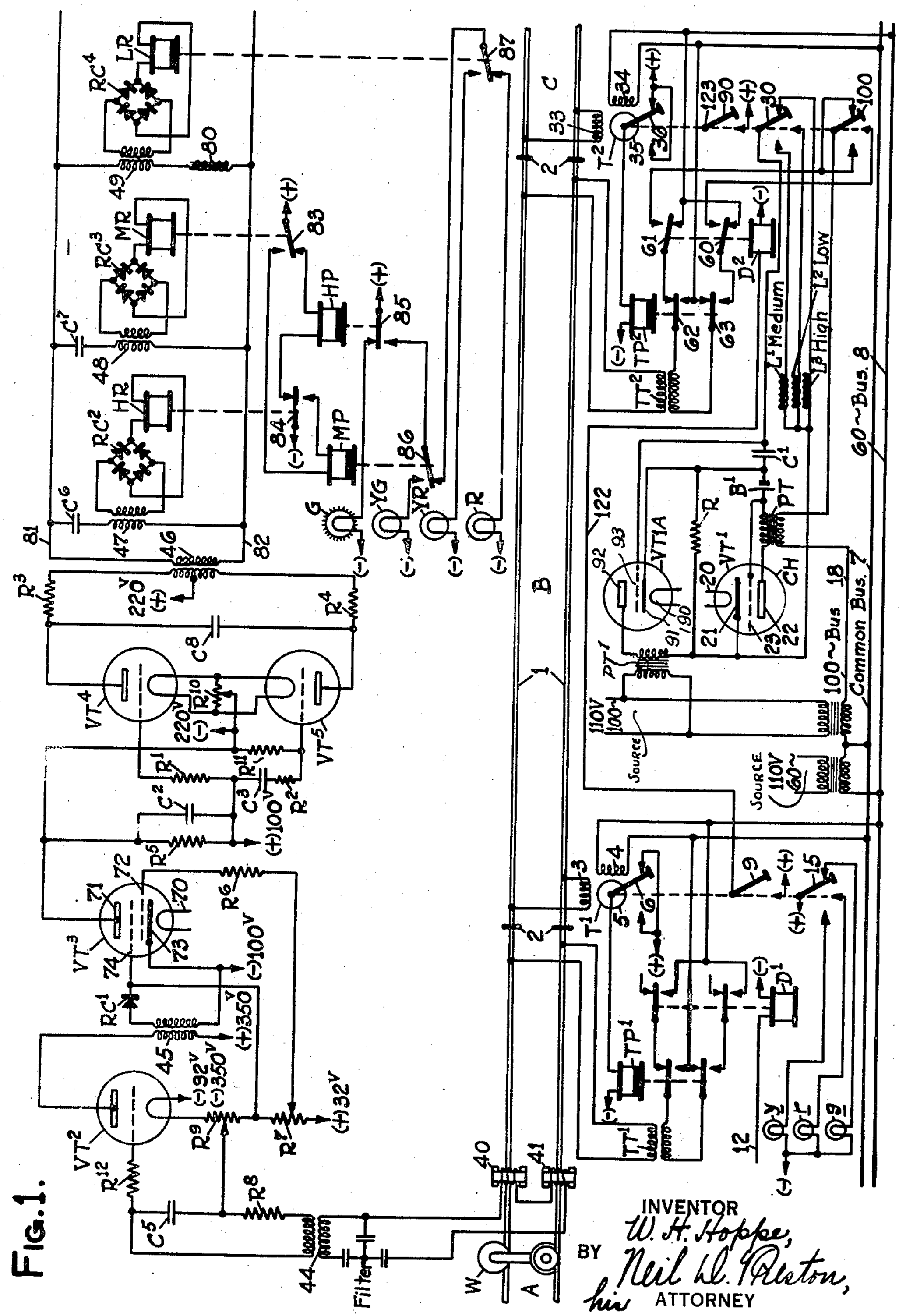
Nov. 2, 1937. W. H. HOPPE 2,098,041

CONTINUOUS INDUCTIVE CODED CAB SIGNALING SYSTEM

Filed March 19, 1936 2 Sheets-Sheet 1



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Filed March 19, 1936 2 Sheets-Sheet 2

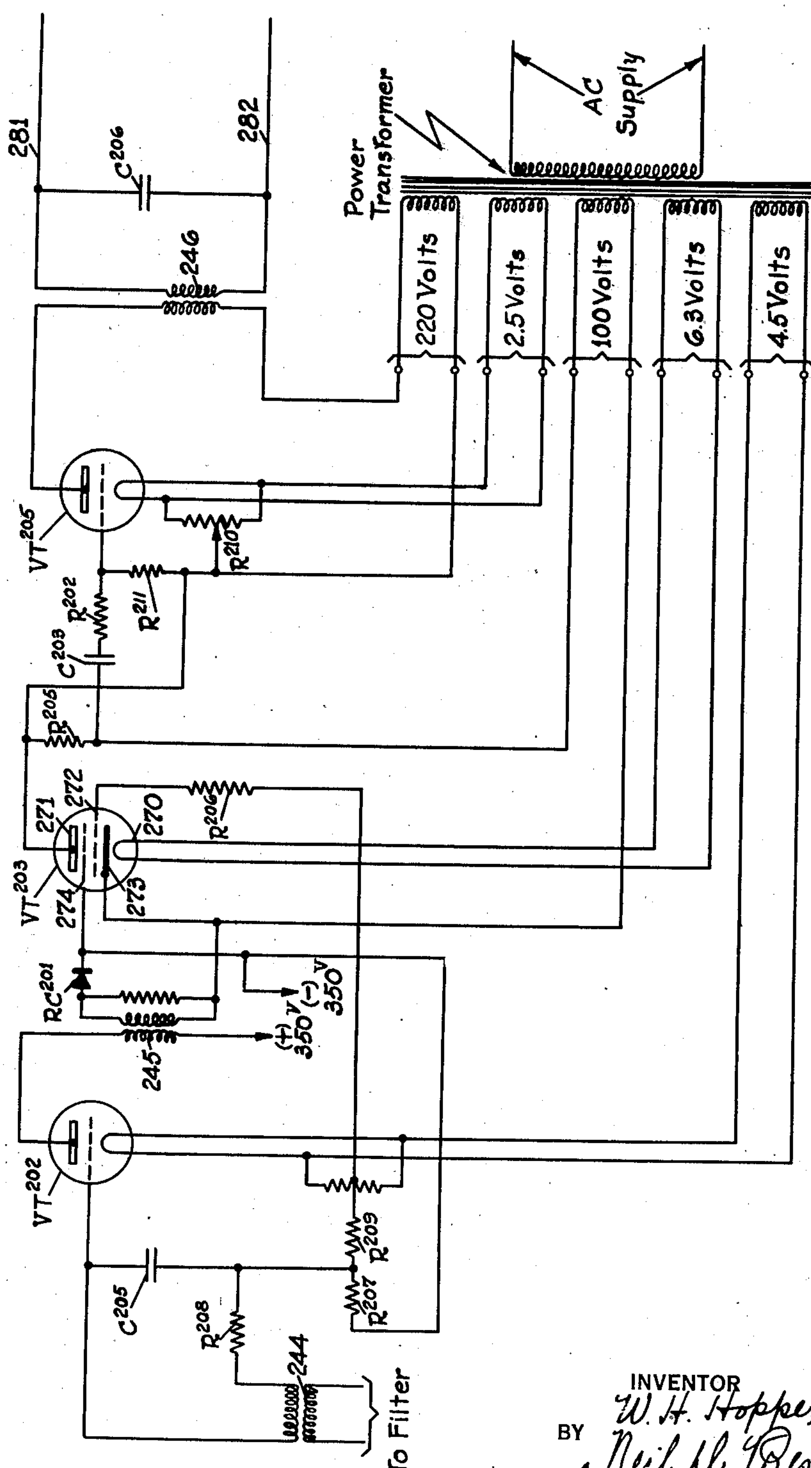

FIG. 2.

INVENTOR
W. H. Hoppe,
BY Neil W. Preston,
his ATTORNEY

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CONTINUOUS INDUCTIVE CODED CAB SIGNALING SYSTEM

Walter H. Hoppe, Rochester, N. Y., assignor to General Railway Signal Company, Rochester, N. Y.

Application March 19, 1936, Serial No. 69,618

22 Claims. (Cl. 246—63)

This invention relates to train control and cab signaling systems and it more particularly pertains to a coder and a decoder for use in train control and cab signaling systems of the continuous inductive coded type.

A train control or cab signaling system of the continuous inductive type is one in which car-carried electro-responsive relays and devices are maintained energized in response to current in the track rails, so that failure of the current supply will result in the deenergization of the devices. In other words, the system operates on the closed circuit principle which causes a more restrictive indication to be given in the event of current failure.

A continuous inductive coded type system is one in which current in the track rails is coded, with the car-carried relays operating in combination in accordance with the character of the code applied to the track circuit and received by the apparatus on the car. The present invention is illustrated in the drawings as applied to a railway cab signaling system but it will be obvious, since the present invention is more particularly directed to a vacuum tube coder and to the use of a vacuum tube decoder instead of the usual mechanical coder and relay type decoder, that the invention may be used in other systems, such as train control and the like.

In coding the track circuit current in cab signaling systems of the type under consideration, it is expedient to provide apparatus along the trackway for characterizing the code, that is, applying impulses in one code which are distinctive from impulses in another code.

The code forming or "chopper" arrangement in the present invention is an improvement on the similar apparatus disclosed in my prior application Ser. No. 29,116 filed June 29, 1935.

The decoder arrangement in the present invention is likewise an improvement on the primary decoder relay identified by the reference characters CPR in the above-mentioned prior application.

It has been customary to employ a coder of the motor driven type for coding a fixed frequency alternating current. Such a coder has certain disadvantages which the present invention overcomes by using a vacuum tube "chopper" for modulating the usual fixed frequency alternating current, which is usually 100 cycle current. By the use of a "chopper" of the type disclosed in the present invention, it has been found that a more constant and reliable coding arrangement is provided than formerly obtained from motor-driven apparatus, and since there are no mechanically moving parts in such a coder, it is more reliable and more economical to maintain.

By making use of the particular type of vacuum tube arrangement disclosed in the present invention instead of the usual decoder relay, it has been found that a more reliable decoder is provided for responding to the code characters received by the car-carried apparatus, and since there are no mechanically moving parts in such a decoder it is more reliable and more economical to maintain.

By making use of the particular type of vacuum tube disclosed in the present invention in place of the usual decoder relay, it has been found that the decoder more faithfully responds to the code characters received by the car-carried apparatus, and since there are no mechanically moving parts in such a decoder it is more reliable and more economical to maintain. The decoder portion of the present invention is an improvement over the decoder disclosed in the prior application of Reichard Ser. No. 15,645 filed April 10, 1935, and no claim to the invention disclosed in said Reichard application is made herein.

In view of the foregoing and other important considerations it is proposed, in accordance with the present invention, to employ a vacuum tube coder arranged to "chop" or modulate a 100 cycle current supply at rates of 75, 120 and 180 impulses per minute. Although the particular embodiment chosen to illustrate the present invention makes use of an oscillator frequency of 100 cycles per second and codes of 75, 120 and 180 per minute, it is to be understood that the invention is not limited to a system making use of the above values, since these values have been chosen for convenience in describing the invention.

From the foregoing it will be observed that the use of a vacuum tube coder has another advantage over the usual code wheel type coder driven by a motor, in that any desired code frequency can be readily provided for most efficient operation. With the mechanical or code wheel type coder, it is necessary to make use of frequencies which are multiples of the rate of rotation of the motor shaft. For example, with a motor shaft rotating at 20 R. P. M., the codes usually provided by code wheels or cam contactors are 80, 120 and 180 impulses per minute.

By making use of the vacuum tube arrangement of the type proposed in the present invention for the decoder or code following device in connection with the car-carried apparatus, the usual time lag following the start of each train of 100 cycle impulses, due to the inductive reactance of the relay (when a relay type decoder is used) is eliminated, the usual time required for change-over from one contact to another is eliminated and other disadvantages in connection with a relay of the mechanical type are overcome.

Other objects, purposes and characteristic features of the present invention will be apparent from the accompanying drawings when considered in connection with the following description.

Fig. 1 illustrates in diagrammatic form one embodiment of trackway apparatus and one embodiment of car-carried apparatus in accordance with the present invention.

Fig. 2 illustrates diagrammatically a modified form of apparatus which may be used in place of the car-carried apparatus illustrated in Fig. 1.

Coding apparatus

The trackway apparatus has been illustrated as applied to a railway track having rails **1** divided by insulating joints **2** into sections A, B and C. Each section is preferably provided with a track circuit comprising the track rails themselves, a circuit including a supply transformer TT (with suitable exponent) at the exit end of the section for supplying alternating current to the rails and a circuit including one winding of a track relay T (with suitable exponent) at the entrance end of the section.

Each track relay, in the form shown, is of the poly-phase motor type, comprising two stator windings **3** and **4** of relay T^1 (windings **33** and **34** of relay T^2) and a rotor **5** (**35** of relay T^2) which actuates contact finger **6** of relay T^1 (**36** of relay T^2). Winding **3** of relay T^1 and winding **33** of relay T^2 are the track windings of the track relays and are connected directly with the track rails of the corresponding section, while the other windings (**4** of T^1 and **34** of T^2) are the polarizing windings permanently supplied with alternating current from the same source as the track rails, that is supply buses **7** and **8**.

A 110 volt 60 cycle transformer is illustrated in the drawings with its secondary winding connected to buses **7** and **8** which, as above mentioned, are the 60 cycle buses. A separate 100 cycle transformer has one terminal of its secondary connected to bus **7** and the other terminal of its secondary connected to bus **18**. Bus **7** is therefore common to both the 60 cycle and 100 cycle circuits.

When current is sent through the track winding **3** of track relay T^1, for example, in one phase, the rotor **5** is actuated in one sense. When current is sent through the track winding **3** in an opposite phase the rotor **5** is actuated in the opposite sense, and when there is no current in the track winding, or no current in the polarizing winding, or no current in either winding, the relay is deenergized and the rotor assumes a neutral position. The relay therefore provides for three positions based on shifting the phase of current in the track circuit and stopping the current flow. For convenience, these relay positions will be referred to as normal with the contacts in their right-hand positions as illustrated, reverse with the contacts in their left-hand positions and neutral with the contacts in their mid-positions.

One contact of each track relay in its three positions is arranged to control the wayside signals. Other contacts of the track relays control various other circuits as will be more clearly pointed out later in the description.

Since the apparatus of the various sections is the same, like parts of each section have been designated by like reference characters having a distinguishing exponent corresponding to the section. Furthermore, the vacuum tube coder CH and its control by the track relay, as well as the selection of its out-put codes, has been illustrated in connection with the exit end of section B only. It will be understood that a like coder is associated with the exit end of each other section and controlled by the track relay associated with the entrance end of the next section in advance in a like manner.

Although wayside signals will ordinarily be located at the entrance to each section, for the sake of simplicity they have not all been illustrated in the accompanying drawings. These signals may be of any suitable type and controlled by the track relay in its normal, reverse and neutral positions. Since the track relay manifests clear, caution and stop conditions by actuating its contacts to normal, reverse and neutral positions respectively, it is obvious that these manifestations may be provided by operating semaphore or light signals over circuits controlled by the track relay contacts. This portion of the railway signaling system however forms no part of the present invention. As an example of the control of wayside signals, signals *g*, *r* and *y* are illustrated as controlled by contact **15** of relay T^1.

At each signal location a neutral type distant relay D (with suitable exponent) is provided and controlled over a line circuit in such a way that it is normally deenergized, being energized when a train enters the section. Relay D switches the track circuit from the 60 cycle track current to the 100 cycle coded current.

A track repeater relay TP (with suitable exponent), of the slow-acting neutral type, is associated with each track relay. Its function is to reverse the alternating current applied to the track at the exit end of the section for reversing the track relay at the entrance end when the next section in advance is occupied.

Although the TP and D relays and the wayside signals are illustrated as being energized from direct current, it is obvious that they can be energized from an alternating current source of supply, such as the 110 volt 60 cycle buses. In this event the relays will be of the alternating current type.

The coder connected to the exit end of each section by the picking up of the associated D relay comprises vacuum tube VT^1. Since it is proposed to code or modulate a 100 cycle source of alternating current, this source is illustrated as being applied to the buses **7** and **18** by means of the 100 cycle transformer. Although the vacuum tube coder associated with the exit end of section B is the only one illustrated in detail, it will be understood that those at the exit ends of other sections are of similar arrangement.

Vacuum tubes VT1A and VT^1 comprise a "chopper" or code impulser, the function of which is to provide the low, medium and high rate impulses for making up the codes which are applied to the track circuit under various conditions, as determined by the selection of inductor L^1, L^2, or L^3 by contact **30** of relay T^2.

The "chopper" modulates the 100 cycle current in accordance with the selected rate, this current being applied to the track circuit in accordance with the position of contact **100** of relay T^2, by way of contacts 60 and 61 of relay D^2 and contacts 62 and 63 of relay TP^2 in a manner which will be described in detail.

It will be of course obvious that, if necessary, the 100 cycle modulated current may be stepped up or amplified by means of a power amplifier before it is applied to the track circuit in order to obtain a current value suitable for operating the car-carried code responsive device.

Tubes VT1A and VT^1 are of the gas filled type, known by the trade name "Thyratron". Tube VT^1 comprises filament 20, cathode 21, plate 22 and grid 23. In the illustration the grid is normally biased by battery B^1 through resistance R. Tube VT1A comprises filament 190, cathode 91, plate 92 and grid 93.

As is well known, discharge devices of this type exhibit a trigger action tending to permit space current to flow when once started, regardless of the subsequent grid potential. In other words, when the plate is rendered positive, the tube is "triggered" or "fired" by swinging the grid sufficiently positive with respect to its normal value. Space current then flows in the plate circuit under the control of the plate potential alone and can only be stopped by opening the space current circuit, or by lowering the plate potential to the cut-off value. This means that, when the tube is "fired", the grid loses control and plate current is only stopped by removing the positive plate potential or lowering it to the cut-off value as determined by the characteristics of the tube.

Decoding apparatus

Referring to the car-carried signaling apparatus shown above the track in Fig. 1, this apparatus includes two inductors or receivers 40 and 41, each comprising a laminated core structure having projected poles and containing a winding disposed over the track rails directly ahead of the first axle and wheels W of the train. These receivers are so connected in series that voltage induced in their windings, due to alternating current flowing in one direction in one rail and in the other direction in the other rail, are cumulative. The circuit including coils 40 and 41 also includes the filter and the primary winding of transformer 44, this circuit being tuned to 100 cycles per second.

The secondary winding of transformer 44 is connected to a circuit including condenser C^5 and resistance R^8 to which the in-put of first stage voltage amplifier tube VT^2, of the ordinary amplifier type, is connected. R^{12} is the grid resistor and R^9 is a resistance in the filament circuit for obtaining the grid bias for operating the tube at the proper point on its characteristic curve. The out-put of the first stage voltage amplifier is connected to the in-put of a second stage voltage amplifier, comprising tube VT^3, by coupling transformer 45. The in-put of tube VT^3 includes a rectifier RC^1, with the grid connected to this rectifier and a point between resistances R^7 and R^9. Tube VT^3 is of the gaseous arc discharge type and has low internal plate resistance, high amplification constant and requires only moderate voltages to drive it. One device having these desirable characteristics is the Raytheon Production Corporation, RK-100 tube. This tube comprises the usual filament 70 (not shown connected since it may be lighted in any well known manner) plate 71, "Cathanode" 72, cathode 73 and control grid 74. The characteristics of this tube and its features of operation have been clearly set forth in an article beginning on page 23 of the Q. S. T. Magazine for June, 1935, and need not be repeated here, except to point out how these features function in the present invention.

The out-put of VT^3 is coupled to the in-put of a "chopper" device comprising two gaseous arc discharge devices similar to the tube VT^3 and known to the trade as "Thyratron" tubes VT^4 and VT^5, and the out-put of these tubes supply "chopped" energy to the primary winding of master transformer 46 in accordance with the modulated or "chopped" current received from the track rails.

The secondary of transformer 46 connects to the decoding relay circuits, comprising a circuit including condenser C^6 and primary winding of transformer 47, tuned to the high or 180 per minute code rate. Another circuit connected to the secondary of transformer 46 includes condenser C^7 and the primary winding of transformer 48, tuned to the medium or 120 per minute code rate. Still another circuit is connected to the secondary of transformer 46 and includes the primary winding of transformer 49 and reactance 80, responsive to the low or 75 per minute code rate.

The secondaries of these three transformers include full-wave rectifier units RC^2, RC^3 and RC^4 for passing unidirectional current through associated relays HR, MR and LR respectively, when coded current of 180, 120 and 75 impulses per minute respectively are received. Relays HR, MR and LR are comparatively quick in picking up so that they will pick up on a single impulse of the code rate to which they respond. Relays HR and MR may or may not release during the intervals between impulses, since slow acting repeating relay HP picks up and remains up during the reception of the 180 per minute code and slow acting repeating relay MP picks up and remains up during the reception of the 120 per minute code. Relay LR, being slow to release, holds up during the reception of the 75 per minute code.

Resistances R^3 and R^4 are for the purpose of limiting the current in the out-put of tubes VT^4 and VT^5 to the values limited by the tube characteristics. Resistances R^1 and R^2 are for the purpose of limiting the grid current of these tubes and also cooperate with condenser C^3 to provide proper time phasing for the in-put potentials of these tubes for switching from one to the other, so that the upper and lower windings of transformer 46 will be alternately energized. C^8 is a timing and phasing condenser to provide the proper "firing" time of tubes VT^4 and VT^5. R^5 is the plate resistor for tube VT^3 and condenser C^2 is for the purpose of smoothing out or maintaining the voltage across R^5 more nearly uniform. R^{11} is a grid leak for tube VT^5, used when required. R^{10} is a voltage divider for providing a connection to the mid-potential point of the filaments of VT^4 and VT^5. It will be understood that the filaments of the tubes may be energized in any approved manner, such as by means of a filament battery or rectified alternating current.

The plate and filament voltages shown connected to the various vacuum tube circuits are typical of those which may be used and these values are not to be construed as limiting the invention to any such values.

Operation

Coding.—A description will first be given of the coding as controlled by the operation of the apparatus illustrated below the track in Fig. 1. In the following description, it will be assumed that the filaments of all tubes are lighted, either continuously, or the filaments of tubes VT1A and VT^1 may be connected to the source of supply by the operation of the D relay when a car enters the associated section. The heater elements or cathodes of the tubes are thus rendered active.

With the track sections in the conditions illustrated in Fig. 1, the "chopper" tube VT^1 is not operating because the lower winding of transformer PT is open at front contact 61 of relay D^2. As will be seen from the following description, the plate potential for VT^1 is that which is induced across the terminals of the upper winding of transformer PT, therefore when the 100 cycle supply circuit, including the lower winding of this transformer, is open the tube is rendered inactive.

With a car in section A as illustrated, the car-carried apparatus is receiving the 180 rate code (clear) because the next two sections are unoccupied and relay T^1 is in its normal position. The car in block A will therefore receive the 180 code when blocks B—C are unoccupied.

If section C is occupied, relay T^2 will be in its neutral position which deenergizes relay TP^2 at open contact 36. With relay TP^2 deenergized the 60 cycle current to block B is reversed, which in turn causes relay T^1 to switch its contacts to their reverse positions. Contacts of relay T^1 (corresponding to contacts 30 and 100 of relay T^2) in their reverse positions cause the 120 rate code (second section in advance occupied) to be applied to section A. The car in block A will therefore receive the 120 code when block B is unoccupied and block C is occupied.

With section B occupied, relay T^1 will be in its neutral position which deenergizes relay TP^1 at open contact 6. Relay TP^1 reverses the 60 cycle current to section A, but due to the shunt provided by the car in block A, the track relay (not shown) connected to section A is in its neutral position. Contacts of relay T^1 (corresponding to contacts 30 and 100 of relay T^2) in their neutral positions cause the 75 rate code (next section in advance occupied) to be applied to section A. The car in block A will therefore receive the 75 code when block B is occupied.

With section A occupied (by another car when the illustrated car enters block A) no code will be received by the illustrated car-carried apparatus because of the shunt ahead of the receiver coils 40 and 41. The above code rates are selected and applied by the coder in a manner which will be obvious from the following description relating to the operation when a car enters section B.

When a car shunt is applied to the rails of section B, winding 3 of relay T^1 is shunted which effects the actuation of the relay contacts to their neutral positions. A circuit is now closed for picking up relay D^2 which extends from (+), contact 9 of relay T^1 in its neutral position, conductor 122 and winding of relay D^2 to (—). Red wayside signal *r* is lighted by a circuit closed by contact 15 in its neutral position.

Since contact 30 of relay T^2 is in its normal (right hand) position (assuming block C unoccupied), "chopper" CH is conditioned for modulating the 100 cycle alternating current at the high (180) code rate. The operation of the "chopper" tube to effect the modulation or "chopping" of the 100 cycle current for application to the track rails of section B will be described later.

With relay T^2 in its reverse (left hand) position, manifesting the occupancy of the second section in advance of section B (section D for example), contact 30 causes "chopper" CH to modulate the 100 cycle current at the medium (120) code rate, and this code is applied to the rails of section B over the above-described circuit including contact 100 of relay T^2, but this time in its reverse position.

With relay T^2 in its neutral position, manifesting the occupancy of the next section in advance of section B (section C), contact 30 causes "chopper" CH to modulate the 100 cycle current at the low (75) code rate and this code is applied to the rails of section B over the above-described circuit including contact 100 of relay T^2, but this time in its neutral position. The circuit may be traced from the right-hand terminal of the secondary of the 100 cycle transformer, bus 18, lower winding of transformer PT, contact 100 of relay T^2 in its neutral position, front contact 60 of relay D^2, back contact 63 of relay TP^2 (deenergized because of open contact 36 of relay T^2), lower winding of transformer TT^2, back contact 62 of relay TP^2 and bus 7 to the left-hand terminal of the 100 cycle transformer.

The circuit for relay D^1, including conductor 12, is for the purpose of switching the 100 cycle coded current onto block A when a car enters this section. Similarly, the circuit including contact 90 of relay T^2 and conductor 123 is for the purpose of switching the 100 cycle coding current onto section C when a car enters this section.

With section B unoccupied and relay T^1 actuated to the right, as an indication that the next two sections in advance are unoccupied as above described, a circuit is closed by contact 15 for lighting wayside lamp *g*. With section C occupied, relays T^2 and TP^2 will be down for actuating the contacts of relay T^1 to the left as previously described, which closes a circuit at contact 15 for lighting wayside lamp *y*.

It will now be explained how the 100 cycle alternating current supply is "chopped" or modulated by the operation of tubes VT1A and VT^1 in accordance with the position of contact 30 of relay T^2, which operation is typical of the operation at other locations.

The 100 cycle supply circuit extends from the secondary winding of the 100 cycle power transformer to the primary of track transformer TT^2 and includes the lower winding of transformer PT. This circuit was previously traced in detail and includes contacts of relay D^2 in their picked up positions. Therefore, because of transformer PT, a voltage of comparatively high frequency (100 cycles per second) is induced in the output circuit of tube VT^1, including plate 22 and cathode 21, when relay D^2 is picked up. This 100 cycle alternating voltage is applied to the track by way of transformer TT^2 and is modulated at a comparatively low rate by tube VT^1 in cooperation with auxiliary tube VT1A, which varies the reactance in the circuit including bus 18. The current in this circuit is at a maximum value when tube VT^1 conducts and at a minimum value when space current flow in this tube is stopped. Because of transformer TT^2 the track voltage is likewise at a maximum value when the tube VT^1 conducts and at a minimum value when this tube is non-conducting. Therefore the 100 cycle voltage applied to the track circuit is modulated to produce envelopes or blocks at rates determined by the rate at which tube VT^1 modulates the reactance in the supply circuit, which is in turn determined by the position of contact 30 as will now be explained.

With 100 cycle voltage applied to the plate circuits of tubes VT1A and VT^1 by transformers PT^1 and PT respectively, it will first be assumed that contact 30 is in its normal position as illustrated. When the voltage of the upper terminal of the secondary winding of transformer PT^1 swings positive, the gas within the tube is ionized and plate current flows from this terminal, plate-cathode 92—91, load resistor R to the lower (negative) terminal of the transformer winding. This is because grid 93 is not sufficiently negative to prevent "firing" the tube.

When the voltage of the upper terminal of the secondary winding of transformer PT^1 swings negative, the tube is de-ionized and the flow of plate current is stopped. This operation is repeated for each positive and negative swing of the 100 cycle per second voltage applied to the plate circuit of tube VT1A. Since condenser C^1 is connected in multiple with load resistor R, it will gradually accumulate a charge across its terminals each time current flows through R, with the terminal of C^1 which is connected to grid 93 becoming more and more negative with respect to the terminal of C^1 which is connected to cathode 91.

The terminal of C^1 which is connected to grid 93, and consequently grid 93 itself, will finally become sufficiently negative to prevent "firing" or plate current flow in tube VT1A, even on the positive swings of the plate. The charge on condenser C^1 will now gradually leak off through load resistor R, inductance L^3 and the circuit including contact 30 in its right hand position. The rate at which this charge is dissipated is governed by the LCR values of this circuit. When the terminal of C^1 connected to grid 93 dissipates its negative charge to a point below a value which prevents "firing" of tube VT1A, this tube is again "fired" by the positive swings of the plate as before and this cycle of operations is repeated at a rate which is determined by the LCR values of the above circuit.

The value of L^3 is such that tube VT1A is "fired" as above described 180 times per minute. The value of L^1 is such that tube VT1A is "fired" 120 times per minute. The value of L^2 is such that tube VT1A is "fired" 75 times per minute.

Tube VT^1 is a repeater or amplifier of tube VT1A, in that it repeats the "firing" rate of VT1A. Since the input circuit of VT^1, including grid 23 and cathode 21, is connected across resistor R, it will be obvious that the voltage drop across this resistor (due to the current through R as above described) will "fire" VT^1 at the same rate that VT1A is "fired". This is due to the values of grid bias battery B^1 and the characteristics of tube VT^1 being such that the positive swings of the terminal of R which is connected to grid 23, renders grid 23 sufficiently positive with respect to cathode 21 for tube VT^1 to "fire" on each positive swing of plate 22. Then, at the first positive swing of plate 21, when grid 23 is less positive than the "triggering" value of the tube, this tube fails to "fire" and therefore the cycles of "firing" and "non-firing" of VT1A are repeated by VT^1.

From the above it will be seen that the 100 cycle current is supplied to transformer TT^2 over a circuit whose reactance is varied at a rate determined by the selection made by contact 30. With contact 30 in the position shown, this rate will be 180 per minute. With contact 30 in its reverse position, this rate will be 120 per minute due to inductance L^1. With contact 30 in its neutral position, this rate will be 75 per minute due to inductance L^2.

A brief statement of the above operation is that 100 cycle alternating voltage is applied to the track in blocks of maximum and minimum values, with these blocks occurring at a rate determined by the rate at which the reactance of the circuit including the primary of transformer TT^2 is varied, which is in turn determined by the "firing" and "non-firing" periods of tube VT^1, which is in turn determined by the constants of the grid circuit of tube VT1A as selected by contact 30. It will now be explained how these blocks of maximum and minimum values of the 100 cycle potentials are applied to the track rails at the 75, 120 and 180 per minute rates, are detected by the car-carried apparatus and decoded for operating the cab signals.

Decoding.—When the receiver coils 40—41 pick up 100 cycle impulses in blocks or modulations of 180 per minute, as applied to the track rails of section B under clear conditions (sections C and D unoccupied as above explained), the induced current in the secondary of transformer 44 flows through the circuit including resistance R^8 and condenser C^5. This current is effective to so control tube VT^2 (due to the potential difference set up between the grid and cathode connected across the condenser C^5) that it produces 100 cycle current "chopped" at the 180 per minute rate in the primary winding of transformer 45. In other words tube VT^2 is an ordinary voltage amplifier tube for stepping up the voltage waves applied to its in-put for energizing transformer 45 connected in its out-put.

In the operation of the code receiving car-carried apparatus, it is desired to "fire" the "chopper", comprising tubes VT^4 and VT^5, at the earliest point in each block of the train of 100 cycle waves received, in order to provide as great a percentage of "on" or impulse period as possible. This is accomplished by the rectifier-amplifier arrangement including tube VT^3, having the advantages that low energy is required for driving it, high out-put voltage is obtained for "firing" the "chopper" and the length of the impulse or "on" period is a maximum.

The "cathanode" 72 of tube VT^3 is normally maintained at a comparatively low positive potential with respect to "cathode" 73 by the IR drop across resistor R^7, which with the voltage developed in transformer 45 ionizes the tube so that a comparatively low developed voltage at transformer 45 is required to "fire" it. Furthermore, when the positive potential is removed from "cathanode" 72, the tube is extinguished (plate current is cut off) the same as if a "cathanode" potential existed and a high negative bias were applied to grid 74. If the voltage for "firing" and extinguishing tube VT^3 were only that across the secondary of transformer 45 and due to the signal picked up by the receiver, it will be obvious that the comparatively low signal voltage would need to be amplified by additional stages of voltage amplification and the length of the impulse period would be reduced.

This is overcome in the present circuit by maintaining the normal voltage between "cathanode" 72 and cathode 73 at a point just below the ionizing value of the tube. Then the generated voltage across the secondary of transformer 45 (due to the signal) is added to this normal voltage by way of rectifier RC^1 and applied to the input of tube VT^1, comprising grid 74 and cathode 73, which "fires" the tube. Since the normal voltage between "cathanode" 72 and cathode 73 is just below the ionizing value, the loss of the signal voltage in the input circuit extinguishes the tube. Thus practically a constant "firing" voltage over a relatively wide range is provided for VT^3 by relatively weak voltage of variable magnitude received from the out-put of the voltage amplifier VT^2.

The blocks of 180 per minute coded impulses in the out-put of VT^3 are available for "firing" or "triggering" the "chopper", which in turn applies impulses of 180 per minute to master transformer 46 for operating relay HR. This out-put includes plate resistor R^5 bridged by condenser C^2, which as above mentioned, smooths out the pulsating waves in the out-put circuit.

Current impulses in the output circuit of tube VT^3 flow through resistor R^5 and obviously these impulses of current produce a voltage across the terminals of R^5 when and only when impulse current flows in the output circuit. Since the current flow of these impulses is always upward through resistor R^5, the lower terminal of R^5 is rendered positive with respect to its upper terminal, but only when impulse current flows in the output of VT^3.

The impulses in the output circuit of tube VT^3 are applied to the input circuit of tube VT^4 over a path which includes a connection from the upper terminal of R^5 to the filament of VT^4, by way of voltage divider R^{10}. The lower terminal of R^5 leads to the grid of VT^4 by way of resistor R^1. These impulses render the grid of VT^4 positive with respect to the filament of this tube, therefore the tube will be "fired" by an impulse in the output of VT^3.

Since tubes VT^4 and VT^5 have direct current applied to their plate circuits, there will be no negative half cycles to extinguish a "fired" tube, as in the case of tubes VT1A and VT^1. It will now be explained how tube VT^5 is "fired" and how VT^4 and VT^5 are alternately extinguished after "firing".

After tube VT^4 has been "fired", as above described, by an impulse through resistor R^5, it will remain "fired" during the absence of voltage at the terminals of R^5. It will be assumed that tube VT^5 is extinguished at this time. Upon the application of voltage to the terminals of R^5, tube VT^5 will be "fired" and tube VT^4 will be extinguished. Then tube VT^5 will remain "fired" during the absence of voltage of terminals R^5. This action is repeated by the presence and absence of voltage across the terminals of R^5, to first "fire" VT^4, then to "fire" VT^5, then to extinguish VT^4, then to "fire" VT^4, then to extinguish VT^5, etc. This provides pulsating energy at the secondary terminals of transformer 46, since the primary windings of this transformer are connected in the output circuits of tubes VT^4 and VT^5.

The above operation of "firing" and "quenching" tubes VT^4 and VT^5 is not new with applicant, a similar arrangement being shown in Fig. 3 and described on page 5, lines 4 to 43 inclusive of Patent No. 1,971,755. The operation of the present arrangement will be understood by engineers, from the above discussion, it being understood that condenser C^3 acts as a phasing condenser to provide proper "firing" of tube VT^5. Also, that resistors R^1 and R^2 are for the purpose of limiting the grid current and for cooperating with condenser C^3 to determine its charging time. Resistor R^{11} is the usual grid leak and may or may not be required as practical conditions dictate.

During the time that VT^4 is conducting, condenser C^8 is being charged, with its lower terminal taking on a positive charge and its upper terminal taking on a negative charge. This is because its lower terminal is connected to (+)220, through R^4 and a winding of transformer 46 in series, with its upper terminal connected to the plate of VT^4. During the time that VT^3 is non-conducting VT^5 "fires" and "quenches" VT^4 as will now be described.

Since the plates of the tubes are tied together by condenser C^8 and since this condenser is charged with its upper terminal negative and its lower terminal positive, as above explained, the plate of tube VT^4 will swing negative with respect to its filament, because the condenser potential will be applied through the plate-filament circuit of VT^5 across the plate-filament circuit of VT^4 in opposition to the potential from the 220 volt direct current source. Since condenser C^8 cannot discharge immediately, the opposite potentials across the plate-filament circuit of VT^4 cause this tube to become non-conducting, or in other words, it is "quenched". By so choosing the circuit constants that the existing ions in tube VT^4 can diffuse before the plate voltage again becomes positive (by the dissipation of the charge on C^8), the grid of tube VT^4 resumes control and the tube is extinguished. Similarly, when the grid of tube VT^4 next swings positive, this tube will conduct and condenser C^6 will function to extinguish VT^5 in a similar manner, since it is oppositely charged by the "firing" of VT^4.

It will be seen from the above that tubes VT^4 and VT^5 alternately conduct in response to a series of pulsating impulses in the out-put of tube VT^3. Since the conducting path for each tube of the pair is through a primary winding of transformer 46, an alternating voltage is applied to buses 81 and 82 connected to the secondary winding of this transformer, in blocks having a frequency dependent upon the code rate, in the assumed example 180 per minute.

It is believed obvious that the reception of the 120 or the 75 code rate will likewise apply blocks of alternating voltage at these rates to buses 81 and 82. Because of the tuned circuit including transformer 47, the 180 rate will cause unidirectional impulses to be applied through rectifier RC^2 to the winding of relay HR for operating this relay. Because of the tuned circuit including transformer 48, the 120 rate will cause unidirectional impulses to be applied to relay MR through rectifier RC^3 for operating this relay. Because of the tuned circuit including transformer 49, the 75 rate will cause unidirectional impulses to be applied to relay LR through rectifier RC^4 for operating this relay.

With a clear code (180 rate) being received, relay HR will be up and relays MR and LR will be down. A circuit is now closed for picking up relay HP which extends from (+), back contact 83 of relay MR, winding of relay HP and front contact 84 of relay HR to (−). Lamp G is lighted over a circuit completed at front contact 85 of relay HP. With a first caution code (120 rate) being received, relay MR will be up and relays HR and LR will be down. A circuit is now closed for picking up relay MP which extends from (+), front contact 83 of relay MR, winding of relay MP and back contact 84 of relay HR to (−). Lamp YG is lighted over a circuit completed at back contact 85 of relay HP and front contact 86 of relay MP. With a more restricted caution code (75 rate) being received, relay LR will be up and relays MR and HR will be down. Lamp YR is lighted over a circuit extending from (+), back contact 85 of relay HP, back contact 86 of relay MP, front contact 87 of relay LR and lamp YR to (−).

With a stop condition no code will be received, which effects the release of all relays and a circuit is closed for lighting lamp R extending from (+), back contact 85 of relay HP, back contact 86 of relay MP, back contact 87 of relay LR and lamp R to (−). Likewise, in the event of a trouble condition which prevents the coding of the 100 cycle current but permits the reception of continuous 100 cycle current, none of the relays will be picked up and the above circuit will light lamp R.

Fig. 2 Modification

The modification of Fig. 2 is similar to the car-carried apparatus of Fig. 1. All tubes in Fig. 2, however, are operated from alternating current and a single "chopper" tube VT^{205} is used instead of the two tubes VT^4 and VT^5 of Fig. 1. The apparatus in Fig. 2 has been given reference characters corresponding to similar parts in Fig. 1, except that they are in the 200 series. Buses 281 and 282 correspond to buses 81 and 82 of Fig. 1 and it will be understood that the same tuned circuit arrangement for operating the relays and lights illustrated in Fig. 1 may be used in Fig. 2. It is therefore believed unnecessary to duplicate this portion of the Fig. 1 apparatus in Fig. 2.

The primary of transformer 244 connects to the receivers by way of the filter, the same as in Fig. 1. Tube VT^{202} is shown connected to a source of direct current plate voltage and it will be obvious that this may be rectified alternating current derived from the power transformer, or it may be from a battery or direct current generator. The voltages indicated at the terminals of the transformer windings are typical only and may be varied to suit various requirements.

The voltage in the secondary of transformer 244 is stepped up by voltage amplifier VT^{202} and the out-put of this tube develops voltage for driving VT^{203} by the voltage induced in the secondary winding of transformer 245. The "firing" of VT^{203} is maintained at the critical points by rendering its "cathanode" 272 positive by the voltage drop in resistors R^{207} and R^{209} through which the plate current of VT^{202} flows, as in Fig. 1. A voltage is developed in the out-put of VT^{203} for "firing" VT^{205}, but since an alternating voltage is used for the plate circuit of VT^{205}, it extinguishes itself during the negative half-cycles, as above pointed out, and thus no extinguishing tube is required.

Having thus described one specific embodiment of a cab signaling system, it is desired to be understood that the particular arrangements illustrated and suggested are only typical of applicant's invention and are not intended to indicate the exact circuit design and specific arrangement of parts to carry out the features of the invention. These particular forms have been chosen to facilitate in the disclosure, rather than to limit the number of forms which the invention may assume and it is further desired to be understood that various modifications may be made in order to meet the various problems encountered in practice. Furthermore, the arrangements illustrated may be used in a train control system as well as in a cab signaling system, the system may be varied in the number of track sections to which the invention is applied and the amount of apparatus at each section and carried by the car may be varied to suit local conditions, all without in any manner departing from the spirit or scope of the present invention, except as limited by the appended claims.

What I claim is:

1. In a track circuit; track rails; a first source of alternating current and a second source of alternating current; a polyphase track relay; means controlled by different traffic conditions for connecting said first source of current to said track relay in different phase relations, whereby said track relay is selectively operated; means including a reactive circuit for connecting said second source of current to said track rails; and means controlled by said second source of current for selectively varying the reactance of said reactive circuit in accordance with the position of said track relay.

2. In a track circuit; track rails; a first source of alternating current and a second source of alternating current; a polyphase track relay; means controlled by different traffic conditions for connecting said first source of current to said track relay in different phase relations, whereby said track relay is selectively operated; means including a reactive circuit for connecting said second source of current to said track rails; and means controlled by said second source of current for selectively varying the reactance of said reactive circuit at different code rates in accordance with the position of said track relay, whereby said second source of current is applied to said track rails in code formations.

3. In a track circuit; track rails; a first source of alternating current and a second source of alternating current; a polyphase track relay; means controlled by different traffic conditions for connecting said first source of current to said track relay in different phase relations, whereby said track relay is selectively operated; means including a reactive circuit for connecting said second source of current to said track rails; means controlled by said second source of current for selectively varying the reactance of said reactive circuit at different code rates in accordance with the position of said track relay, whereby said second source of current is applied to said track rails in code formations; and a decoder controlled by the current in said track rails for decoding said code formations.

4. In a track circuit, track rails, a source of alternating current, means including a reactive circuit for applying a potential derived from said source of current to said track rails, a vacuum tube modulator, means controlled by said alternating current for operating said modulator, means controlled by traffic conditions for causing said modulator to modulate the reactance of said reactive circuit, and means controlled by the modulated reactance of said circuit for modulating the potential applied to said track rails.

5. In a track circuit, track rails, a source of alternating current, means including a reactive circuit for applying a potential derived from said source of current to said track rails, a vacuum tube modulator, means controlled by said alternating current for operating said modulator, means controlled by traffic conditions for caus-

ing said modulator to modulate the reactance of said reactive circuit at different coded rates, and means controlled by the modulated reactance of said circuit for modulating the potential applied to said track rails at said coded rates.

6. In a track circuit, track rails, a source of alternating current, means including a reactive circuit for applying a potential derived from said source of current to said track rails, a vacuum tube modulator having input and output circuits, means controlled by said alternating current for energizing the output circuit of said modulator, means responsive to traffic conditions and including the input circuit of said modulator for causing its output circuit to modulate the reactance of said reactive circuit, and means controlled by the modulated reactance of said reactive circuit for modulating the potential applied to said track rails.

7. In a track circuit, track rails, a source of alternating current, means including a reactive circuit for applying a potential derived from said source of current to said track rails, a vacuum tube modulator having input and output circuits, means controlled by said alternating current for energizing the output circuit of said modulator, means responsive to traffic conditions and including the input circuit of said modulator for causing its output circuit to modulate the reactance of said reactive circuit at different coded rates, and means controlled by the modulated reactance of said reactive circuit for modulating the potential applied to said track rails at said coded rates.

8. In a decoder for detecting and decoding codes of electrical impulses in a railway track circuit, an electrostatically controlled arc discharge tube having input and output circuits, a plurality of signals, means for detecting said impulses, means for applying the detected impulses to said input circuit, a source of current connected to said output circuit, means responsive to the application of said impulses to said input circuit for starting current flow from said source through said output circuit, an arc quenching means associated with said tube, means controlled by said impulses for causing said arc quenching means to stop the flow of current in said output circuit, and means controlled by the current flow in said output circuit for operating said signals in accordance with the codes of impulses in said track circuit.

9. In a decoder for detecting and decoding codes of electrical impulses in a railway track circuit, a pair of electrostatically controlled arc discharge tubes having input and output circuits, a plurality of signals, means for detecting said impulses, means for applying the detected impulses to said input circuits in opposite phase relation, a source of current connected to said output circuits, means responsive to the application of said impulses to said input circuits for alternately starting current flow from said source through said output circuits, an arc quenching means associated with each of said tubes, means controlled by said impulses for causing said arc quenching means to alternately stop the flow of current in said output circuits, and means controlled by the current flow in said output circuits for operating said signals in accordance with the codes of impulses in said track circuit.

10. In a decoder for detecting and decoding codes of electrical impulses in a railway track circuit, an electrostatically controlled arc discharge tube having input and output circuits, a plurality of signals, means for detecting said impulses, means for amplifying the detected impulses and applying the amplified impulses to said input circuit, a source of current connected to said output circuit, means responsive to the application of said amplified impulses to said input circuit for starting current flow from said source through said output circuit, an arc quenching means associated with said tube, means controlled by said amplified impulses for causing said arc quenching means to stop the flow of current in said output circuit, and means controlled by the current flow in said output circuit for operating said signals in accordance with the codes of impulses in said track circuit.

11. In a decoder for detecting and repeating codes of electrical impulses received from a railway track circuit; means for detecting said impulses; a pair of electrostatically controlled arc discharge tubes having input and output circuits; a circuit network; means for applying said detected impulses to said network; means for connecting the input circuits of said tubes to said network in such a manner that they will alternately respond to said detected impulses; a source of current connected to said output circuits; arc quenching means connected to the respective tubes; means controlled by the alternate response of said input circuits to said detected impulses for causing repeated current impulses to alternately flow from said source through the output circuits of said tubes; and means actuated by the flow of current through the output circuit of one tube for generating a potential in the arc quenching means of the other tube.

12. In a cab signaling system for railroads; a receiving circuit; a control circuit to be controlled by code impulses received by said receiving circuit; apparatus for repeating said code impulses from said receiving circuit to said control circuit, comprising a source of current, a gaseous ionizable arc discharge path interposed between said source of current and said control circuit; arc quenching means associated with said path; and means actuated by a current impulse transmitted to said control circuit across said path for generating a potential which causes said arc quenching means to quench the current across said path.

13. In a cab signaling system for railroads; a receiving circuit; a control circuit to be controlled by code impulses received by said receiving circuit; apparatus for repeating said code impulses from said receiving circuit to said control circuit, comprising a source of current, a gaseous ionizable arc discharge path interposed between said source of current and said control circuit; arc quenching means associated with said path; and means controlled in part by one of said code impulses and in part actuated by a current impulse transmitted to said control circuit across said path for generating a potential which causes said arc quenching means to quench the current across said path.

14. In a cab signaling system for railroads; a receiving circuit; a control circuit to be controlled by code impulses received by said receiving circuit; apparatus for repeating said code impulses from said receiving circuit to said control circuit, comprising a source of current, a pair of gaseous ionizable arc discharge paths interposed between said source of current and said control circuit; arc quenching means associated with each of said paths; means controlled by the impulses received by said receiving circuit for alter-

nately conditioning said paths for operation and for alternately preventing the operation of the opposite path; and means controlled by a current impulse transmitted to said control circuit by way of one of said paths for generating a potential which quenches the current flowing by way of the other path.

15. In combination; a coder for applying coded impulses to a track circuit; a decoder carried by a railway vehicle; and means controlled by said decoder for detecting and decoding said coded impulses, said decoder including an electrostatically controlled arc discharge device rendered conductive by said impulses.

16. In combination; a coder for applying coded impulses to a track circuit; a decoder carried by a railway vehicle; and means controlled by said decoder for detecting and decoding said coded impulses, said decoder including an electrostatically controlled arc discharge device rendered conductive by a low impedance high amplification amplifier driven by said impulses.

17. In combination; a coder for applying coded impulses to a track circuit; a decoder carried by a railway vehicle; and means controlled by said decoder for detecting and decoding said coded impulses, said decoder including a pair of electrostatically controlled arc discharge tubes alternately rendered conductive by said impulses and each tube alternately rendered non-conductive by current flowing through the other tube.

18. In a coded track circuit for railroads, track rails, a load circuit including said track rails, circuit means for connecting said load circuit to a source of high frequency alternating current, and an arc discharge device included in said circuit means for applying current from said current source to said load circuit at different low frequency rates.

19. In a coded track circuit for railroads, track rails, a load circuit including said track rails, circuit means for connecting said load circuit to a source of high frequency alternating current, a pair of arc discharge devices included in said circuit means for applying current from said current source to said load circuit at different low frequency rates, and control means so connected in said circuit means and including one of said arc discharge devices for rendering the other of said arc discharge devices non-conducting.

20. In a coded track circuit for railroads, track rails, a load circuit including said track rails, circuit means for connecting said load circuit to a source of high frequency alternating current, a pair of arc discharge devices included in said circuit means for applying current from said current source to said load circuit at different low frequency rates, control means so connected in said circuit means and including one of said arc discharge devices for rendering the other of said arc discharge devices non-conducting, and means connected to said load circuit for selectively and visually indicating said different low frequency rates.

21. In a cab signaling system for railroads, track rails, means for applying high frequency alternating current to said rails at different low frequency rates, a car carried receiving means for receiving said different low frequency rates, an indicator for visually indicating the different low frequency rates being received, a pair of inversely connected arc discharge devices included in said receiving means for controlling the transfer of said different low frequency rates from said rails to said indicator, control means connected to sequentially cause said arc discharge devices to become conducting in response to the receipt of said alternating current, and means responsive to one of said arc discharge devices becoming conducting for rendering the other of said arc discharge devices non-conducting.

22. In a cab signaling system for railroads, track rails, means for applying high frequency alternating current to said rails at different low frequency rates, a car carried receiving means for receiving said different low frequency rates, an indicator for visually indicating the different low frequency rates being received, a pair of inversely connected arc discharge devices included in said receiving means for controlling the transfer of said different low frequency rates from said rails to said indicator, control means connected to sequentially cause said arc discharge devices to become conducting in response to the receipt of said alternating current, and means responsive to said arc discharge devices becoming sequentially conducting for rendering non-conducting the first one of said arc discharge devices which becomes conducting.

WALTER H. HOPPE.