is closed. This second snubbing circuit includes capacitor **C2** and resistor **R2** and adds to the release time of relay TEP to provide a preselected delay period for slow speed operation of the signaling system. As further explanation, it may be noted that each of these R–C snubbing circuits are connected in multiple between the right hand terminal of the winding of relay TEP and terminal N of the power source. This is a conventional arrangement for obtaining a slow release characteristic for a conventional, d.c. neutral relay.

Since the illustrated system has assumed two direction operation of trains over the stretch of track, directional stick relays are needed to eliminate the so-called back ringing of the highway signal as a train recedes from the actual highway crossing. This operation is provided by the directional stick relays ES and WS, the former being associated with eastbound train movements and relay WS with westbound movements. Each of these relays has an inherent slow release characteristic providing a nominal timing period so that the relay, once energized, will not release as its energizing circuit is shifted between the various circuit paths which will shortly be traced. The normal energizing circuit for relay ES for an eastbound train movement is completed when relay 1TR releases and relay TXP subsequently picks up. This circuit is traced from terminal B over front contact *c* of relay TXP, back contact *b* of relay 1TR, front contact *b* of relay 3TP, front contact *b* of relay 4TP, front contact *b* of relay 2TR, back contact *c* of relay WS, and the winding of relay ES to terminal N. The front contact of relay TXP in this circuit assures that relay ES will not long remain energized if relay 1TR has released because of a track circuit failure.

An initial stick circuit for relay ES includes front contact *c* of relay TXP, back contact *b* of relay 1TR, front contact *b* of relay 3TP, and front contact *a* of relay ES, thence over back contact *c* of relay WS to the winding of relay ES. As soon as an eastbound train enters approach control section AE, however, a second stick circuit is completed for relay ES, which includes front contact *d* of relay ES and back contact *b* of relay 3TP, as well as front contact *a* of relay ES and back contact *c* of relay WS of the initial stick circuit. A second connection to terminal B for this second stick circuit is also provided over back contact *a* of relay 5TR when this relay releases as the train closely approaches the highway crossing. However, this connection is primarily provided for other purposes which will be described later. The stick circuit for relay ES as the train proceeds through the entire stretch of track continues to include front contact *d* of relay ES, but shifts to include back contact *b* of relay 4TP as the train occupies section AW in its receding move and later, as the train occupies only section MW, the circuit includes back contacts *d* of relays WS and TXP, back contact *b* of relay 2TR, and front contact *b* of relay 4TP. These shifts in the stick circuit for relay ES will be more clearly understood when the circuits shown in the drawing are examined and will therefore not be completely described since such operation is somewhat conventional. The result of the stick circuit arrangement is that relay ES holds in its pick up position as the train moves through the stretch of track and the resulting elimination of the back ringing will be more fully described in connection with the signal operation. Similar circuits, both for pick up and holding of relay WS in connection with a westbound train movement, will also be evident from a study of the circuits in the drawing when taken with reference to the description of the circuits for relay ES. It is believed that a full description of the circuits for relay WS would be redundant and is therefore not included.

Crossing signal HG is controlled by the crossing relay XR over its back contact *a*, the signal being energized or actuated when this back contact is closed. Relay XR is normally energized, and thus picked up so that its back contact *a* is open, over a circuit including in series front contacts *c* of relays 3TP and 4TP. Obviously the crossing relay and thus signal HG are directly controlled normally by occupancy of the approach control track sections. However, in a conventional manner, front contacts *c* of relays 3TP and 4TP are each bypassed by front contacts *e* of relays WS and ES, respectively. In this manner the circuit for relay XR is retained complete when a train occupies one of the approach control track sections as it recedes from the crossing. For specific example, when relay ES is picked up and held energized by its stick circuits during an eastbound train movement, relay XR will be held energized as the train moves in a receding direction through section AW by a circuit including front contact *c* of relay 3TP, which contact is closed since the train has cleared the eastbound approach section, and front contact *e* of relay ES, which is held closed during the receding movement.

It remains only then to describe the control circuits for one final relay, the crossing time element relay XTE previously mentioned. This relay provides cut-out or halting of the warning signal if a train stops during its approach to the crossing or if a train is moving very slowly so that the usual speed measuring time element relays will still not avoid an unusually long warning period. A first energizing circuit for relay XTE is completed from terminal B over back contact *c* of relay 3TP, front contact *f* of relay ES, front contact *b* of relay 5TR, and the winding of relay XTE to terminal N. The second energizing circuit for relay XTE includes front contact *c* of relay 3TP, back contact *c* of relay 4TP, front contact *f* of relay WS, and front contact *b* of relay 5TR. The slow pickup time of relay XTE is preset at a relatively long interval, which will be at least three times the minimum warning time desired for the highway crossing, in order to allow for a train approaching at a very slow speed, or one stopping and then starting during its approach. It is to be noted that the front contacts of the directional stick relays S in the two energizing circuits for relay XTE assure that the corresponding release of a track repeater relay TP to establish the circuit is a normal release due to a train advancing into the approach control section as it moves through the stretch and is not the result of a track circuit failure. The energization of relay XTE is interrupted under any conditions when relay 5TR releases. When relay XTE picks up at the end of its timing interval to close its front contact *a*, it provides an energizing circuit for relay XR which will cause this relay to pick up to open its back contact *a* and deactivate crossing signal HG and thus halt its warning condition. However, any train that has approached close enough to the crossing to shunt the restart track circuit, so that relay 5TR releases, will cause relay XTE to release and subsequently relay XR so that the warning signal condition will be restored. It may also be noted that another holding circuit for relay XR is provided to delay the release of this relay, and thus the operation of the crossing signal, over front contact *b* of relay TEP. This latter circuit will hold or delay the release of relay XR, until relay TEP releases at the end of whatever slow release period has been selected, after a train enters one of the approach control track sections and causes the release of a track repeater relay TP.

We shall now describe the operation of the FIG. 1 circuit arrangement embodying one form of the system of our invention. It is assumed initially that a train moving in a eastbound direction through the stretch of track shown is traveling at the maximum speed authorized for trains in the area which, for example, may be an 80 mile per hour speed limit. As this train enters section ME, relay 1TR releases. This causes the energization, over the previously traced circuit, of relay TXP since front contact *a* of relay 3TP is still closed. In turn, the closing of front contacts *a* and *b* of relay TXP energizes timing relays MTE and STE. Relay ES is also energized at this time and picks up to complete its initial stick circuit. It is to be noted that relay TXR is deenergized by the opening of front contact *a* of relay 1TR but the slow release characteristics of relay TXR cause it to retain its front contacts closed for the present.

When the train enters section AE, relay 3TR and subsequently relay 3TP release. The opening of front contact *a* of relay 3TP interrupts the circuit for relay TXP which thus releases. Since the timing periods of relays MTE and STE are set for slower moving trains, they do not complete their timing period and pick up to close front contacts during the passage of this maximum speed train through section ME. Since front contact *a* of relay MTE thus does not close before the relay is deenergized, relay TEP is not energized at this time. Therefore, the release of relay 3TP to open its front contact *c* interrupts the circuit for relay XR which releases. The closing of back contact *a* of this latter relay activates crossing signal HG to its warning condition, thus indicating to users of the highway that a train is approaching and will arrive within approximately 20 seconds.

The release of relay 3TP to close its back contact *b* completes the second stick circuit for relay ES. As the train continues through the stretch of track, the warning signal continues to operate until the train reaches the highway crossing. Since track circuit 3 includes the highway crossing itself, the signal will continue to operate since relay 3TP remains released. As the train continues, relays 4TR and 2TR release, also causing the release of relay 4TP. The various stick circuits for relay ES are established in turn, as the train continues its movement, to hold this relay in its picked up position. When the train clears the actual highway crossing, relays 1TR and 3TR are reenergized by their track circuit apparatus and pick up. Relay 3TP is also reenergized. The closing of front contact *c* of relay 3TP, with front contact *e* of relay ES already closed, completes a second circuit for relay XR which, thus reenergized, picks up. The opening of back contact *a* of relay XR deenergizes the crossing signal HG so that it ceases its warning operation as the train recedes from the crossing through sections AW and MW. Since this train continued without stopping, it was not occupying section AE for a period long enough for relay XTE to complete its timing period, although the winding of this relay was energized until relay 5TR released. Thus, the crossing signal in this instance was actuated to its warning condition as soon as the train entered approach control section AE and the signal continued to operate until the rear of the train cleared the highway crossing so that relay 3TR could again pick up. As the train receded, there was no back ringing operation of signal HG since directional stick relay ES completed the bypass circuit to reenergize the crossing signal control relay.

For any specific highway crossing signal installation, knowing the speed ranges at which the trains move over the stretch of track, that is, the fixed maximum speed limits for the various classes of trains, and the other speed limits which may be enforced by the wayside signal system, the exact distances or lengths of the timing and approach track sections may be calculated. Also the timing periods of relays MTE, STE, and TEP may be preset by proper selection of the relays to obtain a relatively uniform selected warning time operation by crossing signal HG, for example, a 20 second or a 30 second warning period. If we herein assume that the maximum authorized speed is 80 miles per hour, that the medium speed limit is 60 miles per hour, and that the slow or approach speed limit is 30 miles per hour, and that a 20 second warning time is desired for all trains, specific examples for the length of sections ME and MW may be approximately 400 feet and the length of the approach control sections AE and AW approximately 2,400 feet. Under these conditions, the timing period of relay MTE prior to pickup would be set between 4.0 and 4.5 seconds while the timing period for relay STE would be set between 8.5 and 9.0 seconds. Relay TEP would be selected and its snubbing circuits so arranged as to provide a release time between 6 and 7 seconds when only the first snubbing circuit is in use and on the order of approximately 30 seconds when the second snubbing circuit is also connected in multiple with the relay winding over contact *b* of relay STE. Under these conditions, a warning time of 20 seconds will be provided for users of the highway prior to the arrival of a train moving at maximum speed. It is to be understood, of course, that these specific lengths and times are examples only and are not a specific and absolute requirement for every installation of a highway crossing signaling system embodying our invention.

If the previously described train is now assumed to be moving at or slightly below the medium speed limit of 60 miles per hour in this example, the passage of the train through section ME will require sufficient time that relay MTE will complete its timing period and pick up, closing its front contact *a* to energize relay TEP. However, the timing period for relay STE is not completed during the passage of the train at medium speed so that this latter relay does not pick up and its front contact *b* is not closed to add the second snubbing circuit to extend the release period of relay TEP. When the train enters section AE, the release of relay 3TP deenergizes relay TXP and the release of this relay in turn deenergizes relays MTE and STE. However, the opening of front contact *c* of relay 3TP does not deenergize relay XR since front contact *b* of relay TEP is now closed. The principal snubbing circuit for relay TEP provides a slow release period between 6 and 7 seconds, in the assumed example, for this relay. At the end of this period relay TEP releases, deenergizing relay XR which thus releases to actuate the highway crossing signal operation. This initiation of the warning condition of signal HG occurs at a point in the train's movement through section AE when approximately 20 seconds time remains before the train arrives at the highway crossing. Thus the warning period under these conditions is the desired or selected uniform time of 20 seconds.

If the train is now assumed to be moving at only 30 miles per hour, that is, the slow or approach speed because of wayside conditions, its passage through section ME will require sufficient time that both relays MTE and STE complete their timing periods and pick up to close front contacts. Again, the closing of front contact *a* of relay MTE energizes relay TEP which picks up to close its front contact *a* which prepares the stick circuit for relay STE. The pickup of relay STE completes its stick circuit and closes its front contact *b* to add the second snubbing circuit in multiple with the principal snubbing circuit for relay TEP. This extends the release time established for relay TEP. The release of relay 3TP when the train enters section AE interrupts the circuit for relay TXP which releases. The release of this latter relay in turn interrupts the energizing circuits for relays MTE and STE. The former relay releases but relay STE is held by its already established stick circuit and thus retains the additional snubbing circuit in multiple with the winding of relay TEP. Relay XR is again held energized, even though front contact *c* of relay 3TP opens, by the circuit over front contact *b* of relay TEP. Relay TEP now releases at the end of its longer release period, assumed in the example to be approximately 30 seconds. This release of relay TEP deenergizes relay XR which releases and thus activates the operation of signal HG. Under these conditions, signal HG will provide a warning signal condition between 20 to 24 seconds prior to the arrival of this train moving at the 30 mile per hour limit towards the highway crossing. Thus again the arrangement provides a relatively uniform operating time for signal HG.

If the train should halt after it occupies section AE or occupies this section for more than 60 seconds because it is moving at a very slow speed, relay XTE will complete its timing period and pick up, providing that the train has not moved so far as to be within the range of the restart track circuit to cause the release of relay 5TR. Relay XTE, of course, was energized as soon as the train entered section AE as it is for any train. The circuit in this example includes back contact *c* of relay 3TP and front contact *f* of relay ES as well as front contact *b* of relay 5TR. When relay XTE picks up to close its front contact *a*, relay XR is reenergized and picks up to halt the operation of signal HG. When the train starts again and moves forward in the stretch, it shortly occupies the track circuit established by transmitter T5 and receiver R5, thus causing the release of relay 5TR. The opening of front contact *b* of this latter relay deenergizes relay XTE which releases and in turn deenergizes relay XR. This latter relay again releases, closing its back contact *a* to reactivate crossing signal HG to provide a warning signal condition.

If one of the measuring or timing track circuits fails, releasing either relay 1TR or 2TR to energize relay TXP and deenergize relay TXR, relays MTE, STE, and the corresponding directional relay S will be energized and will pick up, the timing relays of course at the end of their preset operating periods. However, the absence of any subsequent release of the associated TP relay for the approach control track section holds relay XR energized so that no operation of signal XG occurs. The continued energization of the TP relays retains relay TXR deenergized beyond its slow release period and this latter relay will eventually release after the track circuit failure. The release of relay TXR deenergizes relay TXP which immediately releases and thus deenergizes time element relay MTE which releases to deenergize relay TEP. The eventual release of relay TEP interrupts the stick circuit for relay STE which then releases. The opening of the front contacts of relay TXP will also interrupt the stick circuit for whichever S relay is picked up and this relay also will release. The subsequent approach of a train will not under these conditions be timed and the release of the corresponding TP relay will immediately actuate the operation of signal HG, regardless of the speed of the train.

If the train enters from the end at which the track circuit has failed, the eventual release of relay 5TR, when the train approaches that close with the signal already operating, will energize the corresponding S relay and thus eliminate any back ringing of the crossing signal. The circuit for the S relay under these conditions will include back contact *a* of relay 5TR and back contact *b* of the TP relay associated with that direction of train movement. For example, if track circuit 1 has failed so that relay 1TR is released over a long period, an eastbound train will actuate the operation of signal HG as soon as it enters section AE and causes the release of relay 3TP, regardless of the speed of the train. When this train has advanced sufficiently far through section AE to cause the release of relay 5TR, a circuit for relay ES is established including back contact *a* of relay 5TR, back contact *b* of relay 3TP, front contacts *b* of relays 4TP and 2TR, and back contact *c* of relay WS. It is to be noted that the entry of a train from a spur track which, for example, may join the main line somewhere in the length of section AE will also, by the eventual release of relay 5TR, energize the eastbound directional stick relay ES so that back ringing of the highway signal will not occur. However, there will be no timing of the movement of a train entering from a siding track and any unusual and undesirable length of operation of signal HG will have to be avoided over special circuits, not here shown, including switch circuit controller contacts for cutting out the operation of a signal until the desired time. Such arrangements, however, are not within the scope of our invention and are not shown in detail.

Referring now to FIG. 2 in illustrating the second form of our invention, we have omitted any showing of the track stretch and the track circuit connections including the transmitters and receiver units. The track circuit arrangements are identical with those illustrated for the FIG. 1 embodiment and reference is made to that figure for the circuit connections. However, relays 1TR, 2TR, 3TP, 4TP, and 5TR are shown by phantom or dotted symbols without control circuits in order to establish the relationship and operation of the various track relay contacts responsive to train occupancy of the various track sections which are used in the circuit arrangements of FIG. 2. Obviously, reference may be made to FIG. 1 for the manner in which the track relays or their direct repeaters operate. The conventional illustration of the crossing signal HG is shown near the bottom of FIG. 2, controlled as before over back contact *a* of crossing relay XR. In other words, when relay XR releases to close its back contact *a*, crossing signal HG is actuated to provide a warning signal for users of the highway. The basic control circuits for relay XR are the same as those shown in FIG. 1. For example, the series circuit for holding relay XR normally energized includes front contacts *c* of relays 3TP and 4TP. Each of these front contacts *c* is bypassed by a front contact *e* of the opposite directional stick relay. Specifically, front contact *c* of relay 3TP is bypassed by front contact *e* of relay WS while front contact *c* of relay 4TP is bypassed by front contact *e* of relay ES. Of course, the front contacts of relays ES and WS are normally open and are closed only when a train moving in the corresponding direction is receding from the crossing location. As explained before, this prevents any back ringing of the crossing signal HG as the train recedes and thus allows motorists to cross the track after a train has cleared the crossing.

The circuit network for the directional stick relays as shown in FIG. 2 is modified over that previously discussed. For example, the energizing circuit for the eastbound stick relay ES can be traced from terminal B at back contact *b* of relay 3TP over back contact *a* of relay 5TR, front contact *b* of relay 4TP, back contact *c* of the opposite direction stick relay WS, and through the winding of relay ES to terminal N. When relay ES picks up, the closing of its front contact *a* completes an initial stick circuit which bypasses front contact *b* of relay 4TP. It is obvious that relay ES picks up only when restart track circuit relay 5TR releases, which occurs when the train has closely approached the actual highway crossing, as previously explained. A final stick circuit for holding relay ES energized after that train has cleared the highway includes back contact *b* of relay 4TP, front contact *a* of relay ES, and back contact *c* of relay WS. This stick circuit will hold relay ES picked up while the train recedes through track section AW but not while the train is clearing timing section MW. Relay ES has sufficient slow release characteristics to bridge the pickup time of relay 4TP, to restore the previously traced normal energizing circuit for relay XR, at the moment that the rear of the train clears section AW. The tracing of the energizing and stick circuits for the westbound directional stick relay WS and the description of the operation of that relay would be redundant, being equivalent to that just discussed for relay ES, and are omitted.

Relay XR has a first alternate or holding circuit which includes front contact *a* of the signal cut-out or crossing time element relay XTE. This circuit is similar to that previously described in connection with the arrangement of FIG. 1 and is used to cut-out or halt the warning operation of signal HG if a train stops in the approach track sections or is approaching the highway crossing at a very slow speed. Relay XTE is of the time element type which has a preset timing period which must expire, after the relay is initially energized, before the relay responds to pick up and close its front contacts. A first energizing circuit for relay XTE includes back contact *c* of relay 3TP and front contact *b* of relay 5TR. A second energizing circuit effective when a train is approaching in a westbound direction includes front contact *c* of relay 3TP, back contact *c* of relay 4TP, and front contact *b* of relay 5TR. It is to be noted that the release of relay 5TR when a train occupies the restart track section, as it closely approaches the actual highway crossing, provides an absolute release for relay XTE so that it will open its front contact *a* to release relay XR to actuate the warning signal.

The circuits shown here for relay XTE differ from those of FIG. 1 in that no front contacts of directional stick relays ES and WS are provided to avoid a lockout of the crossing signal in the event of a failure of the track circuit for one of the approach track sections. This change is necessary due to the different operation of the stick relays with the circuits shown in FIG. 2. Specifically, relay ES or WS, depending upon the train direction, is only energized when that train close approaches the actual crossing to release relay 5TR. If a front contact of the corresponding directional stick relay was used in each of the energizing circuits for relay XTE, no energy would be supplied to this relay during the time the train occupied the approach sections. Thus relay XTE would not be energized to run its time period to cut out the warning signal when the train was stopped on the approach section. If the arrangement of FIG. 2 is used to control a highway crossing signal, the failure of an approach track circuit must be reflected into the wayside signal system. In other words, in addition to the usual track circuit control of the wayside signals, arrangements must be included so that the failure of one of the crossing signal overlay track circuits to cause the inadvertent release of relay 3TP or 4TP will be reflected in a restricted speed signal aspect in the wayside signals. This causes trains to approach the crossing at a slow speed so that the release of relay 5TR will provide sufficient warning time for users of the highway before the arrival of the train. However, if the cutout relay XTE and associated controls are not provided, this direct tie-in with the wayside signals is not necessary.

An alternate circuit network for the directional stick relays is shown in FIG. 3 which may be substituted for that shown in the embodiment of FIG. 2. Referring now to FIG. 3, an energizing circuit for relay ES may be traced from terminal B over front contact *b* of relay 4TP, back contact *b* of relay 3TP, back contact *c* of relay WS, and the winding of relay ES to terminal N. Thus relay ES will be energized when the train occupies approach section AE to cause the release of relays 3TR and 3TP in succession. A first stick circuit for relay ES is completed when relay 5TR releases as the train continues its movement and includes back contact *a* of relay 5TR and front contact *a* of relay ES. The final stick circuit for holding relay ES energized as the train recedes from the crossing includes front contact *b* of relay 3TP, back contact *b* of relay 4TP, and front contact *c* of relay ES. The initial stick circuit controlled by relay 5TR holds relay ES energized while the shift is made between the energizing and final stick circuits as relays 3TP and 4TP respectively pick up and release as the train clears the highway crossing. The slow release characteristics of relay ES help to bridge any gaps in the actual energization of the relay winding during the shift between the various circuits. It will be noted that the circuits for relay WS shown in FIG. 3 are similar. For this reason they are not specifically traced and reference is made to the immediate preceding description and the circuits of FIG. 3 for an understanding of the control of relay WS. If the directional stick circuit network of FIG. 3 is used in the second embodiment of our invention, the circuits for the crossing time element relay XTE may include front contacts of these stick relays in a manner illustrated in FIG. 1. This is possible since by way of specific example, relay ES picks up when the train enters approach section AE and thus will provide control energy for relay XTE during the entire time that the train occupies that track section. The directional stick relay networks shown in FIGS. 2 and 3 are the more conventional type also used in various ones of the prior art crossing signal control systems.

The timing circuit network shown in the FIG. 2 arrangement is split to provide separate timing circuits for each direction of train operation. This may be used, for a specific example, if different speed ranges are in effect for opposite directions of travel over the particular stretch of track involved because of special circumstances of grades, station stopping, or speed restrictions for wayside hazards. Further, only one speed range for timing is illustrated in FIG. 2 for each direction, since this is sufficient to illustrate the principles of operation of the separate timing networks. It will become obvious as the description progresses that additional speed timing may be added to the arrangement of FIG. 2 in a manner similar to that described for the first embodiment of FIG. 1. It will also become obvious that a single timing network for both directions with whatever speed ranges are desired, similar to the network of FIG. 1, may be used in the embodiment of FIG. 2. In other words, the use of a single combined timing circuit arrangement or a separate arrangement for each direction of travel is a matter of choice made during the design of each specific crossing signal installation in accordance with the existing requirements of the location.

We shall consider now the timing circuits of FIG. 2 for an eastbound train. The eastbound timing crossing relay ETXR is normally energized by a simple and obvious circuit including only front contact *a* of relay 1TR. Relay ETXR is provided with a slow release characteristic, similar to that described for relay TXR in FIG. 1, to provide a slow release period of about 15 seconds. The second energizing circuit for relay ETXR, completed when an approaching train occupies both measuring section ME and approach section AE, includes back contact *a* of relay 1TR and back contact *a* of relay 3TP. Normally, this circuit will be completed prior to the release of relay ETXR after front contact *a* of relay 1TR opens. In other words, normally a train will not occupy only section ME for a sufficient period to allow release of relay ETXR. During the time the train is occupying only section ME, the circuit is completed for energizing the eastbound timing crossing repeater relay ETXP which includes back contact *a* of relay 1TR and front contacts *a*, in series, of relays 3TP and ETXR. It may be noted at this point that, if relay 1TR releases due to a fault in the track circuit apparatus for section ME, relay ETXR will eventually release at the completion of its slow release period and deenergize relay ETXP so that the timing action is halted.

When relay ETXP is energized and picks up, energy is also applied to the eastbound medium speed time element relay EMTE over the circuit completed by the closing of front contact *a* of relay ETXP. Relay EMTE is equivalent to the medium speed time element relay MTE described in FIG. 1 and is of the time element type having a preset timing period, at the end of which it will pick up to close front contacts. Similar also to the first embodiment, relay EMTE picks up to close front contacts only if the train is moving at a selected medium speed, for example, less than 60 miles per hour as in FIG. 1, so that it occupies only section ME for a sufficient period to allow relay EMTE to complete its timing period. When relay EMTE does pick up to close its front contact *a*, the eastbound time element repeater relay ETEP is energized by the simple circuit including only this front contact. Relay ETEP is provided with slow release characteristics by the connection of a snubbing circuit, including capacitor EC1 and resistor ER1, in multiple with the relay winding, in a manner previously described. If timing for other speed ranges is added to this network, additional snubbing circuits will be provided and connected in multiple with the winding of relay ETEP in a manner equivalent to that already described.

When relay ETEP picks up to close its front contact *b*, it completes another holding circuit for crossing relay XR. This circuit retains relay XR picked up and thus the crossing signal HG in its non-warning condition after relay 3TP releases until the timing delay period established by the capacitor-resistor snub of relay ETEP expires and this latter relay releases. As previously explained, this delays the operation of signal HG to a warning condition until that instant in time when a medium speed train is a time period of 20 seconds or slightly more from the highway crossing. Obviously, if additional speed timings are provided, the connection of additional snubbing circuits to delay the release of relay ETEP will further delay the operation of signal HG for slower speed trains so that an equivalent length warning period will be provided. The circuits and the operation of relays WTXR, WTXP, WMTE, and WTEP for a westbound train movement are equivalent to those just described for the eastbound train. For this reason, a detailed description is not provided since the circuits may be traced by reference to the arrangement shown in FIG. 2 when considered with the description already provided. However, relay WMTE will have a different timing period, based for specific example on a westbound medium speed limit of 45 mph and the fixed length of section MW. It may be noted that front contact *b* of relay WTEP provides a parallel holding circuit for relay XR which will delay the release of this relay for a medium speed westbound train in the specific showing provided. The operation of either group of timing relays when a receding train occupies sections MW or ME for eastbound and westbound trains, respectively, is not important and has no significant effect upon the warning signal system. It may be noted that, in the timing circuits of the FIG. 1 arrangement, directional stick relay contacts bypass this reduntant action. However, in the FIG. 2 and 3 stick relay arrangements, the S relays hold only until the opposite TP relay has picked up, that is, the train has cleared the receding approach control section. Thus the use of such relay contacts in the network for relays TXR and TXP will serve no useful purpose and thus have been omitted.

In summary then, our invention provides a highway crossing signal arrangement having a uniform operating time. However, by using overlay type track circuits for detecting the approach of trains and for timing control, the arrangement avoids any requirement for a plurality of insulated track sections with their associated insulated rail joints. This reduces the expense of installation and maintenance of the arrangement of our invention and increases the efficiency by avoiding the possibility of insulated joint failure which would result in an undesired, although safe, warning operation of the crossing signal. This arrangement thus does not interfere with the existing regular wayside signal system since the conventional track circuit control of such signals is not modified or otherwise affected. The arrangement of our invention also allows the majority of the apparatus to be assembled in a single location at the highway crossing using only a single housing unit for protection against weather and other hazards. Further, only a single source of operating power is required at this master location. At each distant end of the approach track sections, only a small protective case for the track circuit transmitters and a relatively small capacity power source is required. This reduces the expense for power apparatus and for equipment housing and thus similarly reduces the cost of installation since fewer locations must be installed. Our invention thus results in a less expensive and a more efficient highway crossing signaling system with the desirable features of uniform operating time and a safe operation of the signal under all conditions.

Although we have herein shown and described but two forms of the signaling system embodying the features of our invention, it is to be understood that various changes and modifications in the illustrated arrangements may be made within the scope of the appended claims without 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 a stretch of railroad track having electrically continuous rails without insulated joints and intersected by a highway at which crossing is located a warning signal selectively operable by an associated signal control means to a clear and a warning condition, comprising in combination,

a. first and second overlay track circuits for the stretch of track over which trains approach said highway crossing in one direction for separately detecting approaching trains occupying the track circuits, each track circuit including a transmitter means and a receiver means coupled to the track rails a selected distance apart to define the limits of the corresponding track circuit,
   1. the first circuit transmitter means coupled to the track rails a preselected distance farther from said crossing than the second circuit transmitter means to form a measuring section which an approaching train occupies prior to occupying the adjoining approach control section,
   2. both receiver means being coupled to the track rails in the vicinity of said crossing in such manner as to maintain detection of a train moving in said one direction until it clears the crossing,

b. said pair of track circuit receiver means connected for controlling said signal control means to normally operate said signal to its warning condition when an approaching train occupies said approach control section,

c. timing control relay means controlled by both circuit receiver means for repeating the occupancy by an approaching train of only the measuring section and for subsequently detecting the continued approach of that train toward said crossing,

d. a plurality of timing means, each operable when actuated for measuring a different and successively longer preselected timing period, each preselected timing period being at least longer than a minimum time interval required by a maximum speed train to traverse said measuring section, and

e. a delay means including an equivalent plurality of delay elements, each delay element connected by a particular timing means to control said delay means for establishing a different one of a plurality of successively longer predetermined delay periods when said particular timing means completes its timing period,

f. said delay means connected to said signal control means for delaying the operation of said signal to its warning condition for the established predetermined delay period after an approaching train occupies said approach control section,

g. said timing control relay means connected for actuating said plurality of timing means to measure said preselected timing periods when an approaching train occupies only said measuring section for a time interval longer than one or more of said preselected timing periods,

h. said timing control relay means also connected for interrupting the established delay period when continued approach of a train toward said crossing is not detected.

2. A highway crossing signal system as defined in claim 1 further including,

a. third and fourth overlay track circuits for the stretch of track in the other direction of approach to said crossing for detecting trains approaching in that direction, each circuit including a transmitter means and a receiver means,
   1. the third and fourth track circuit transmitter means also coupled to the rails a preselected distance apart to form a measuring section and approach control section consecutively in said other direction of approach,
   2. the receiver means of said third and fourth track circuits coupled to said rails in the vicinity of said crossing in a manner to maintain detection of a train moving in said other direction until it clears said crossing,

b. said third and fourth track circuit receiver means also connected for controlling said signal control means to normally operate said signal to its warning condition when a train approaching in said other direction occupies the corresponding approach control section,

c. the first and second pairs of track circuit receiver means selectively controlling said timing control relay means in accordance with the direction of approach of a train for repeating the occupancy of only the corresponding measuring section and for subsequently detecting the continued approach of that train toward said crossing.

3. A highway crossing signal system as defined in claim 2 which further includes,

a. a directional relay arrangement controlled by both pairs of track circuit receiver means and by said timing control relay means for establishing and storing an indication of the direction in which a particular train is traversing the crossing stretch when a measuring section is initially occupied,
   1. the direction indication storage being cancelled when said timing control relay means fails to detect the continued approach of said particular train towards said crossing,

b. said directional relay arrangement further controlled by said track circuit receiver means for retaining said direction indication storage while said particular train traverses the remainder of the crossing track stretch,

c. said directional relay arrangement connected to bypass track circuit control for actuating said signal control means to operate said signal to its clear condition while said particular train recedes from said crossing.

4. A highway crossing signal system as defined in claim 3 in which each track circuit includes a train detection device controlled by the corresponding receiver means for indicating the occupancy of the circuit by a train, said device and the receiver means for each track circuit being located at the highway crossing, together with said timing means, said delay means, said timing control relay means, and said directional relay arrangement.

5. A highway crossing signal system as defined in claim 2 in which,

a. each timing means comprises a time element relay with a preselected different timing period and an energizing circuit controlled by said timing control relay means for energizing the associated time element relay only when an approaching train occupies only a measuring section,

b. said time delay means is a slow release relay energized by the shortest timing period time element relay when its timing period is completed,

c. said delay elements are resistor-capacitor circuit paths, each connected by the corresponding time element relay when its preselected timing period is completed to snub said slow release relay to add to the established delay period.

6. A highway crossing signal system as defined in claim **1** which further includes,

a. third and fourth overlay track circuits for the stretch of track in the other direction of approach to said crossing for detecting trains approaching in that direction, each circuit including a transmitter means and a receiver means,

1. the third an fourth track circuit transmitter means also coupled to the rails a preselected distance apart to form a second measuring section and a second approach control section consecutively in said other direction of approach,

2. the receiver means of said third and fourth track circuits coupled to said rails in the vicinity of said crossing in a manner to maintain detection of a train moving in said other direction until it clears said crossing,

b. said third and fourth track circuit receiver means also connected for controlling said signal control means to normally operate said signal to its warning condition when a train approaching in said other direction occupies the second approach control section,

c. a second timing control relay means controlled by said third and fourth track circuit receiver means for repeating the occupancy, by a train approaching in said other direction, of only said second measuring section and for subsequently detecting the continued approach of the other direction train toward said crossing,

d. a second plurality of timing means, each operable when actuated for measuring a different and successively longer preselected timing period, each period at least longer than the minimum time interval a maximum speed train occupies only said second measuring section, said second timing periods also being different than those of the first plurality of timing means,

e. a second delay means including a plurality of delay elements equivalent to the second plurality of timing periods, each delay element connected by a particular second plurality timing means to control said second delay means for establishing a different one of a second plurality of delay periods when said particular timing means completes its timing period,

f. said second delay means also connected to said signal control means for delaying the operation of said signal to its warning condition for the established delay period after an approaching train occupies said second approach control section,

g. said second timing control relay means connected for actuating said second plurality of timing means to measure the corresponding timing periods when said second measuring section only is occupied,

h. said second timing control relay means also connected for interrupting the established delay period of said second delay means when continued approach by a train moving in said other direction is not detected.

7. A highway crossing signal system as defined in claim **6** in which,

a. each timing means is a time element relay with a preselected different timing period and an energizing circuit controlled by the timing control relay means for the corresponding train direction for energizing that time element relay only when an approaching train occupies only the corresponding measuring section,

b. each time delay means is a slow release relay energized by the shortest timing period time element relay for the corresponding train direction when its timing period is completed,

c. said delay elements are resistor-capacitor circuit paths, each connected by the corresponding time element relay when its timing period is completed to snub the associated slow release relay to add to the established delay period.

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