Sept. 29, 1942. A. G. WILLIAMSON ET AL 2,297,119

RAILWAY TRAFFIC CONTROLLING APPARATUS

Filed Dec. 5, 1941 3 Sheets-Sheet 1

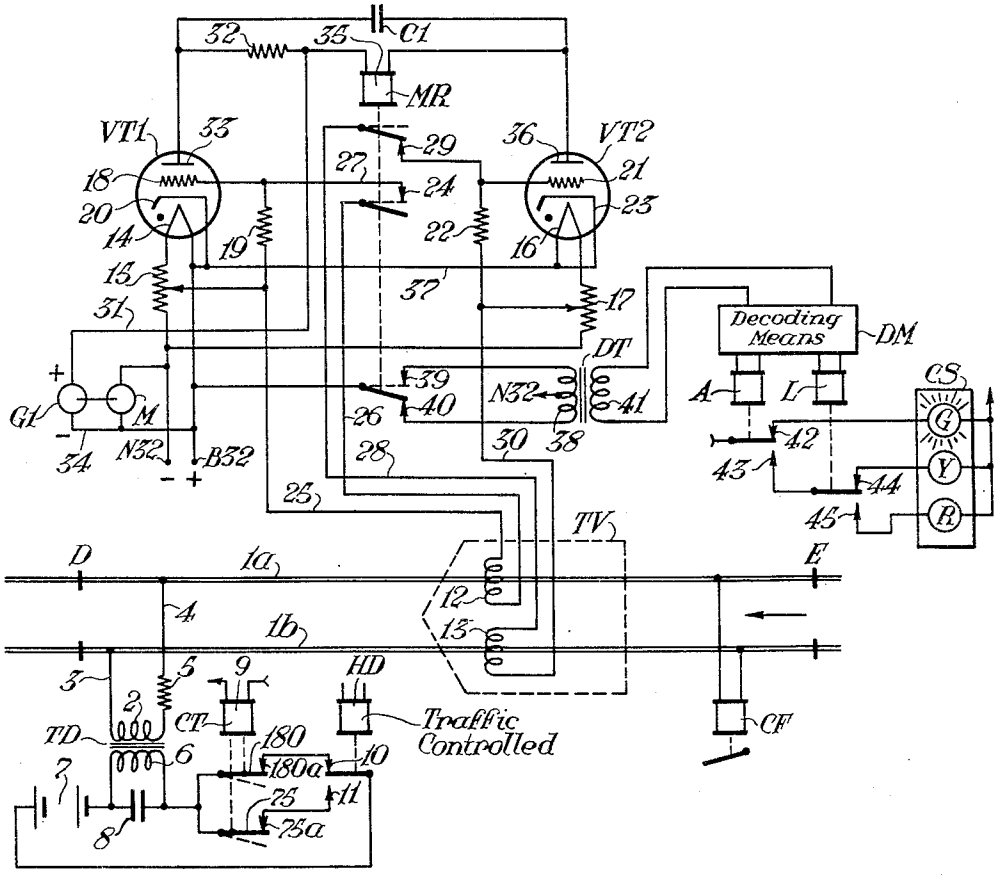


Fig. 1.

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RAILWAY TRAFFIC CONTROLLING APPARATUS

Filed Dec. 5, 1941 3 Sheets-Sheet 2

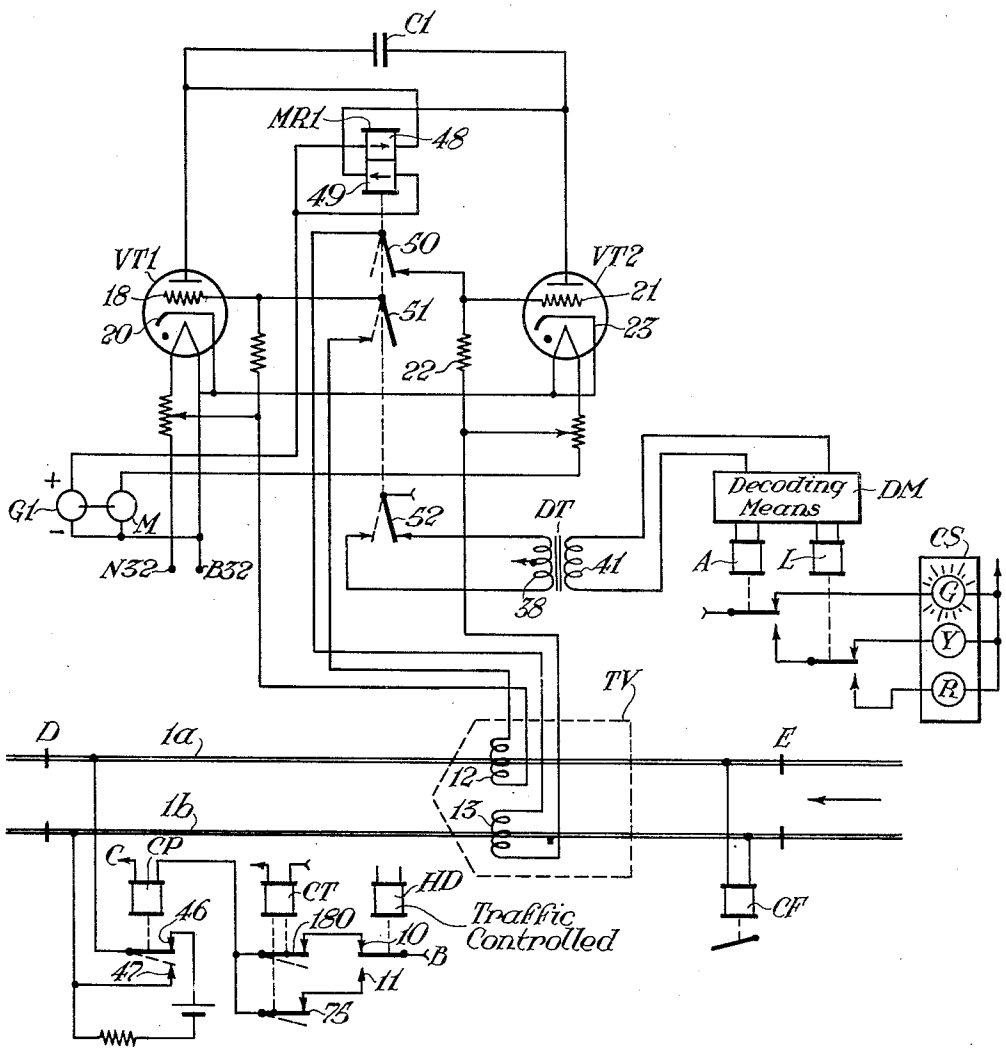


Fig. 2.

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RAILWAY TRAFFIC CONTROLLING APPARATUS

Filed Dec. 5, 1941 3 Sheets-Sheet 3

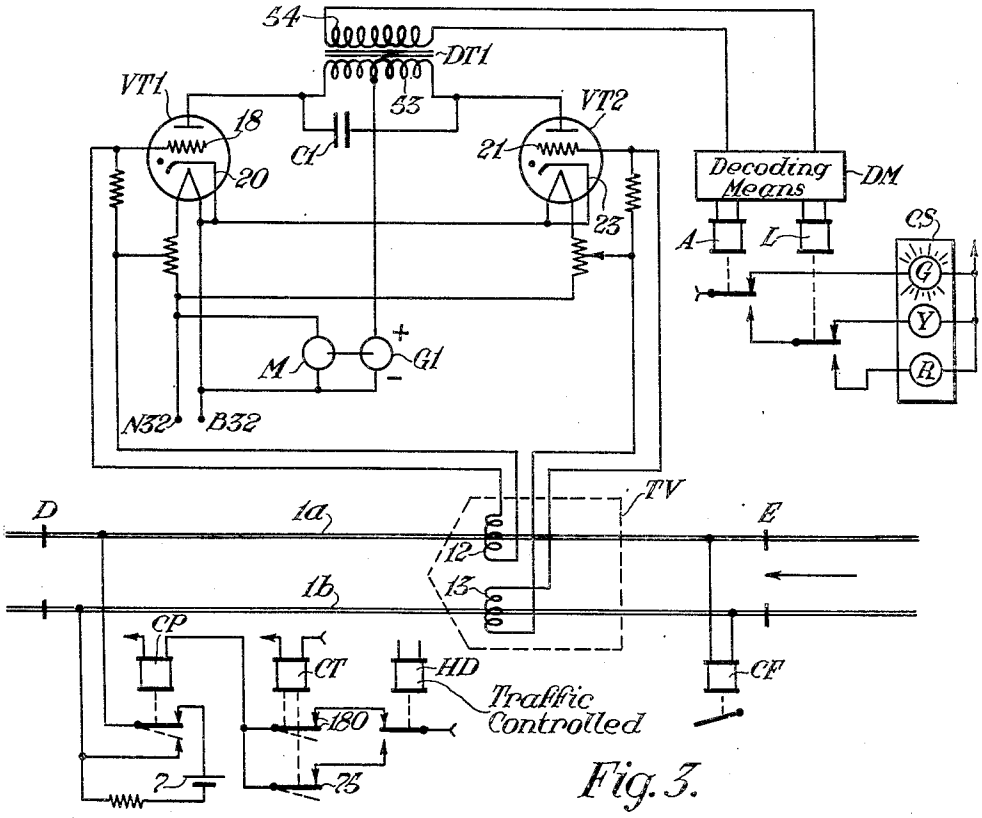


Fig. 3.

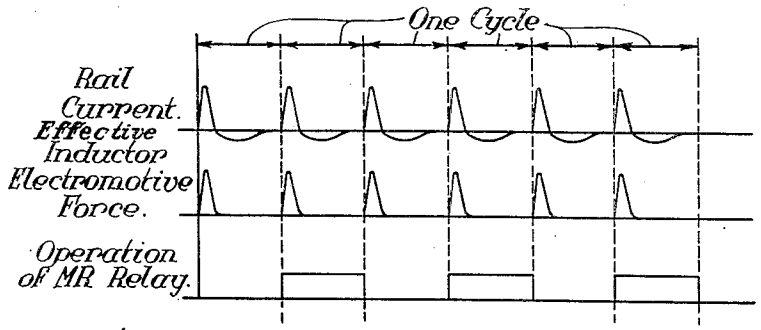


Fig. 4.

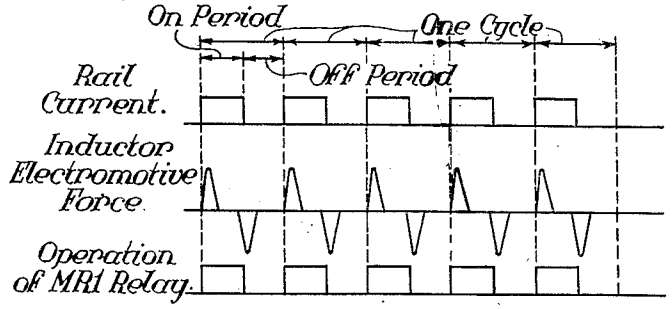


Fig. 5.

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2,297,119

UNITED STATES PATENT OFFICE

2,297,119

RAILWAY TRAFFIC CONTROLLING APPARATUS

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Application December 5, 1941, Serial No. 421,764

15 Claims. (Cl. 246—63)

Our invention relates to railway traffic controlling apparatus, and more particularly to train carried train control apparatus responsive to coded energy.

Coded energy is used in railway traffic controlling apparatus for governing train carried train control apparatus and wayside train governing signals, and when thus used such energy is supplied across the track rails at the exit end of a track section so that current flows in the rails in series to energize a track relay connected across the rails at the entrance end of the section when the section is unoccupied and to inductively energize a train carried receiver when such train travels the section in the normal direction of traffic. The coding is generally effected by periodically interrupting the supply circuit at a preselected code rate and a plurality of different rates are provided to reflect a plurality of different traffic conditions, the rates of 180, 120 and 75 interruptions per minute being those generally employed to reflect clear, approach-medium and approach traffic conditions, respectively. The track relay governs wayside signals according to the code rate at which it is energized, while the energy picked up by the train carried receiver is decoded and used to operate a cab signal or other train control device according to the code rate of the energy thus picked up.

Track sections are of a length predetermined in part according to braking distance required for trains. The braking distance required depends upon the maximum permissible speed and the class of equipment. The high speeds prescribed for present day traffic require relatively long braking distances and hence a relatively long track section if a train is to be brought from maximum speed to a stop in a single track section. For this reason track sections of the order of 11,000 feet in length are desirable where high train speeds prevail. Broken rail protection is also an essential feature in such railway traffic controlling apparatus, and a single track circuit for a track section of 11,000 feet in length provides satisfactory broken rail protection only when either alternating current of a relatively low frequency or direct current is used. Thus some signal systems use coded direct current which assures satisfactory broken rail protection and which can be obtained from local batteries without expensive transmission lines.

Each code cycle of frequency codes of the type here involved consists of an on and an off period. That is, each code cycle includes an on period during which current flows and an off period during which no current flows. The on and off code periods may be of substantially equal durations. However, it has been proposed to make the on period short as compared to the off period. This latter form of coding is advantageous when direct current is used because it conserves the output of the current source, which is ordinarily a battery. On the other hand, the standard form of decoding apparatus used in railway traffic controlling apparatus of the type here involved is most satisfactorily operated in response to substantially equal on and off periods of operation of the code following relay.

Furthermore, when coded direct current is used difficulty may be experienced in the control of train carried apparatus because of the possible energization of the train carried receiver by so-called "magnetized spots" of the track rails. Such magnetized rail spots occur at random and act to induce electromotive forces in a train carried receiver as the train moves over such magnetized spots.

The direct current for such coded track circuit current is ordinarily obtained from a battery, there being one battery usually provided for each track section, and hence it is advantageous that the energy output be held at a low level, and to accomplish this result the train carried apparatus must be effectively controlled by a relatively low induced electromotive force.

Because of these various conditions imposed upon railway traffic controlling apparatus of the class herein contemplated, a feature of our invention is the provision of a novel and improved organization of railway traffic controlling apparatus which is effectively responsive to coded energy.

Another feature of our invention is the provision of a novel and improved organization of train carried train control apparatus responsive to coded direct current.

Still another feature of our invention is the provision of train carried train control apparatus incorporating a novel and improved receiving and amplifying means which is effectively excited only by time spaced electromotive forces derived from the two track rails alternately.

Again, a feature of our invention is the provision of novel train carried train control apparatus of the type here involved wherewith code distortion is avoided and substantially equal on and off periods are effected for operating a decoding means, notwithstanding the control impulses of current may be of short duration as compared to the duration between successive impulses.

Furthermore, a feature of our invention is the provision of train carried train control apparatus that is simple and of low cost, and which is effectively controlled by coded track circuit current of a relatively low energy level.

Other features, advantages and objects of our invention will appear as the specification progresses.

The above features, advantages and objects of our invention are obtained by providing on a train adapted to travel a track section whose rails are provided with coded direct current, a novel two-channel receiving and amplifying means and a decoding and signaling means. Each channel of the receiving and amplifying means comprises an inductor mounted on the train in advance of the leading pair of wheels and a gas filled or controlled ionization type of electron tube. The inductor of the first channel is mounted over one rail, and is connected to the grid circuit of the tube of the first channel, while the inductor of the second channel is mounted over the other rail and connected to the grid circuit of the second channel tube. Each of the tubes is provided with a plate circuit including a source of direct current which is of a voltage insufficient to normally fire the tube but is sufficient to cause the tube to become fired when a predetermined control electromotive force of the proper polarity is applied to the grid of the tube. The grid loses control when the tube once is fired and the tube can be extinguished only by either a decrease of plate voltage or a plate voltage of the reverse polarity for an interval at least equal to the deionization time of the tube. The two receiving channels are inter-related for only one channel to be operative at a time and for the two channels to be alternately operative. This alternate operation is accomplished by providing circuit connections for the inductors which permit the predetermined control electromotive forces to be applied first to one tube and then to the other, and by interconnecting the plate circuits of the tube through an extinguishing device, such as a condenser, which is charged when either tube is fired at a polarity such that when the second tube is fired the condenser discharges through the tubes in series in a direction that extinguishes the first fired tube leaving such first tube in condition to be refired by the next control electromotive force. Thus a first control electromotive force is picked up from a first one of the rails to fire the tube of a first one of the receiving channels, a second control electromotive force is picked up from the second rail to fire the tube of the second receiving channel, and when the second channel tube is fired, the first channel tube is immediately extinguished by the condenser and made ready to be refired by the third control electromotive force which must be received from the first track rail. In other words, a first effective control electromotive force is picked up from one rail and the next effective control electromotive force is picked up from the other rail and such back and forth action of the control electromotive forces from one rail to the other is required for effective operation of the train carried apparatus. An electromotive force picked up at random due to a magnetized rail spot is ineffective to exert a control on a receiving channel unless such stray electromotive force occurs just at a time the channel associated with the rail on which such magnetized spot occurs is at the moment conditioned to receive a control electromotive force and the stray electromotive force is of proper polarity, and under such circumstances no unsafe operation results.

In one form of the invention, the winding of a code following relay is interposed in the plate circuit of a preselected one of the electron tubes, and such relay is therefore energized and operated at a rate corresponding to the code rate at which the two receiving channels are alternately operated.

In another form of the invention, a two-winding polar code following relay has one winding included in the plate circuit of one of the two tubes and its other winding in the plate circuit of the other tube and this relay is operated at a rate corresponding to the code rate at which the two receiving channels are alternately operated.

In still another form of the invention, a primary winding of a decoding transformer is divided into two portions and one portion is interposed in the plate circuit of one tube and the other portion is interposed in the plate circuit of the other tube and thus there is induced in the secondary winding of this transformer an alternating electromotive force of a frequency corresponding to the rate at which current is alternately supplied to the two portions of the primary winding, and in turn corresponding to the rate at which the two receiving channels are alternately operated. When a code following relay is provided, contacts of the relay are used to control the supply of direct current to preselected portions of the primary winding of the decoding transformer for inducing in a secondary winding of the transformer an alternating electromotive force of a frequency corresponding to the rate at which the relay is operated and in turn corresponding to the rate at which the receiving channels are alternately operated. The secondary winding of the decoding transformer is connected to a standard form of decoding means and which means ordinarily comprises tuned circuits selectively responsive to the frequency of the electromotive force applied thereto and through which tuned circuits control relays are selectively energized, such control relays being used in turn to govern a multiple position cab signal or other train governing device.

The connection of each train carried inductor to the associated grid circuit is made such that the electromotive force picked up by an inductor is of the polarity that will effect the firing of the associated tube only if it is the proper time for that tube to be fired in the cyclic operation of the two receiving channels. When a code following relay is used we preferably connect the inductors to the grid circuits of the respective tubes over contacts of the code following relay, the connection of an inductor to the associated grid circuit being closed only when the next received electromotive force is the one to fire the respective tube. This switching of the connections of the inductors serves as an aid in assuring no untimely firing of a tube due to a stray magnetic field.

We shall describe three forms of apparatus embodying our invention, and shall then point out the novel features thereof in claims.

In the accompanying drawings, Fig. 1 is a diagrammatic view showing one form of apparatus embodying our invention when used with train carried train control apparatus. Figs. 2 and 3 are diagrammatic views showing two different modifications of the apparatus of Fig. 1 and each of which modified forms of apparatus also

embodies our invention. Figs. 4 and 5 are diagrams illustrating operating characteristics of the apparatus of Figs. 1 and 2, respectively.

In each of the several views like reference characters are used to designate similar parts.

Referring to Fig. 1, the reference characters *1a* and *1b* designate the track rails of a stretch of railway over which traffic normally moves in the direction indicated by an arrow and which rails are formed by the usual insulated rail joints with a track section D—E and which section may be one section of a series of consecutive track sections of a signal system. The track section D—E is provided with a track circuit which is typical of all sections and which comprises a source of coded direct current connected across the rails at the exit end of the section and a code following relay connected across the rails at the entrance end of the section. In Fig. 1, the source of coded direct current for the track circuit of section D—E comprises a battery **7**, a code transmitter or coder CT, a track transformer or reactor TD, and a traffic controlled relay HD. Secondary winding **2** of transformer TD is connected across the rails at exit end D over wires **3** and **4**, a current limiting resistor **5** being preferably interposed in wire **4**. Primary winding **6** of transformer TD is connected to battery **7** over either code contact member **75** or **180** of coder CT according to the position of traffic controlled relay HD. A condenser **8** is preferably connected across the primary winding **6**.

Code transmitter CT may take the form of any one of several well-known structures for such devices and it is sufficient to point out that as long as operating winding **9** of the code transmitter is supplied with current from any convenient source of current, not shown, the code contact members **75** and **180** are operated at preselected code rates. For example, contact member **75** is operated to engage and disengage a contact **75***a* at the rate of 75 times per minute, and contact member **180** is operated to engage and disengage a contact **180***a* at the rate of 180 times per minute. The relay HD is controlled by traffic conditions in advance of section D—E, but such control apparatus is not shown since it would be in accordance with standard practice and forms no part of our present invention. It is sufficient for this application to point out that relay HD is picked up to close front contact **10** when the section next in advance of section D—E is unoccupied and clear traffic conditions prevail, and the relay is released closing back contact **11** when the section next in advance is occupied and approach traffic conditions prevail. When relay HD is picked up closing front contact **10**, battery **7** is connected to primary winding **6** over a circuit including contact member **180** of coder CT, and during each interval that contact **180**—**180***a* is closed direct current flows in winding **6** causing magnetic energy to be stored in the magnetic core of transformer TD. The circuit including battery **7**, front contact **10** of relay HD and primary winding **6** of transformer TD is so proportioned as to its time constant that the magnetic energy builds up relatively slow and little, if any, electromotive force is induced in secondary winding **2**, at least such electromotive force is so small it can be neglected. When contact member **180** breaks engagement with contact **180***a*, the flow of current from battery **7** is interrupted and the magnetic energy stored in transformer TD decays rapidly and an electromotive force of relatively high voltage is induced in secondary winding **2** and a current impulse of relatively high peak voltage is supplied to the rails of the section. This impulse of direct current is of a given polarity and is of a short duration. For example, the parts may be proportioned to provide an impulse of current having a duration of the order of say .05 second. Thus, a code impulse of current is supplied to the rails each operation of code contact member **180** and code impulses of the code rate of 180 impulses per minute are supplied to the rails as long as relay HD is picked up. Under approach traffic conditions, and relay HD is released closing back contact **11**, battery **7** is connected to primary winding **6** over contact member **75** of the code transmitter and the operation is the same as described above except that the current impulses are of the code rate of 75 impulses per minute. Such code impulses of rail current are illustrated in the top series of graphs of Fig. 4, and it is to be observed that the duration of a current impulse is short as compared to the duration between successive impulses. For example, if the current impulse is of a duration of the order of .05 second as here assumed for illustration, the duration between successive impulses of the 180 code rate is of the order of .28 second and the duration between successive impulses of the 75 code rate is of the order of .75 second. It will be understood, of course, that our invention is not limited to code rates of 75 and 180 impulses per minute or to impulses of the duration of the order of .05 second but such code rates and characteristics for direct current impulses have been found satisfactory.

A code following track relay CF is connected across the rails at entrance end E and when section D—E is unoccupied, that is, when the train shown conventionally at TV does not occupy the section, relay CF is operated at a code rate corresponding to the code rate of the current impulses supplied to the rails through transformer TD in the manner just explained. Track relay CF would be used to govern apparatus including a control relay for the section next in the rear of section D—E and which relay would be similar to control relay HD governed by traffic in the section in advance of section D—E, but such apparatus governed by track relay CF is not shown for the sake of simplicity, since, as stated hereinbefore, such control apparatus forms no part of our present invention and would be in accordance with standard practice.

The train shown conventionally at TV of Fig. 1 is provided with train carried apparatus embodying our invention and which apparatus comprises a receiving and amplifying means to be shortly described, a code following relay MR, a decoding transformer DT, decoding means DM, control relays A and L and a cab signal CS.

The receiving and amplifying means comprises inductors **12** and **13** and electron tubes VT1 and VT2, inductor **12** and tube VT1 being associated to form a first receiving channel, and inductor **13** and tube VT2 being associated to form a second receiving channel. Inductors **12** and **13** are preferably alike and are mounted on the train ahead of the leading pair of wheels with inductor **12** above rail *1a* and inductor **13** above rail *1b*. When train TV occupies section D—E and there is no other train between it and the exit end of the section an electromotive force is induced in each inductor **12** and **13** in response to each code impulse of rail current supplied to the rails through track transformer TD in the man-

ner explained hereinbefore. The effective electromotive force picked up by each inductor 12 and 13 is of a character illustrated by the center series of graphs of Fig. 4 and it is to be observed that the electromotive force picked up by each inductor is of a predetermined polarity and of a code rate corresponding to that of the rail current. This is so because each current impulse flows in a predetermined direction which is opposite for the two rails, and is of the same magnitude in each rail.

Electron tubes VT1 and VT2 are preferably alike and are of the gas filled grid controlled indirect heater type. Filament 14 of tube VT1 is connected across terminals B32 and N32 of a suitable source of current, such as the usual train carried 32 volt battery or generator, a resistor 15 being included in the heater circuit of tube VT1. Similarly, filament 16 of tube VT2 is connected across terminals B32 and N32 with a resistor 17 interposed in the circuit. Consequently, both tubes VT1 and VT2 are normally in an active condition.

Tube VT1 is provided with a grid circuit that extends from grid 18 over resistor 19, a preselected portion of heater circuit resistor 15 and filament 14 to cathode 20 of the tube. Tube VT2 is provided with a similar grid circuit which extends from grid 21 over resistor 22, a preselected portion of heater circuit resistor 17 and filament 16 to cathode 23. Inductor 12 is connected to the grid circuit of the associated tube VT1 by being connected across resistor 19 over a front contact 24 of code following relay MR. As viewed in the drawings, the top terminal of inductor 12 is connected to the lower terminal of resistor 19 over wire 25, and the lower terminal of inductor 12 is connected to the top terminal of resistor 19 over wire 26, front contact 24 of relay MR and wire 27. In like manner, inductor 13 is connected to the grid circuit of the associated tube VT2 by being connected across resistor 22 over a back contact 29 of code following relay MR. Again, as viewed in the drawings, the top terminal of inductor 13 is connected to the top terminal of resistor 22 over wire 28 and back contact 29 of relay MR, and the lower terminal of inductor 13 is connected to the lower terminal of resistor 22 over wire 30. Each tube VT1 and VT2 is provided with a negative grid bias voltage equal to the voltage drop across that portion of the heater circuit resistor interposed in the grid circuit, the value of such negative grid bias voltage being predetermined by the position of the connection to the heater circuit resistor and can be readily made of a value to normally avoid firing of the tube. When the electromotive force picked up by inductor 12 or 13, as the case may be, and applied to the grid circuit of the associated tube is of a given polarity it opposes the negative grid bias voltage and drives the grid in the positive direction by an amount determined by the value of the picked up electromotive force.

Each of the tubes VT1 and VT2 is provided with a plate circuit that includes a source of direct current, such as a generator G1, which generator as here shown is the generator of a motor-generator whose motor element M is driven by current from the B32—N32 train carried current source. To be explicit, the plate circuit for tube VT1 can be traced from the positive terminal of generator G1 over wire 31, a resistor 32, plate 33 of tube VT1, intervening tube space to cathode 20, and wire 34 to the negative terminal of generator G1. The plate circuit of tube VT2 includes the positive terminal of generator G1, wire 31, winding 35 of relay MR, plate 36 of tube VT2, intervening tube space to cathode 23, wires 37 and 34, and the negative terminal of generator G1. The voltage of generator G1 and the normal negative grid bias voltage provided for each tube are such that each tube is normally non-conductive, but that the change in the grid voltage effected by the electromotive force of proper polarity picked up by an inductor causes the tube to be fired, and after which the grid loses control due to the nature of the tube and the tube can be extinguished only by a lowering of the plate voltage for an interval at least equal to the deionization time of the tube.

An extinguishing device is provided which as here shown is a condenser C1 connected between plates 33 and 36 of the two tubes, as will be apparent by an inspection of Fig. 1. The operation of such extinguishing device will appear later.

Relay MR, whose winding 35 is interposed in the plate circuit of tube VT2, is a code following relay of any one of several well-known types. Relay MR controls the supply of direct current to decoding transformer DT in addition to controlling the connections of inductors 12 and 13 to the respective grid circuits as explained hereinbefore. Direct current from any convenient source, such as the 32 volt train carried source is alternately supplied to two portions of primary winding 38 of transformer DT over front contact 39 and back contact 40 of relay MR. Hence there is induced in secondary winding 41 of transformer DT an alternating electromotive force of a frequency corresponding to the rate at which code following relay MR is operated. Secondary winding 41 of transformer DT is connected to the input terminals of a decoding means shown conventionally at DM. Decoding means DM is preferably of the standard form and comprises tuned circuits to which are connected the two control relays A and L. It is sufficient for this application to point out that relay A is effectively energized and picked up only when the alternating electromotive force applied to the decoding means DM is of a frequency corresponding to the 180 code rate for the rail current impulses, and relay L is effectively energized and picked up in response to alternating electromotive forces created in response to rail current of either the 180 or 75 code rate.

Control relays A and L govern the operating circuits of cab signal CS, the arrangement being such that when relay A is picked up closing front contact 42, an operating circuit is formed for lamp G and that lamp is illuminated to cause signal CS to display a clear signal indication; when relay A is released closing back contact 43, and relay L is picked up closing front contact 44, an operating circuit is formed for lamp Y and that lamp is illuminated to cause signal CS to display an approach signal indication; and when both relays A and L are released closing back contacts 43 and 45, respectively, an operating circuit is formed for lamp R, and that lamp is illuminated to cause signal CS to display a slow speed signal indication.

In describing the operation of the apparatus of Fig. 1, we shall first consider that train TV occupies section D—E at a time when relay HD is picked up in response to clear traffic conditions in advance and code impulses of the code rate of 180 are supplied to the rails of the section. Each impulse of rail current induces an electromotive

force in each one of the inductors 12 and 13. As a starting point, we shall assume that code following relay MR is released to close back contact 29 and open front contact 24 so that the connection of inductor 13 to the grid circuit of tube VT2 is closed but inductor 12 is disconnected from the grid circuit of tube VT1. Inductor 13 is poled so that the electromotive force induced therein due to the impulse of rail current is of a polarity that causes grid 21 to be driven in the positive direction in potential with respect to cathode 23 and tube VT2 is fired and becomes conductive. Current now flows in the plate circuit of tube VT2 and code following relay MR is energized and picked up. When tube VT2 is thus made conductive, it remains conductive subsequent to the impulse of electromotive force that caused it to be fired until such time as its plate voltage is reduced. With tube VT2 conductive, the condenser C1 is charged at a potential substantially equal to the voltage drop across winding 35 of relay MR, the left-hand terminal of condenser C1 being the positive terminal. At the next impulse of rail current the electromotive force induced in inductor 12 is applied to the grid circuit of tube VT1 because its connection is closed at front contact 24 of relay MR, but the electromotive force induced in inductor 13 is ineffective because the connection of inductor 13 to the grid circuit of tube VT2 is open at back contact 29 of relay MR. Inductor 12 is poled so that this electromotive force is of a polarity that causes grid 18 to be driven in the positive direction in potential with respect to cathode 20 and tube VT1 is fired and becomes conductive. With both tubes conductive, condenser C1 discharges through the two tubes in series and in the direction that causes cathode 23 of tube VT2 to be positioned with respect to the plate of that tube, and tube VT2 is immediately extinguished. Tube VT1 remains conductive subsequent to the termination of the control electromotive force that caused it to be fired and plate current continues to flow with the result that condenser C1 is recharged due to the voltage drop across resistor 32, the right-hand terminal of condenser C1 being this time positive and the left-hand terminal negative. When tube VT2 is extinguished code following relay MR is deenergized and released to close back contact 29 and open front contact 24 so that at the next impulse of rail current the electromotive force induced in inductor 13 is effective to cause tube VT2 to be fired and the electromotive force picked up by inductor 13 is ineffective. When tube VT2 is fired condenser C1 discharges through the tubes in series, the discharge being this time in a direction that causes cathode 20 of tube VT1 to be positive with respect to the plate of that tube, and tube VT1 is extinguished. Relay MR is again picked up due to the flow of plate current of tube VT2 and on picking up serves to switch the connections of inductors 12 and 13. Such alternate operation of the two receiving channels is continued as long as the train occupies the section and code impulses of direct current are applied to the track rails. Relay MR is thus operated at a rate corresponding to the code rate at which the two receiving channels are alternately operated and in turn at a rate corresponding to the code rate of the rail current. Operation of relay MR causes direct current to be alternately supplied to the two portions of primary winding 38 of transformer DT so that there is induced in secondary winding 41 an alternating electromotive force of a corresponding frequency. The operating characteristics of relay MR are illustrated by the bottom series of graphs of Fig. 4, and it is to be pointed out that the relay is operated at substantially equal on and off periods notwithstanding the fact that the duration of the on periods of the rail current is short as compared to the duration of the off periods.

Operation of relay MR to thus create an alternating electromotive force in the decoding transformer causes relay A to be energized and picked up due to the frequency of such alternating electromotive force, and relay A on being picked up causes signal CS to display a clear signal indication.

In the event relay HD is released due to approach traffic conditions in advance and current impulses of the 75 code rate are supplied to the rails of sections D—E at a time the section is occupied by train TV, the train carried apparatus is operated in a manner similar to that effected under clear traffic conditions except for the fact that the receiving channels are now alternately operated at the 75 code rate causing relay MR to be operated at a corresponding rate, and which rate of operation of relay MR in turn causes the alternating electromotive forces created in the decoding transformer DT to be of a frequency that results in relay L being picked up and relay A being released. This set up of the control relays A and L causes signal CS to display an approach signal indication.

In the event section D—E is occupied by another train ahead of train TV, then the rail current is shunted by the leading train and the apparatus of train TV is inactive and both relays A and L are released to cause signal CS to display a slow speed signal indication.

Referring to Fig. 2, the track rails 1a and 1b of a stretch of railway are formed with a track section D—E which is provided with a track circuit the same as in Fig. 1. In Fig. 2, the means for supplying coded direct current to the rails at exit end D of the section comprises battery 7, code transmitter CT, a code repeater relay CP and traffic controlled relay HD, relay HD being governed by traffic conditions in advance and code transmitter CT being operated to actuate contact members 75 and 180 the same as in Fig. 1. When relay HD of Fig. 2 is picked up closing front contact 10, code repeater relay CP is energized over a circuit including terminal B of a convenient source of current, such as a battery not shown, front contact 10 of relay HD, code contact member 180 of code transmitter CT, winding of relay CP, and terminal C of the same source of current. It follows that repeater relay CP is picked up and released in step with the operation of code contact member 180. Relay CP when picked up to close front contact 46 completes the connection of battery 7 to the rails, and when the relay is released battery 7 is disconnected from the rails and the rails are short circuited through a path including back contact 47. Hence, during each operation cycle of contact member 180, direct current is supplied to the rails for substantially one-half of the cycle and the current is interrupted for substantially one-half of the cycle. The top series of graphs of Fig. 5 illustrates such coding of the rail current, the raised portions of Fig. 5 illustrating the on periods when current flows in the rails and the depressed portions illustrating the off pe-

riods when no current flows. With relay HD released closing back contact 11, repeater relay CP is controlled over code contact member 75 and the operation of coding the current supplied to the rails is substantially the same as before except for the fact that the coding is now of the 75 code rate.

Code following track relay CF of Fig. 2 is operated by the coded direct current supplied to the rails at the exit end D in substantially the same manner as explained in connection with Fig. 1 and relay CF would be used to control wayside signals and other apparatus the same as in Fig. 1.

The train carried apparatus for train TV of Fig. 2 comprises a two-channel receiving and amplifying means and a standard form of decoding and signaling means that are the same as in Fig. 1, except that resistor 32 interposed in the plate circuit of tube VT1 and code following relay MR interposed in the plate circuit of tube VT2 of Fig. 1 are replaced by a two-winding polar code following relay MR1 whose top winding 48 is interposed in the plate circuit of tube VT1 and whose lower winding 49 is interposed in the plate circuit of tube VT2. It is believed that the train carried apparatus of Fig. 2 can best be understood from a description of its apparatus when taken in connection with the detailed description of the train carried apparatus of Fig. 1.

In describing the operation of the apparatus of Fig. 2, we shall first consider the operating steps when train TV occupies the section D—E with relay HD picked up because of clear traffic conditions and direct current of the 180 code rate is supplied to the rails. At the start of an on code period and current builds up in the rails, an electromotive force is induced in each inductor 12 and 13, the polarity of such electromotive forces being predetermined according to the direction the current is made to flow in the rails. We shall assume that at the time these electromotive forces are thus induced in inductors 12 and 13, the code following relay MR1 occupies its right-hand position as illustrated by the solid lines for contact members 50, 51 and 52 of the relay. At the right-hand position of relay MR1 the connection of inductor 13 to the grid circuit of tube VT2 is closed at the right-hand polar contact of contact member 50, but the connection of inductor 12 to the grid circuit of tube VT1 is opened at contact member 51. Consequently, the electromotive force induced in inductor 13 is applied to the tube VT2, but the electromotive force induced in inductor 12 is ineffective. Inductor 13 is poled so that the polarity of the electromotive force induced therein due to the building up of rail current is such as to drive grid 21 of tube VT2 in the positive direction in potential with respect to cathode 23 and tube VT2 is fired and becomes conductive. Plate circuit current flows through tube VT2 and energizes winding 49 of relay MR1, the current flowing in winding 49 in the direction that energizes the relay at a polarity that operates the contact members 50, 51 and 52 to the left-hand position, that is, to the position indicated by dotted lines in Fig. 2. Condenser C1 is charged due to the voltage drop across winding 49, its left-hand terminal being the positive terminal. At the end of this on code period of the rail current and the current dies away, another electromotive force is induced in each of the inductors 12 and 13. For each inductor, the polarity of such electromotive force is opposite to that of the electromotive forces picked up when the current builds up at the start of the on code period. The electromotive force induced in inductor 12 at the end of an on code period is applied to tube VT1 because contact member 51 engages a left-hand polar contact but the electromotive force induced in inductor 13 is ineffective because the connection of that inductor is now open. Inductor 12 is poled so that the polarity of the electromotive force picked up due to the dying away of rail current drives the grid 18 of tube VT1 in the positive direction in potential with respect to cathode 20 and the tube is fired and made conductive. Condenser C1 now discharges through the tubes in series to extinguish tube VT2. The plate circuit current for tube VT1 flowing in winding 48 of relay MR1 energizes the relay at a polarity that operates the contact members 50, 51 and 52 back to the right-hand position. Also this plate current flowing in tube VT1 recharges condenser C1, the right-hand terminal being the positive terminal. At the start of the next on code period of rail current, the electromotive forces picked up by inductors 12 and 13 are of the polarity explained in connection with the start of the first on code period and the electromotive force picked up by inductor 13 is effective to cause tube VT2 to be fired which results in operation of relay MR1 to its left-hand position. Condenser C1 now discharges through the tubes in series to extinguish tube VT1, and is then recharged due to the plate circuit current for tube VT2. The above described alternate operation of the two receiving channels of Fig. 2 and in turn operation of code following relay MR1 is repeated as long as the train TV remains in section D—E and coded direct current is supplied to the track rails. The electromotive forces picked up at the start and at the end of each on code period are illustrated by the center series of graphs of Fig. 5, and the operation of relay MR1 is illustrated by the bottom series of graphs of Fig. 5.

Code following relay MR1 at its contact member 52 controls the supply of direct current to the two portions of primary winding 38 of decoding transformer DT and there is induced in secondary winding 41 an alternating electromotive force of a frequency corresponding to the rate at which relay MR1 is operated and under clear traffic conditions the alternating electromotive force induced in secondary winding 41 is of a frequency corresponding to the 180 code rate of the rail current. This electromotive force induced in secondary winding 41 when applied to the decoding means DM energizes relay A and causes signal CS to display a clear signal indication.

In the event train TV of Fig. 2 occupies the section D—E under approach traffic conditions and the current is coded at the 75 code rate, the operation of the apparatus is the same as described in connection with current of the 180 code rate except for the rate at which relay MR1 is operated and this time the alternating electromotive force created in the decoding transformer is of a frequency that causes relay L to be picked up and relay A to be released so that signal CS displays an approach signal indication. Also in connection with Fig. 2, if a train ahead of the train TV shunts the rail current, the train carried apparatus of train TV is inactive and a slow speed cab signal indication is displayed.

Referring to Figs. 4 and 5, it is to be observed that the code following relay MR1 of Fig. 2 is operated at a rate twice that of code following relay MR of Fig. 1. This means that the tuned circuits of the decoding means DM would be adjusted for the particular rate at which the respective code following relay is operated.

In connection with Fig. 2, it is to be pointed out that while inductors 12 and 13 are made alternately effective and ineffective by the control of their connections by the code following relay MR1, such control by the code following relay may not be required and alternate operation of the receiving channels would be effected with such control of the code following relay omitted. For example, the electromotive force picked up by inductor 13 at the start of each on code period is of a polarity that will cause tube VT2 to be fired, whereas the polarity of the electromotive force induced in inductor 13 at the end of each on code period is opposite and is of a polarity that drives grid 23 more negative in potential with respect to the cathode and hence would not serve to cause the tube to fire. Similarly, the electromotive force created in inductor 12 at the end of each on code period is of a polarity that causes tube VT1 to be fired whereas the polarity of the electromotive force created at the start of the on code period of the rail current tends to drive grid 18 of tube VT1 more negative in potential with respect to the cathode of the tube.

Referring to Fig. 3, the track apparatus for track section D—E is the same as in Fig. 2 and the description thereof need not be repeated except to point out that the direct current is coded in the manner illustrated by the top series of graphs of Fig. 5.

The train carried apparatus provided for train TV of Fig. 3 comprises two receiving channels together with standard decoding and signaling means the same as in Fig. 1, except resistor 32, code following relay MR and decoding transformer DT of Fig. 1 are replaced by a decoding transformer DT1. One portion of primary winding 53 of transformer DT1 is interposed in the plate circuit of tube VT1 and a second portion of primary winding 53 is interposed in the plate circuit of tube VT2. It is believed that the apparatus of Fig. 3 will best be understood from a description of its operation taken in connection with the description of the apparatus of the train TV of Fig. 1.

In describing the operation of the apparatus of Fig. 3 we shall first take up the operating steps effected when train TV occupies section D—E under clear traffic conditions and current coded at the 180 code rate is supplied to the rails. When current builds up in the rails at the start of an on code period, an electromotive force is induced in each inductor 12 and 13. Inductor 13 which is connected to the grid circuit of tube VT2, is poled so that the electromotive force picked up by inductor 13 due to the building up of rail current is of a polarity such as to drive grid 21 of tube VT2 in the positive direction and cause that tube to be fired. Inductor 12 which is connected to the grid circuit of tube VT1, is poled so that the electromotive force picked up by inductor 12 due to the building up of rail current is of a polarity to drive the grid of tube VT1 more negative in potential with respect to the cathode and tube VT1 remains extinguished. The plate current flowing when tube VT2 is made conductive energizes the right-hand portion of primary winding 53 of transformer VT1 and also causes condenser C1 to be charged in the manner explained hereinbefore, the left-hand terminal of condenser C1 being the positive terminal. At the end of the on period of the rail current an electromotive force is induced in each of inductors 12 and 13 as the current dies away, the polarity of each such electromotive force being opposite to that created at the beginning of the on code period. This time the electromotive force of inductor 12 is of a polarity that causes tube VT1 to be fired, while the electromotive force of inductor 13 is of a polarity that drives the grid of tube VT2 in the negative direction. With both tubes fired, condenser C1 discharges to extinguish tube VT2 and the plate current flowing in tube VT1 energizes the left-hand portion of primary winding 53 of transformer DT1 and charges condenser C1 with its right-hand terminal the positive terminal. At the next on period of the rail current, the tubes are alternately fired, tube VT2 being fired at the beginning of the on period and tube VT1 being fired at the end of the on period. Such alternate operation of the receiving channels of Fig. 3 causes an alternating electromotive force to be created in secondary winding 54 of transformer DT1 which has a frequency corresponding to the code rate at which the receiving channels are alternately operated. Secondary winding 54 is connected to the input side of the decoding means DM causing thereby control relay A to be picked up and signal CS to display a clear signal indication in response to the 180 code rate for the rail current.

Under approach traffic conditions for the apparatus of Fig. 3, the operation is the same as explained for clear traffic conditions except the receiving channels are now alternately operated at the 75 code rate with the result that control relay L is picked up and relay A is released causing signal CS to display an approach signal indication. Furthermore, when section D—E is occupied by another train ahead of train TV the train carried apparatus of train TV is inactive and a slow speed signal indication is displayed.

In connection with Fig. 3, it is to be observed that the two tubes serve as a code following relay and their plate circuit currents are used to energize the decoding transformer.

Apparatus herein described has the advantages that direct current can be used to assure effective broken rail protection for long track sections, the train carried receiving and amplifying means is effectively responsive to a relatively low energy of rail current so that a saving in the output of the track battery is obtained and substantially equal on and off periods are obtained for control of the standard decoding means, notwithstanding unequal on and off periods of the coded rail current may exit due either to the form of coding employed or to code distortion. Furthermore, false energization of the train carried receiving means by stray magnetic fields, such as magnetized rail spots is avoided.

Although we have herein shown and described but three forms of railway traffic controlling apparatus embodying our invention, it is understood that various changes and modifications may be made therein 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. In combination, a track section, a train to travel such section, means connected to the rails of said section to supply to the rails direct current coded at a preselected code rate; two train carried receiving channels each of which includes an inductor, a gas filled tube and a circuit connection to connect the inductor to the grid of the tube; said tubes each provided with a plate circuit which includes a source of direct current of a voltage normally ineffective to fire the respective tube, said inductors mounted one in inductive relation to one rail and the other in inductive relation to the other rail for each inductor to pick up an electromotive force in response to said coded rail current, said circuit connections arranged for said electromotive forces picked up by said inductors to alternately fire the tubes, means including a condenser connected across the plates of said tubes to alternately extinguish said tubes, and signaling means coupled to the plate circuit of at least one of said tubes controlled by the current thus caused to recurrently flow in the plate circuit of said one tube.

2. In combination, a track section, a train to travel such section, trackway means to supply to the rails of said section direct current coded at a predetermined code rate, two train carried receiving channels each of which includes an inductor and a gas filled tube with each inductor provided with a connection to the grid circuit of the tube of the same channel, said inductors one mounted above one rail and the other mounted above the other rail for each inductor to pick up an electromotive force due to said coded rail current, said tubes each provided with a plate circuit including a source of direct current which is normally ineffective to fire the respective tube, said inductor connections arranged to alternately fire said tubes by the electromotive forces picked up by the inductors, means including reactance connected across the plates of said tubes to alternately extinguish the tubes, and train carried signaling means coupled to the plate circuit of at least one of said tubes and controlled by the current thus caused to recurrently flow in the plate circuit of said one tube.

3. In combination, a track section, a train to travel said section, trackway means connected across the rails of the section to supply to the rails direct current coded at a preselected code rate, two receiving channels mounted on said train and each including an inductor and a gas filled tube, said inductors one mounted over one rail and the other mounted over the other rail for each inductor to receive an electromotive force in response to said coded rail current, said tubes each provided with a grid circuit to which the inductor of the same channel is connected, said tubes each provided with a plate circuit which includes a source of direct current of a voltage ineffective to normally fire the tube, said grid circuits arranged in their connections to the respective inductors to alternately fire the tubes in response to said received electromotive forces, means including a condenser connected across the plates of said tubes to alternately extinguish said tubes, and train carried signaling means electrically associated with said receiving channels and controlled by such alternate operation of the channels in response to said coded rail current.

4. In combination, a track section, a train to travel such section, means connected to the rails of said section to supply to the rails time spaced impulses of direct current, two inductors mounted on said train with one inductor above one rail and the other inductor above the other rail for each of said inductors to receive time spaced electromotive forces due to said rail current, two gas filled tubes on said train, a plate circuit for each of said tubes and each said plate circuit including a source of direct current of a voltage insufficient to normally fire the respective tube, a first grid circuit means for one of said tubes and including said one inductor and a second grid circuit means for the other one of said tubes and including said other inductor, said grid circuit means provided with a predetermined relationship to alternately fire said tubes in response to said time spaced electromotive forces received by said inductors, means including a condenser connected across the plates of said tubes to alternately extinguish said tubes, and signaling means on the train electrically associated with said plate circuits and controlled by the currents thus caused to alternately flow in the plate circuits.

5. In combination, a track section, a train to travel such section, means connected across the rails to supply coded direct current that flows in the rails in series, two train carried inductors one mounted over one rail and the other mounted over the other rail for each inductor to receive energy in response to said coded direct current, two train carried gas filled tubes, a heater circuit including a resistor for each of said tubes, a plate circuit including a source of direct current for each of said tubes, a grid circuit for each of said tubes and each grid circuit including at least a portion of the resistor of the heater circuit of the same tube to provide a negative grid bias voltage sufficient to normally retain the tube extinguished, a first circuit connection to connect a selected one of said inductors to the grid circuit of a selected one of said tubes to apply to said one tube the energy received by said one inductor, a second circuit connection to connect the other one of said inductors to the grid circuit of the other one of said tubes to apply to said other tube the energy received by said other inductor, said first and second circuit connections provided with a predetermined relationship to alternately fire said tubes by said received energy, means including a condenser connected across the plates of said tubes to alternately extinguish the tubes, and train carried signaling means electrically coupled to the plate circuit of at least one of said tubes and controlled by such alternate operation of the tubes.

6. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply direct current coded to have alternate on and off periods, two receiving channels on said train each of which channels includes an inductor and a gas filled tube together with a circuit connection to connect the inductor to the grid of the tube, said inductors mounted on the train one over one rail and the other over the other rail for each inductor to pick up an electromotive force at the start and at the end of each on code period of said rail current, a plate circuit including a direct current source for each of said tubes and which direct current source is normally ineffective to fire the respective tube, said inductors oppositely poled to fire a selected one of the tubes by the electromotive force picked up at the start of an on code period and to fire the other tube by the

electromotive force picked up at the end of an on code period, means including a condenser connected to said plate circuits to alternately extinguish said tubes, and train carried signaling means coupled to the plate circuit of at least one of said tubes and controlled by such alternate operation of said tubes.

7. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply coded direct current, two receiving channels on the train and each of which channels includes a grid controlled gas filled tube and an inductor connected to the grid of the tube, said inductors disposed one over one rail and the other over the other rail for each inductor to receive energy of a code corresponding to said coded direct current, a plate circuit for each of said tubes and which plate circuits have a common source of direct current that is normally ineffective to fire the tubes, a code following relay having a winding interposed in the plate circuit of at least one of said tubes, contacts of said relay interposed in said receiving channels to alternately close the connections of said inductors for alternately firing said tubes in response to said received energy, means including a condenser connected to the plates of said tubes to alternately extinguish said tubes, and signaling means on the train controlled by said relay and effectively energized by the operation of said relay due to the alternate operation of the tubes.

8. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply coded direct current, two receiving channels on the train each of which channels includes an inductor and a grid controlled gas filled tube together with a circuit connection to connect the inductor to the grid of the tube, said inductors mounted on the train one over one rail and the other over the other rail for each inductor to pick up an electromotive force of a code corresponding to that of said coded direct current, a plate circuit for each of said tubes, a source of direct current interposed in each of said plate circuits but normally ineffective to fire the tubes, a code following relay operable to a first and a second position and having a winding interposed in the plate circuit of a preselected one of said tubes to operate the relay by the plate current of that tube, a first position contact of said relay interposed in the circuit connection of the channel including said one tube and a second position contact of the relay interposed in the circuit connection of the channel including the other tube to alternately fire the tubes by said picked up electromotive forces, means including a condenser connected to the plates of said tubes to alternately extinguish the tubes to operate the relay according to code of said coded direct current, and train carried signaling means controlled by the relay when thus operated.

9. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply direct current coded to form alternate on and off periods, two receiving channels on said train each of which channels includes an inductor and a grid controlled gas filled tube together with a circuit connection to connect the inductor to the grid of the tube, said inductors mounted on the train one over one rail and the other over the other rail for each inductor to pick up an electromotive force at the start and at the end of each on code period of said rail current, a plate circuit for each of said tubes, a common source of direct current for said plate circuits but of a voltage insufficient to normally fire the tubes, a code following relay having a winding interposed in the plate circuit of at least one of said tubes for energizing the relay by the plate circuit current of said one tube, a first contact of said relay interposed in the circuit connection of one of said channels and a second contact of the relay interposed in the circuit connection of the other one of said channels to permit one tube to be fired in response to the electromotive force picked up at the start of each on code period only and the other tube to be fired in response to the electromotive force picked up at the end of each on code period only, and signaling means controlled by said relay.

10. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply direct current coded to form alternate on and off periods, two receiving channels on said train each of which channels includes an inductor and a grid controlled gas filled tube together with a circuit connection to connect the inductor to the grid of the tube, said inductors mounted on the train one over one rail and the other over the other rail for each inductor to pick up an electromotive force at the start and at the end of each on code period of said rail current, a plate circuit for each of said tubes, a common source of direct current for said plate circuits but of a voltage insufficient to normally fire the tubes, a two winding polar relay one of which windings is interposed in the plate circuit of one tube and the other winding interposed in the plate circuit of the other tube, a normal polar contact of said relay interposed in the circuit connection of one of said channels and a reverse polar contact of the relay interposed in the circuit connection of the other channel to alternately connect said inductors to the grids of the respective tubes for alternately firing said tubes in response to said picked up electromotive forces, and signaling means controlled by said relay.

11. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply impulses of direct current of a preselected code rate and which impulses are of short duration compared to the duration between successive impulses, two receiving channels on said train and each of which channels includes a grid controlled gas filled tube and an inductor connected to the grid of the tube, each inductor disposed for inductive relation to at least one rail for each inductor to pick up an electromotive force of a code corresponding to that of the rail current, a plate circuit for each tube, a common source of direct current for said plate circuit but of a voltage insufficient to normally fire the tubes, a code following relay having a winding interposed in a preselected one of said plate circuits to energize the relay when the associated tube is fired, a back contact of said relay interposed in the inductor connection of one channel and a front contact of the relay interposed in the inductor connection of the other channel to alternately fire the tubes in response to said picked up electromotive forces, means including a condenser connected across the plates of said tubes to alternately extinguish the tubes to operate the relay at a rate corresponding to said preselected code rate and with substantially equal energized and deenergized periods, and signaling means responsive to current of a frequency

corresponding to said code rate controlled over contacts of said relay.

12. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply thereto coded direct current having alternate on and off periods, two train carried inductors one mounted over each rail to receive an electromotive force of a code corresponding to that of the rail current, two train carried gas filled tubes, a plate circuit for each of said tubes, a grid circuit for one of said tubes and including a source of negative grid bias voltage and a selected one of said inductors and which inductor is poled to drive the grid more positive by the electromotive force received at the start of each on code period and cause the tube to fire; a grid circuit for the other one of said tubes and including a source of negative grid bias voltage and the other one of said inductors and which inductor is poled to drive the grid more positive by the electromotive force received at the end of each on code period and cause the tube to fire, a condenser connected across the plates of said tubes to alternately extinguish the tubes to cause plate current to flow in the plate circuit of said one tube each on code period and plate current to flow in the plate circuit of the said other tube each off code period, and signaling means coupled to the plate circuit of at least one of said tubes and controlled by such alternate operation of said tubes.

13. In combination, a track section, a train to travel such section, means connected to the rails of the section to supply thereto coded direct current having alternate on and off periods, two train carried inductors one mounted over each rail for each inductor to inductively receive an electromotive force of a code corresponding to that of the rail current, two train carried gas filled tubes, a plate circuit for each tube each of which plate circuits includes a direct current source and a winding, a grid circuit for each tube and each of which grid circuits includes a resistor and a source of voltage effective to apply a predetermined negative grid bias voltage to normally retain the tube extinguished, one of said inductors connected across the grid circuit resistor of one of the tubes to fire that tube by the electromotive force received at the start of each on code period of the rail current, the other one of said inductors connected across the grid circuit resistor of the other tube to fire that tube by the electromotive force received at the end of the on code period of the rail current, a condenser connected across the plates of said tubes to alternately extinguish the tubes, and signaling means effectively energized by the current thus caused to alternately flow in said plate circuit windings.

14. In combination, a track section, a train to travel such section, means connected across the rails of the section to supply time spaced impulses of current, two train carried inductors one mounted over each rail to inductively receive time spaced electromotive forces in response to said rail current, two train carried gas filled tubes, a plate circuit for each of said tubes including a source of direct current, a heater circuit for each of said tubes including a resistor, a grid circuit for each of said tubes including at least a portion of the resistor of the heater circuit of the same tube to provide a negative grid bias voltage for normally retaining the tube extinguished, one of said inductors connected across the grid and cathode of one of the tubes and the other inductor connected across the grid and cathode of the other tube to apply to the tubes said received electromotive forces, said inductors poled so that the grid of one of said tubes is driven in the positive direction and the tube fired by the electromotive force received when the rail current impulse builds up and the grid of the other tube is driven in the positive direction and the tube fired by the electromotive force received when the rail current impulse dies away, a condenser connected across the plates of said tubes to alternately extinguish the tubes, and signaling means coupled to said plate circuits and effectively energized by the currents thus caused to alternately flow in the two plate circuits.

15. In combination, a track section, a train to travel such section, means connected across the rails of the section to supply coded direct current having alternate on and off periods, two inductors on the train one over each rail for each inductor to receive an electromotive force at the start and at the end of each on period of such rail current, two grid controlled gas filled tubes and a decoding transformer on the train, a plate circuit for each tube and each of which plate circuits includes a preselected portion of a primary winding of said transformer, a train carried source of direct current interposed in each of said plate circuits but normally ineffective to fire the tubes, one of said inductors connected across the grid and cathode of one of said tubes and poled to apply a positive voltage to the grid due to the electromotive force received at the start of each on period of rail current and fire the tube, the other inductor connected across the grid and cathode of the other tube and poled to apply a positive voltage to the grid due to the electromotive force received at the end of each on period of the rail current and fire the tube, means including a condenser connected across the plates of said tubes to alternately extinguish the tubes, and train carried signaling means connected to a secondary winding of said transformer and effectively controlled by the alternating electromotive force induced in the secondary winding due to the direct current caused to alternately flow in said portions of said primary winding by such alternate operation of said tubes.

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