July 22, 1941. R. K. CROOKS 2,250,191

RAILWAY TRAFFIC CONTROLLING APPARATUS

Filed Oct. 16, 1940 4 Sheets-Sheet 1

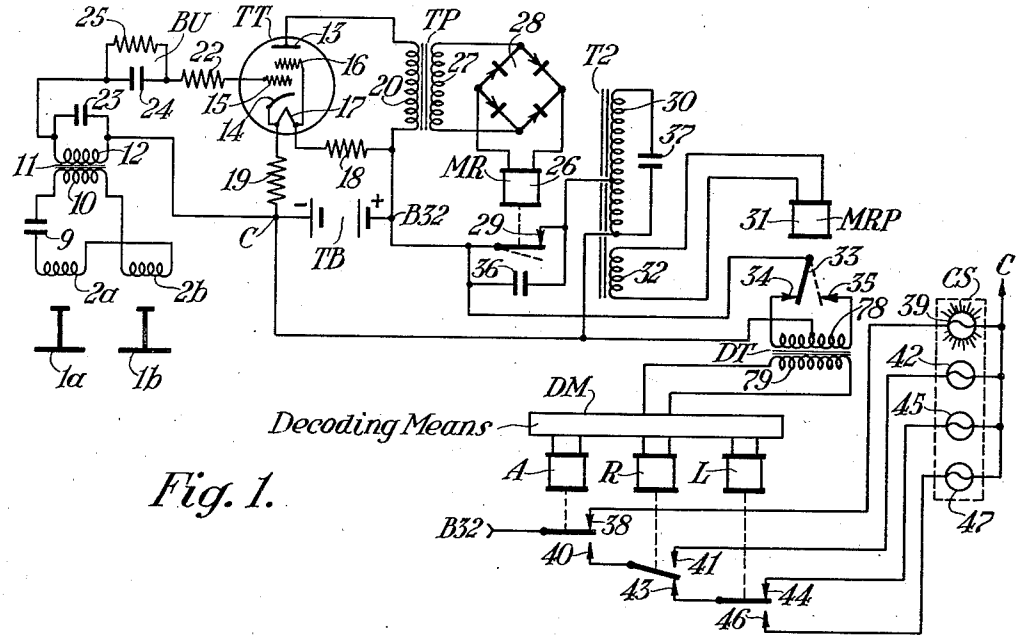


Fig. 1.

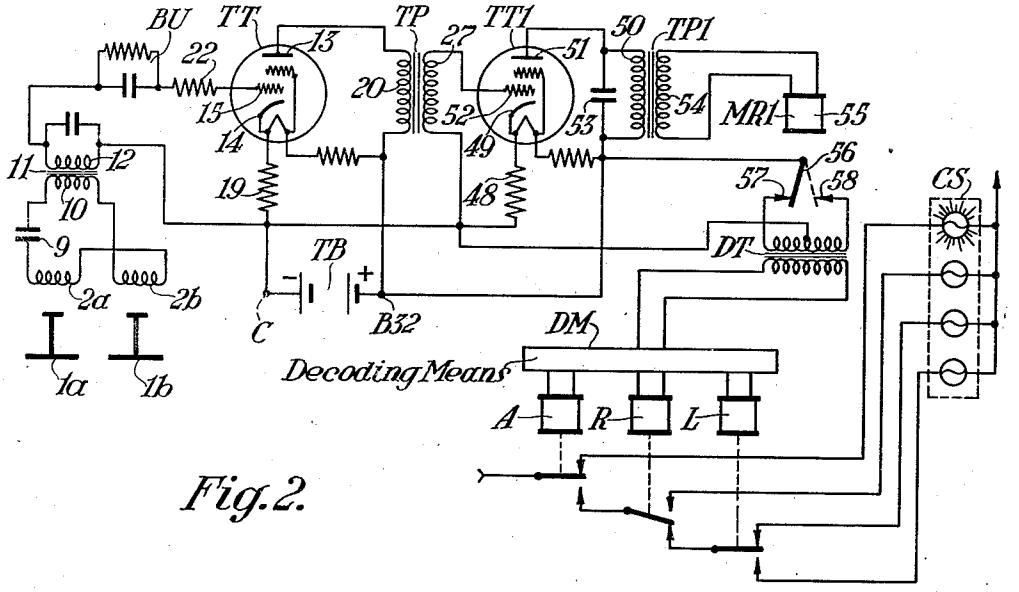


Fig. 2.

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RAILWAY TRAFFIC CONTROLLING APPARATUS

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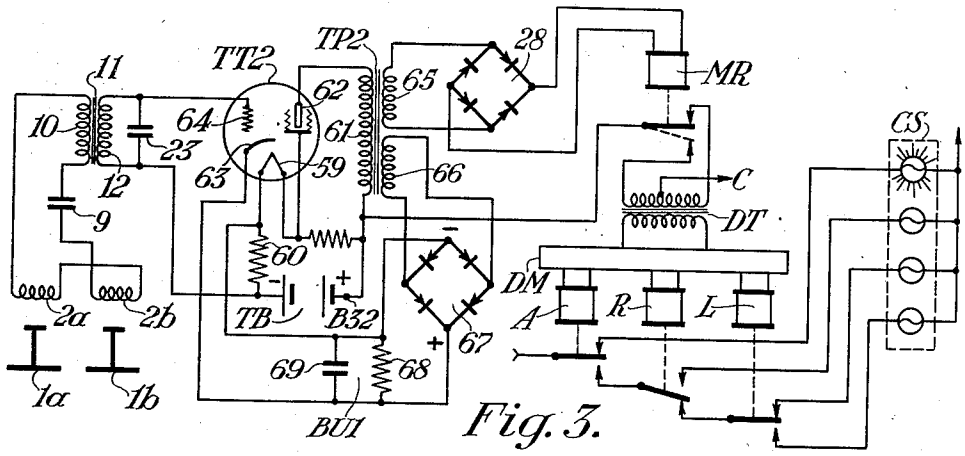


Fig. 3.

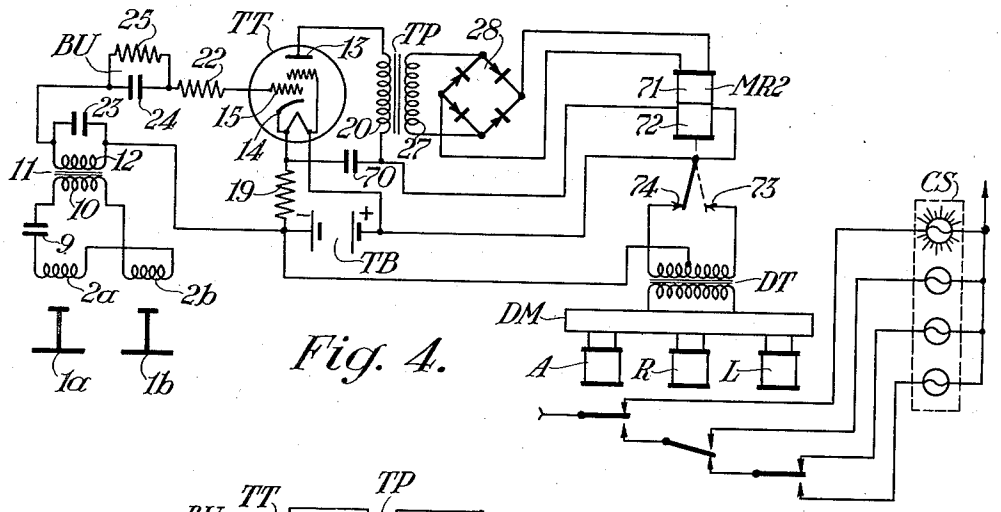


Fig. 4.

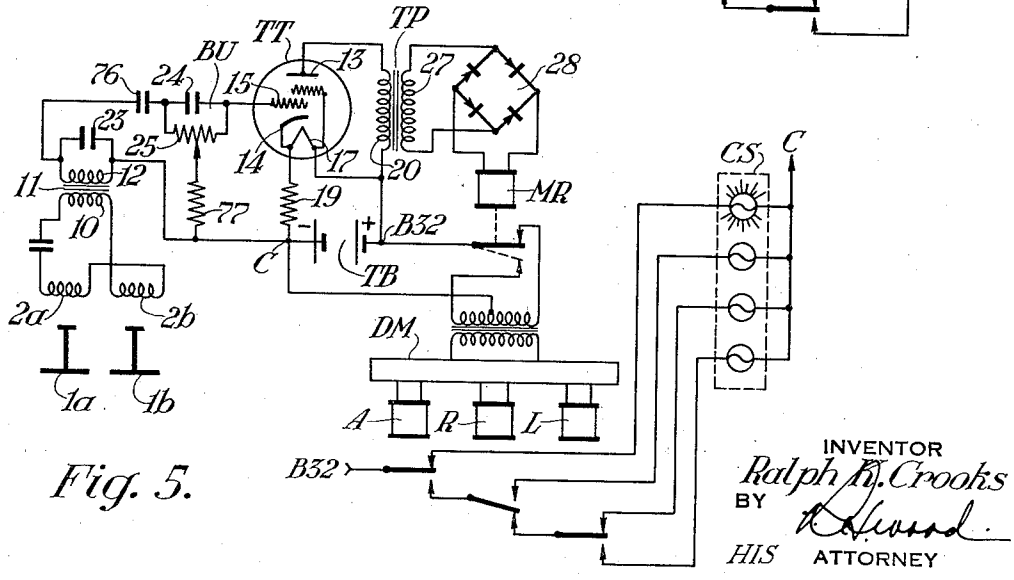


Fig. 5.

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RAILWAY TRAFFIC CONTROLLING APPARATUS

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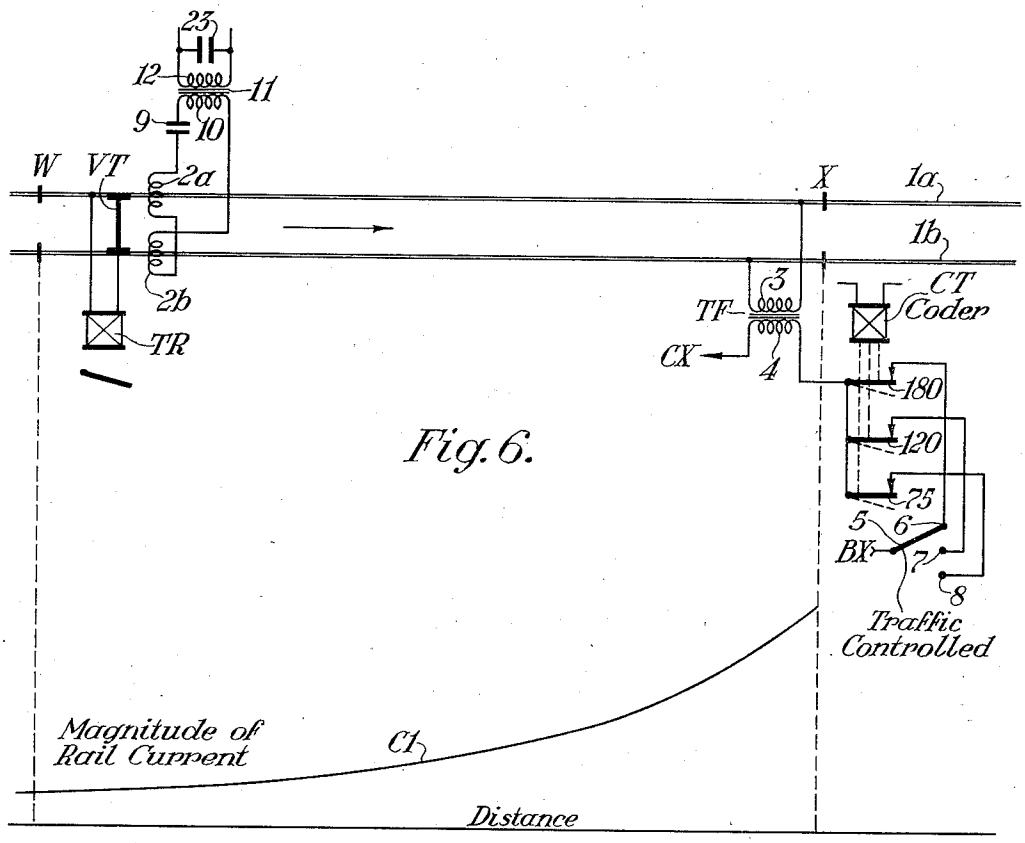


Fig. 6.

Fig. 7.

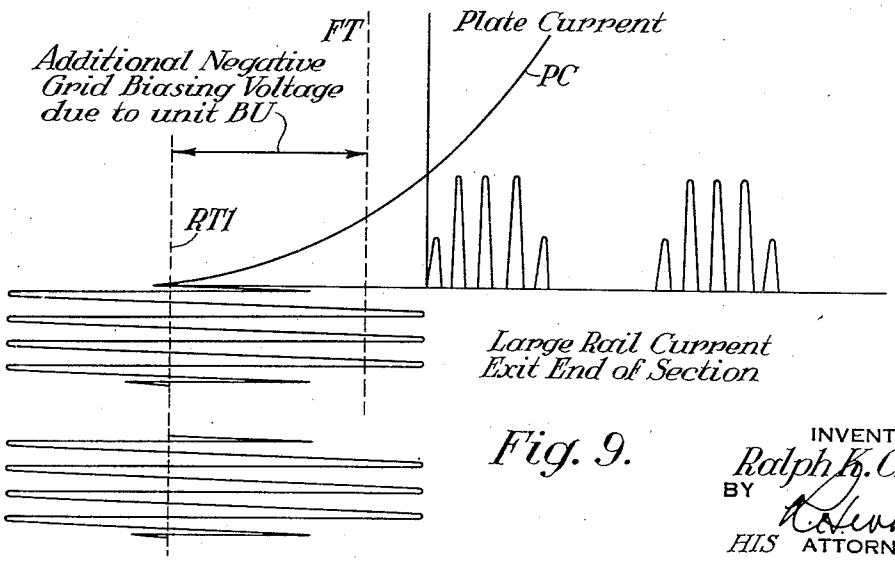


Fig. 9.

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RAILWAY TRAFFIC CONTROLLING APPARATUS

Filed Oct. 16, 1940 4 Sheets-Sheet 4

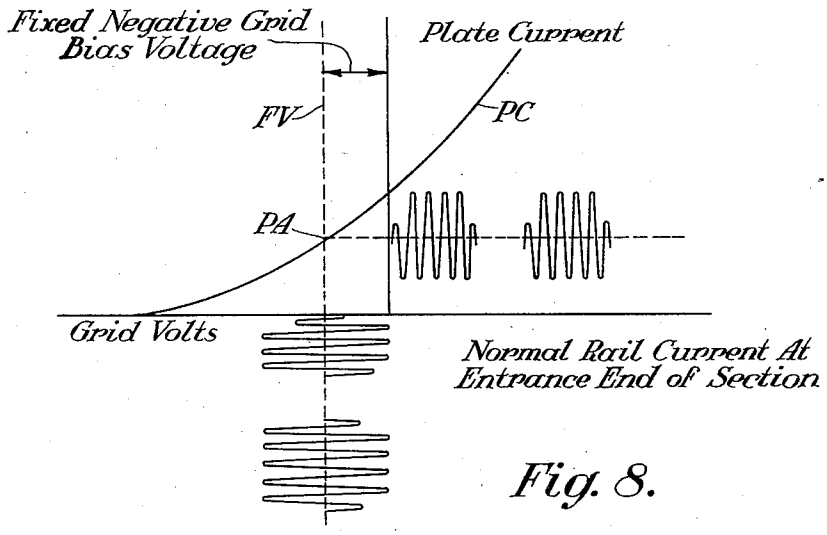


Fig. 8.

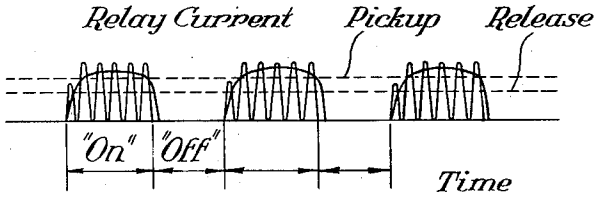


Fig. 10.

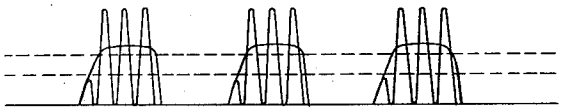


Fig. 11.

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Patented July 22, 1941

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UNITED STATES PATENT OFFICE

2,250,191

RAILWAY TRAFFIC CONTROLLING APPARATUS

Ralph K. Crooks, Sharpsburg, Pa., assignor to The Union Switch & Signal Company, Swissvale, Pa., a corporation of Pennsylvania

Application October 16, 1940, Serial No. 361,344

12 Claims. (Cl. 246—63)

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

Railway traffic controlling apparatus responsive to coded energy is in general use. Also train carried train controlling apparatus responsive to coded alternating track circuit current is used. Such a track circuit customarily includes the track rails of a track section and the source of alternating current is connected across the rails at the exit end of the section and the supply of current is coded by being periodically interrupted at a preselected code rate. Hence such track circuit current has alternate on and off periods, current flowing during each on period and no current flowing during each off period. The durations of the on and off periods of a given code rate are ordinarily of equal intervals and are of durations determined by the code rate. The alternating current is of any convenient frequency, such as, for example, 100 cycles per second and is usually coded at any one of several different code rates according to different traffic conditions in advance of the track section. When a train occupies such a track section the track circuit current flows down one rail, through the train wheels and axle (train shunt) to the other rail and thence back the other rail. When the train is close to the entrance end of the section the magnitude of the current flow may be relatively low because the rails for the full length of the section are in circuit and the circuit impedance is relatively high. Such rail impedance is shunted out as the train moves toward the exit end of the section with the result that the magnitude of the current may progressively increase to a relatively high value as the train moves to the exit end of the section.

A train carried receiving circuit is mounted on the train ahead of the leading wheels in inductive relation to the track rails to inductively receive an electromotive force during each on period of the rail current. Such electromotive force has the same frequency as that of the alternating current, has on and off periods corresponding to those of the code rate of the track circuit current and is of a magnitude proportional to the magnitude of the track circuit current. That is, the magnitude of such electromotive force picked up by the train carried receiving circuit from the track rails may be relatively low when the train is near the entrance end of the section and may increase to a relatively high value when the train moves to the exit end of the section. The supply of alternating current to the track circuit is such that the electromotive force picked up by the train carried receiving circuit when the train is at the entrance end of the section is sufficient to operate the associated apparatus and hence when the train is at the exit end of the section the electromotive force picked up by the train carried receiving circuit may be several times greater than that necessary to operate the associated apparatus.

The electromotive force picked up from the track rails is amplified by means of electron tube amplifiers and is used to operate a code following relay, such relay being operated at a rate corresponding to the code rate of the rail current. A code following relay that is alternately picked up and released in step with a code rate is most satisfactorily operated when its energization is only sufficient to assure proper operation of the relay. If the energization of the relay during any one on period of the code greatly exceeds that of the predetermined value at which the relay is adjusted, the relay is over energized and its release at the beginning of the next off period is delayed due to the longer interval required for the magnetization of the relay to fall away to the release value with the result that code distortion is produced in the circuit governed by such code following relay.

The code following relay in turn selectively governs train carried cab signal and brake control equipment through the medium of a decoding means. Since several different code rates are used to reflect several different traffic conditions the decoding means is provided with a distinctive condition for each of the different code rates and the train carried cab signals and brake control equipment are governed to a distinctive condition according to the condition established for the decoding means. The decoding means usually includes different tuned circuits, each circuit being tuned for response to current of a frequency corresponding to a respective code rate. Most satisfactory operation is obtained for such decoding means when the frequency of the current supplied thereto is free from code distortion. In other words, the code following relay when operated in step with the code rate of the track rail current effects the most satisfactory and reliable control of the decoding means and in turn of the cab signal and brake control equipment.

A 32 volt battery or direct current generator is commonly provided on railway trains as the source of supply for the train lighting circuit, locomotive headlight circuit and similar equip-

ment. Electron tubes of the type heretofore used for train controlling apparatus of the class here involved require a plate voltage of the order of 300 volts and consequently a motor generator or dynamotor is required to convert the 32 volts of the standard train carried source to 300 volts required by the electron tubes. As an alternative arrangement a separate and independent generator may be provided for supplying the required voltage for the electron tubes. Such electron tubes also require a relatively low voltage source for the heater or filament circuit, and hence two different voltages are required. However, low voltage electron tubes of the capacity and character required by such train controlling apparatus are now available.

In view of the foregoing conditions, a feature of my invention is the provision of a novel and improved low voltage electron tube amplifier for railway traffic controlling apparatus.

Another feature of my invention is the provision of a novel and improved electron tube amplifier operable by a single 32 volt source of direct current.

Again a feature of my invention is the provision of novel and improved means to minimize code distortion arising from over energization of a code following relay due to higher than normal values of coded current flowing in a track circuit.

Another feature of my invention is the provision of novel and improved means for varying the operating characteristics of a code following relay according to the energy level of the output of the associated electron tube amplifier.

To attain the above mentioned features, as well as other advantages of my invention which will become apparent as the specification progresses, I provide a low voltage type of electron tube with heater and plate circuits which give effective operation of the tube when each of such circuits is connected to a 32 volt battery or direct current generator. A fixed and a variable grid biasing means are provided for the tube. The fixed grid bias voltage is derived from a resistor in the heater circuit and is of constant value while the variable grid bias voltage is derived from a biasing unit across which a voltage is developed that is proportional to the magnitude of the energy picked up above a normal value. The fixed grid bias voltage is made such as to cause the tube to function as a class "A" amplifier when coded current of a normal value such as that which flows in a track circuit when a train is at the entrance end of the track section is supplied. A circuit comprising a condenser and a resistor in multiple is used as the variable biasing unit. This biasing unit has a time constant of a period somewhat greater than the off period of the lowest code rate used and the unit is included in the grid circuit of the electron tube to develop and maintain a voltage across the terminals of the unit when coded current greater than the normal value is present in the track rails. This biasing unit is different from the grid leak condenser combination commonly used with electron tube amplifiers. In the case of the customary grid leak condenser combination the voltage is retained for substantially only one cycle of the alternating current transmitted and hence is effective to control the tube only during the on period of coded alternating current. The biasing unit here provided maintains the voltage developed across its terminals at a substantially uniform value and exerts a continuous control on the tube as long as the coded current persists. Since the voltage developed across the biasing unit during an on period of the coded current is retained with little loss during the next off period due to the time constant of the unit, the voltage developed across the unit is added to the fixed bias voltage and the resultant bias voltage causes the tube to function as a class "C" amplifier for coded current of the higher magnitude. In other words, when a train is at the entrance end of a track section and coded current of normal value flows in the rails only the fixed bias voltage is present and the tube is caused to function as a class "A" amplifier, and produces a desired response of the plate circuit current. When the train is at the exit end of the section and coded current of a higher magnitude flows in the track rails then the fixed bias voltage is increased by an additional bias voltage developed across the variable biasing unit and the tube is caused to function as a class "C" amplifier and the response of the plate circuit current is substantially the same as before. Another resistor is preferably interposed in the grid circuit in series with the previously mentioned biasing means. When the track circuit current is large the electromotive force picked up is of such magnitude that the higher values of its positive half cycles are greater than the fixed negative grid bias voltage and drive the grid positive in potential with respect to the cathode of the tube and grid current flows. This flow of grid current develops the additional bias voltage across the terminals of the biasing unit. The track circuit current may at times reach abnormally high values and the voltage developed across the biasing unit may be great enough to prevent operation of the tube due to the tube becoming biased beyond cutoff. The voltage drop across such other resistor due to the grid current serves to reduce the voltage developed across the biasing unit and thus functions to aid in retaining uniform response of the plate circuit current.

A code following relay is inductively coupled to the plate circuit and is energized by energy transferred thereto due to the variations of the plate circuit current caused by the variations of the grid voltage during an on period of the rail current. That is, the code following relay is supplied with a current impulse and picked up during each on period of the code and then is deenergized and released during each off period of the code. The code following relay is provided with a substantially uniform energization irrespective of the magnitude of the track circuit current, within limits of course, due to the biasing means provided for the electron tube. With uniform energization of the code following relay, code distortion is avoided, whereas, if the energization of the relay varied in magnitude in proportion to the magnitude of the coded rail current, the release of the relay at the start of each off code period would be delayed at the higher level of energization with the result that the off period of the relay would be shortened and the on period made correspondingly long and code distortion would result when the rail current is of a high value.

In one form of my invention the operating characteristics of the code following relay are automatically altered by means of a second winding of the relay interposed in the plate circuit.

Control of decoding means of the standard type may be improved by the use of a code fol-

lowing repeater relay, as disclosed in one form of my invention. When a repeater relay is provided the master code following relay is required to control at its contact only current sufficient for operation of the repeater relay whereas the repeater relay, which would be energized by the local supply of current, is used to control the current required to operate the standard decoding means. In place of using a repeater relay, a second stage low voltage amplifier may be used as is disclosed in one form of the invention. Such repeater relay or the additional stage of amplification may not be needed.

I shall describe several forms of apparatus embodying my 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 my invention when used with train carried train controlling apparatus and wherein a code following repeater relay is provided. Fig. 2 is a diagrammatic view showing another form of apparatus embodying my invention when used with train carried train controlling apparatus and wherein a second stage tube is provided. Figs. 3, 4 and 5 are diagrammatic views showing other forms of apparatus each of which also embodies my invention when used with train carried train controlling apparatus. Figs. 6 to 11, inclusive, are diagrams illustrating operating characteristics of the apparatus of Figs. 1 to 5, inclusive.

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

Referring first to Fig. 6, 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. The rails *1a* and *1b* are formed of the usual insulated rail joints with a track section W—X which may be one section of a series of consecutive sections of a signal system. The track section W—X is provided with a track circuit including a source of current connected across the rails at the exit end of the section and a track relay connected across the rails at the entrance end of the section. The immediate source of current for the track circuit of section W—X is a track transformer TF whose secondary winding **3** is connected across the rails at the exit end of the section. The primary winding **4** of transformer TF is connected with a convenient source of alternating current, such as a generator not shown, but whose terminals are indicated at BX and CX. The current supplied to primary winding **4** is coded or periodically interrupted by a coder CT at a rate selected according to the position of a traffic controlled contact member **5**. Coder CT is of the well-known type and is provided with three code contact members **180**, **120** and **75** which are operated at the code rate of 180, 120 and 75 times per minute, respectively. When contact member **5** engages a contact **6** due to a first or clear traffic condition in advance, the connection of primary winding **4** to the current source includes code contact member **180** of coder CT and the current is coded or interrupted at the rate of 180 times per minute. When contact member **5** engages a contact member **7** due to a second or approach-medium traffic condition in advance, the connection to primary winding **4** is completed at contact member **120** of coder CT and the current is coded or interrupted at the rate of 120 times per minute. When contact member **5** is set to engage a contact **8** due to a third or approach traffic condition, the code contact member **75** of coder CT is interposed in the connection of primary winding **4** and the current is coded or interrupted at the rate of 75 times per minute. The apparatus for selectively governing the position of contact member **5** according to different traffic conditions in advance may be of any one of the well-known forms and is not shown since its specific structure forms no part of my invention. It is to be understood of course that my invention is not limited to these specific code rates, but such code rates are used for illustration since they are in general use.

A track relay TR is connected across the rails at the entrance end of section W—X and is operated when the section is unoccupied at a rate corresponding to the code rate of the current supplied to the rails of the exit end of the section. Track relay TR is used to control the supply of coded current to the section next in the rear but such apparatus as explained hereinbefore forms no part of my invention and further reference to relay TR and the apparatus controlled thereby is not necessary.

When a train, shown conventionally at VT in Fig. 6, occupies section W—X current flows down one rail through the wheels and axles of the train and back the other rail. When train VT is at the entrance end of the section, the rails *1a* and *1b* for the full length of the section are in circuit and the circuit impedance is relatively large, but with the train near the exit end of the section the rail impedance is shunted out and the circuit impedance is correspondingly reduced. Hence the magnitude of the current flowing in the track rails progressively increases as the train moves from the entrance end of the section to the exit end of the section. In Fig. 7 this progressive increase in the rail current is illustrated by the curve C*1*.

A pair of inductors *2a* and *2b* are mounted on the train VT ahead of the leading wheels and in inductive relation to the track rails *1a* and *1b*, respectively. Inductors *2a* and *2b* are connected together in a train carried receiving circuit in such a manner that the electromotive forces induced therein by current flowing in the rails in opposite directions at any given instant are additive. This train carried receiving circuit also includes a condenser **9** and a primary winding **10** of a transformer **11**. A condenser **23** is connected across the secondary winding **12** of transformer **11** and the receiving circuit together with the transformer **11** form a filter which is tuned to resonance at the frequency of the alternating current used in the track circuit. That is to say this filter is tuned to resonance a 100 cycles per second when 100 cycle alternating current is used. It follows that an electromotive force is induced in the secondary winding **12** of transformer **11** which is of the same frequency and code rate as the track rail current, and the magnitude of which is proportional to the magnitude of the track rail current. The electromotive force thus developed across secondary winding **12** is used to control train carried train controlling apparatus as will shortly appear.

Referring to Fig. 1, a train carried electron tube TT is provided. Electron tube TT may be any one of several types and may be a tetrode having an anode or plate **13**, a cathode **14**, a control grid **15**, another grid **16** and a filament **17**. The reference character TB designates a train carried source of current such as a 32 volt bat-

tery. This current source TB may be the standard train carried battery or generator which supplies current to the usual train lighting circuit, headlight circuit and similar equipment.

A heater circuit is provided for tube TT, the circuit extending from positive terminal B32 of the current source TB over a first resistor 18, filament 17 of tube TT and a current limiting resistor 19 to negative terminal C of battery TB. This heater circuit is arranged so as to create the desired heating of filament 17 and to develop a predetermined voltage drop across current limiting resistor 19. It is clear that a single resistor such as the current limiting resistor 19 only may be needed for this heater circuit. Cathode 14 is connected to the negative end of filament 17 and hence the current limiting resistor 19 is disposed in the lead from cathode 14 to the negative terminal C of the current source. The grid 16 is preferably connected to the positive terminal of filament 17 and functions in the usual manner for tubes of this type. The plate circuit for tube TT extends from positive terminal B32 of the current source over primary winding 20 of a transformer TP, plate 13, intervening tube space to cathode 14, resistor 19 and to the negative terminal C of the current source. A control or grid circuit for tube TT is coupled to the receiving circuit and can be traced from control grid 15 over a resistor 22, a biasing unit BU, winding 12 of transformer 11 and condenser 23 in multiple, current limiting resistor 19 and cathode 14 of tube TT. The biasing unit BU consists of a condenser 24 and a resistor 25 in multiple.

The voltage drop across resistor 19 provides a fixed negative grid bias voltage for tube TT. The circuit comprising condenser 24 and resistor 25 of biasing unit BU has a time constant to effect a substantially constant direct voltage across its terminals when such direct voltage is developed by current flowing in the grid circuit of the tube due to the coded electromotive force induced in winding 12. That is, the time constant of this circuit formed by condenser 24 and resistor 25 is such that the voltage developed across the unit BU due to a grid current flowing during an on code period is but little decreased during an off period for the code rates here contemplated, but an absence of coded current causes the unit BU to be shortly discharged. It is clear therefore that when a voltage is developed across the unit BU it is added to the voltage derived from resistor 19 to form a resultant negative grid bias voltage for tube TT. The manner by which these biasing devices as well as the resistor 22 of the grid circuit function to control the operation of the tube will be described when the operation of the apparatus of Fig. 1 is pointed out.

A first or master code following relay MR is coupled to the plate circuit, winding 26 of relay MR being connected across secondary winding 27 of transformer TP, through a full wave rectifier 28. Consequently electromotive forces induced in secondary winding 27 of transformer TP due to variations of the plate circuit current of tube TT are rectified and supplied to winding 26 of relay MR as unidirectional current for energization of that relay.

A code following repeater relay MRP is controlled by the master code following relay MR through a transformer T2. When relay MR is picked up closing its front contact 29, direct current flows from positive terminal B32 of the current source over front contact 29, at least a portion of winding 30 of transformer T2 and to negative terminal C of the current source. Winding 31 of repeater relay MRP is connected across a secondary winding 32 of transformer T2. Hence when relay MR is operated to periodically interrupt the current supplied to winding 30 of transformer T2, electromotive forces are induced in winding 32 and applied to the repeater relay MRP. Relay MRP is a polar relay and the connections are so arranged that when front contact 29 of relay MR is closed and current builds up in winding 30 of transformer T2 an electromotive force of one polarity is induced in winding 32 and relay MRP is energized as required to operate its polar contact member 33 to a left-hand or normal position to engage a normal contact 34, and when master relay MR releases to open front contact 29 and the current flowing in winding 30 dies away an electromotive force of opposite polarity is induced in winding 32 and relay MRP is energized as required to operate its contact member 33 to a right-hand or reverse position to engage a reverse contact 35. A condenser 36 is connected in shunt with front contact 29 to suppress sparking at the contact, and a condenser 37 is connected across winding 30 of transformer T2 to improve the operation. Consequently operation of master code following relay MR at a particular code rate causes operation of the repeater relay MRP at a corresponding code rate.

Repeater relay MRP controls the supply of current to a decoding means DM, the arrangement being such that when contact member 33 is made to alternately engage normal contact 34 and reverse contact 35, direct curent is alternately supplied to two portions of primary winding 78 of a decoding transformer DT and an electromotive force is induced in secondary winding 79 of that transformer having a frequency corresponding to the rate at which repeater relay MRP is operated. Secondary winding 79 of transformer DT is connected to the input side of decoding means DM.

The decoding means DM may take any one of several well-known forms and preferably would be of the standard type which includes tuned circuits similar to those described and claimed in Letters Patent of the United States No. 1,773,515, granted August 19, 1930, to C. C. Buchanan, for Railway traffic controlling apparatus. It is sufficient for this application to point out that when the current applied to the input side of the decoding means DM is of a frequency corresponding to the 180 code rate, control relays A and L connected to the output side of the decoding means are effectively energized and picked up. When the current applied to the input side of the decoding means is of a frequency corresponding to the 120 code rate, then relays R and L connected to the output side of the decoding means are effectively energized and picked up and relay A is released. When the current applied to the input side of the decoding means is of a frequency corresponding to the 75 code rate relay L is effectively energized and picked up and relays A and R are released. Also when relay MRP is inactive then all three of the relays A, R and L are released.

The control relays A, R and L are used to control the operating circuits of a train controlling means which as here shown is a cab signal CS, signal CS being a four-indication color light signal. The operating circuits are preferably similar to those commonly employed and it is sufficient to point out that when relay A is picked up to close front contact 38, a circuit is formed

for lamp 39 of signal CS and that lamp is illuminated to display a first or clear signal indication. When relay A is released closing back contact 40 and relay R is picked up closing front contact 41, a circuit is formed for lamp 42 of signal CS and that lamp is illuminated to display a second or approach medium signal indication. When relays A and R are released, closing back contacts 40 and 43, respectively, and relay L is picked up closing front contact 44, a circuit is formed for lamp 45 of signal CS and that lamp is illuminated to display a third or approach signal indication. Also when relays A, R and L are released closing the respective back contacts 40, 43 and 46, a circuit is formed for lamp 47 of signal CS and that lamp is illuminated to display a fourth or slow signal indication.

In describing the operation of the apparatus of Fig. 1, I shall assume that the apparatus is mounted on train VT of Fig. 6 and the train moves through section W—X under clear traffic conditions and contact member 5 is set to engage contact 6 so that current of the 180 code rate is applied to the track rails. When the train VT is at the entrance end of the section, the magnitude of the rail current is of normal value. That is, the rail current has a value just sufficient to assure effective operation of the apparatus with proper working limits when the train is at the entrance end of the section. As the train moves through the section the rail current increases in a manner illustrated by the curve C1 of Fig. 7.

As set forth hereinbefore, the heater circuit of tube TT is such that the voltage drop across current limiting resistor 19 provides a fixed negative grid bias voltage for the tube. This fixed grid bias voltage is represented by the line FV of Fig. 8 and is such as to cause a steady plate current of the value indicated at point PA on the plate current grid voltage characteristic curve PC of Fig. 8. It is to be seen, therefore, that tube TT is normally conditioned to function as a class "A" amplifier. When the train VT is at the entrance end of the section and the rail current is of normal value, the magnitude of the electromotive force induced in the train carried receiving circuit and in turn applied to the grid circuit of tube TT is of a corresponding normal value. As illustrated in Fig. 8, this alternating electromotive force thus applied to the grid circuit of tube TT is less than the fixed negative grid bias voltage derived from resistor 19 and grid 15 is not driven positive in potential with respect to the cathode 14 and no grid current flows. Consequently, biasing unit BU and resistor 22 do not function and the plate current is varied in step with the alternating grid voltage. This variation of the plate current is also illustrated in Fig. 8. Such variations of the plate circuit current induce corresponding electromotive forces in secondary winding 27 of transformer TP and unidirectional current is supplied through rectifier 28 to master code following relay MR to operate that relay. As illustrated in Fig. 10 the energization effected for relay MR by the rectified current supplied thereto in response to a normal value of rail current produces an energization for that relay which causes the relay to be picked up and released substantially in step with the on and off periods of the rail current. Thus code following repeater relay MRP is operated in step with relay MR in the manner described hereinbefore, causing current of a frequency corresponding to the 180 code rate to be supplied to the decoding means DM so that control relay A is picked up completing the operating circuit for lamp 39 of signal CS, and causing the display of a clear signal indication. Since the energization of relay MR is just sufficient to provide the desired operation of the relay and the relay is operated substantially in step with the on and off periods of the coded rail current code distortion is substantially avoided and satisfactory operation of the decoding means is effected.

As explained hereinbefore, the rail current may increase in magnitude due to the shunting out of the rail impedance as the train moves toward the exit end of the section so that the magnitude of the current when the train reaches the exit end of the section may be several times that flowing in the rails when the train first enters the section. Such increase of rail current causes a corresponding increase in the magnitude of the electromotive force picked up by the receiving circuit and applied to the grid circuit of tube TT. When the rail current increases to a value where the electromotive force applied to tube TT exceeds the fixed negative grid gias voltage derived from resistor 19 and the grid is driven positive in potential with respect to the cathode 14 during the higher values of the positive half cycle of such electromotive force, grid current flows and a voltage is developed across the biasing unit BU. This voltage developed across biasing unit BU is retained with little loss during the off code period due to the time constant of the circuit formed by condenser 24 and resistor 25. When the train reaches the exit end of the section and the rail current is of its highest value, the electromotive force picked up by the receiving circuit is of its highest value and the voltage developed across biasing unit BU is correspondingly high. This condition of the apparatus when the train reaches the exit end of the section is illustrated in Fig. 9 in which the additional bias voltage applied by unit BU is indicated. The resultant grid bias voltage derived from resistor 19 and unit BU is indicated by line RT1 and conditions the tube for operation as a class "C" amplifier and plate current flows only during the positive half cycle of the electromotive force picked up by the receiving circuit. Again, the variations of plate current caused by the variations of the grid voltage under this condition of maximum rail current, induce electromotive forces in the secondary winding 27 of transformer TP which are in turn rectified and used to energize the master code following relay MR. Due to this change in the grid bias voltage the variations effected in the plate circuit current cause the current impulse supplied to master code following relay MR to be substantially the same as that effected under normal value of rail current with the result that energization of the master code following relay MR is not greatly increased due to the increase in the rail current with the result that the relay MR is still operated substantially in step with the on and off periods of the track circuit current and the code following repeater relay is operated with little or no code distortion. This is illustrated in Fig. 11.

It is to be observed that as long as the voltage of grid 15 remains negative and no grid current flows, the resistor 22 interposed in the grid circuit exerts no effect upon the operation of the tube. When the voltage of grid 15 is caused to swing positive for a portion of each positive half cycle of the electromotive force picked up by the receiving circuit, grid current flows and such flow of current through resistor 22 causes a volt-

age drop with the result that the positive grid voltage is reduced. When the rail current is of an abnormally high value and a relatively large grid current flows, the drop in resistor 22 is correspondingly large with the result that resistor 22 serves to limit the voltage developed across unit BU and aids in effecting a substantially uniform variation of the plate circuit current. It is clear resistor 22 may not be needed.

It is to be seen, therefore, that I have provided a single low voltage electron tube amplifier which is effectively operated from a single 32 volt source of supply, and which operates to cause a substantially uniform variation of the plate circuit current over a relatively large range of track circuit current so that the code following relay controlled by such plate circuit is operated without code distortion.

The operation of the apparatus of Fig. 1 when the rail current is of either the 120 or 75 code rate, is substantially the same as that described for the 180 code rate, except relays MR and MRP are operated at the corresponding code rate to select relays R or L, as the case may be, and establish a corresponding signal indication.

Referring to Fig. 2, the train carried apparatus includes a receiving circuit and an electron tube TT, the same as in Fig. 1, and a description thereof need not be repeated. In Fig. 2, secondary winding 27 of transformer TP is included in the grid circuit of a second tube TT1. Tube TT1 is preferably similar to tube TT and is provided with a heater circuit that receives power from battery TB and includes a current limiting resistor 48 interposed in the lead between cathode 49 of tube TT1 and the negative terminal of battery TB. The plate circuit of tube TT1 includes terminal B32 of the current source, primary winding 50 of transformer TP1, plate 51 and tube space to cathode 49 of tube TT1, and resistor 43 to the negative terminal C. The current limiting resistor 48 causes a negative bias voltage to be applied to control grid 52 of a value such that tube TT1 is characterized as a detector—class "C" amplifier. A condenser 53 is connected across primary winding 50 to by-pass the alternating current component of the plate circuit current. Secondary winding 54 of transformer TP1 is connected to winding 55 of a polar code following relay MR1. It follows that when the average value of the plate current flowing in primary winding 50 of the transformer TP1 during each on code period is increased an electromotive force is induced in secondary winding 54 of one polarity and relay MR1 is operated as required to move its polar contact member 56 to a left-hand position to engage a normal polar contact 57, and when the average value of the plate current decreases during each off code period an electromotive force of the opposite polarity is induced in secondary winding 54 and relay MR1 is energized as required to operate its contact member 56 to the right-hand position to engage reverse polar contact 58. Code following relay MR1 is used to control the decoding means DM in the same manner as the code following repeater relay MRP of Fig. 1 controls the corresponding decoding means and hence relays A, R and L of Fig. 2 are selectively governed according to the code rate of the rail current to selectively control the operating circuits of the cab signal CS in the same manner as in Fig. 1.

Tube TT of Fig. 2 and its associated biasing devices are substantially the same as in Fig. 1, and function in the same manner, and hence the energy transferred through transformer TP to the grid circuit of tube TT1 is substantially of uniform value for all values of the track circuit current. Since tube TT1 functions as a detector—class "C" amplifier, it follows that the uniform variation of the grid voltage of tube TT1 causes a substantially uniform transfer of energy from the plate circuit of tube TT1 through transformer TP1 to the code following relay MR1 and relay MR1 is provided with substantially uniform energization irrespective of the magnitude of the track circuit current. It is to be seen, therefore, that with the apparatus of Fig. 2 mounted on the train VT of Fig. 6, the operation of the apparatus in the control of the decoding means and the associated cab signal is substantially the same as that described for the apparatus of Fig. 1.

In the form of the invention disclosed in Fig. 3, the variable voltage for biasing the electron tube is obtained from the output of the tube. Looking at Fig. 3, a receiving circuit is mounted on the train the same as in Fig. 1. Tube TT2 of Fig. 3 is a low voltage tube of the tetrode type and is provided with a heater circuit which includes filament 59 and a current limiting resistor 60, and which circuit is supplied with current from a 32 volt battery TB. The plate circuit involves terminal B32, primary winding 61 of a transformer TP2, plate 62 and tube space to cathode 63 of tube TT2, a biasing unit BU1 and resistor 60 to the negative terminal of the current source. The grid circuit can be traced from control grid 64, through condenser 23 and winding 12 of transformer 11 in multiple, resistor 69, biasing unit BU1, and to cathode 63. Code following relay MR is connected to a secondary winding 65 of transformer TP2 through rectifier 28 and is energized in response to the energy transferred to winding 65 due to the variations of the plate circuit current created during each on code period. Another secondary winding 66 of transformer TP2 is connected across biasing unit BU1 through a full wave rectifier 67. Hence the electromotive forces induced in the secondary winding 66 due to variations of plate circuit current of tube TT2 are rectified and applied to the biasing unit BU1. The rectifier 67 is so poled that the polarity of the terminals of the unit BU1 is that indicated by the plus and minus signs in Fig. 3. Again, the circuit comprising condenser 69 and resistor 68 of unit BU1 has a time constant sufficiently large to bridge the off period of the code rates here used. It is to be seen, therefore, that the voltage developed across biasing unit BU1 due to the output of the tube TT2 during an on code period is maintained during the next off code period and is added to the fixed grid bias voltage derived from the current limiting resistor 60. Code following relay MR of Fig. 3 governs the current supplied to decoding means DM and in turn controls the control relays A, R and L according to the code rate at which relay MR is operated, relays A, R and L being used to control the operating circuit of signal CS the same as in Fig. 1.

The voltage drop across resistor 60 effects a fixed negative grid bias voltage which conditions tube TT2 to function as a class "A" amplifier. Because of the time constant of unit BU1, the voltage developed across its terminals during an on period of the coded current is retained with little or no loss during the following off code period, and the voltage thus created across the biasing unit BU1 serves as an additional negative

grid bias voltage for the tube. The magnitude of this voltage created across unit BU1 is proportional to the magnitude of the output of the tube, which in turn is governed by the magnitude of the rail current. Consequently, the unit BU1 serves to cause a substantially uniform output for the tube irrespective of the magnitude of the rail current.

It is to be seen therefore that the apparatus of Fig. 3, when mounted on train VT of Fig. 6, will operate in a manner substantially the same as the apparatus of Fig. 1.

In Fig. 4 the apparatus of Fig. 1 is modified by a two winding polar code following relay MR2 replacing the code following relay MR, by omitting resistor 18 and code following repeater relay MR1 and by a condenser 70 being connected between cathode 14 of tube TT and the positive terminal of winding 20 of transformer TP. A first or operating winding 71 of relay MR2 is connected to secondary winding 27 of transformer TP through rectifier 28 and is energized by the energy transferred to winding 27 due to variations of the plate circuit current. A second or control winding 72 of relay MR2 is interposed in the plate circuit, the plate circuit for tube TT including positive terminal of battery TB, winding 72 of relay MR2, primary winding 20 of transformer TP, plate 13 and tube space to cathode 14 and current limiting resistor 19 to the negative terminal of battery TB. The plate circuit current flows through winding 72 in such a direction as to produce a flux that aids the permanent magnetic flux of the relay. With normal rail current the average value of the plate circuit current is a maximum and hence the net opposing flux (permanent magnetic flux plus the auxiliary winding flux) is a maximum. Conversely when the rail circuit current is a maximum, the average value of the plate circuit current is a minimum and the net opposing flux of the permanent magnet and auxiliary winding is a minimum. This change in the net opposing flux of the relay with change of rail current produces a high pick-up and release current with an increase in rail current, and relatively low pick-up and release current with a decrease of rail current. Such changes in the operating characteristics of the code following relay aid in producing less code distortion with varying rail current.

Relay MR2 of Fig. 4 controls at its contacts 73 and 74 the current supplied to decoding transformer DT and in turn the current supplied to decoding means DM and hence controls relays A, R and L in accordance with the code rate at which the relay is operated, relays A, R and L governing the operating circuits of the signal CS the same as in the previous cases.

It is clear therefore that the apparatus of Fig. 4 will operate in a manner similar to that of the apparatus of Fig. 1 with the auxiliary winding 72 of relay MR2 aiding in minimizing code distortion and as an aid in control of standard type decoding means in response to the energy output of a single low voltage amplifier tube.

In the form of the invention disclosed in Fig. 5, the apparatus of Fig. 1 is modified by including a second condenser 76 in the grid circuit of tube TT, by providing a grid leak resistor 77, and by omitting repeater code following relay MRP.

Condenser 76 serves as a blocking condenser through which the alternating current energy derived from the track rail flows to the grid circuit. Resistor 77 is a grid leak which provides the return path for the grid circuit, and such resistor 77 is connected to a tap or mid terminal of resistor 25 of biasing unit BU, so that instead of the total voltage developed across unit BU being added to the voltage derived from the current limiting resistor 19 for providing a negative grid bias voltage for the tube, only a portion of the total voltage developed across the unit BU is applied thereto. By adjustment of the connection of the resistor 77 to resistor 25, the degree of the grid bias control can be varied.

It is clear that the operation of the apparatus of Fig. 5 is substantially the same as that of the apparatus of Fig. 1, except as to modification in the control of the grid bias voltage as effected by condenser 76 and resistor 77.

Although I have herein shown and described only a few forms of apparatus embodying my 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 my invention.

Having thus described my invention, what I claim is:

1. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a single train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined bias voltage across such resistor, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; a grid circuit including a winding coupled to said receiving circuit, said biasing unit and said current limiting resistor and connected across said control grid and cathode to apply to said tube a control electromotive force derived from said track rail current and modified by only the bias voltage of said current limiting resistor when the train is at the entrance end of the section and the rail current is of relatively low magnitude and modified by both the bias voltage of said current limiting resistor and the voltage developed across said biasing unit when the train is at the exit end of the section and the rail current is of relatively high magnitude, a plate circuit including said current source and a winding and connected to said plate and cathode, and a code following relay controlled by said winding in response to the variations of the plate circuit current as effected by the electromotive forces applied to the tube by said grid circuit.

2. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section

due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a single train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined bias voltage across such resistor, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; a grid circuit including a winding coupled to said receiving circuit and connected across said control grid and cathode to apply to said tube a control electromotive force derived from said track rail current, said current limiting resistor interposed in said grid circuit to provide a fixed negative grid bias voltage effective to condition the tube for operation as a class "A" amplifier when the train is at the entrance end of the section and the rail current is of relatively low magnitude, said biasing unit interposed in said grid circuit to provide an additional negative grid bias voltage effective to condition the tube for operation as a class "C" amplifier when the train is at the exit end of the section and the rail current is of relatively high magnitude, a plate circuit including said current source and a winding and connected across said plate and cathode, and a code following relay coupled to said winding and controlled in response to the variations of the plate circuit current as effected by the electromotive forces applied to the tube through said grid circuit.

3. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a single train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined negative bias voltage across such resistor, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; another resistor, a grid circuit including a winding coupled to said receiving circuit, said biasing unit, said other resistor and said current limiting resistor and connected across said control grid and cathode to apply to said tube a control electromotive force derived from said track rail current and modified by the bias voltage of said current limiting resistor only when the train is at the entrance end of a section and the rail current is of relatively low magnitude and modified by both the bias voltage of said current limiting resistor and the voltage developed across said biasing unit when limited by said other resistor when the train is at the exit end of the section and the rail current is of relatively high magnitude, a plate circuit including said current source and a first winding of a transformer and connected to said plate and cathode of the tube, and a code following relay connected to a second winding of said transformer effectively operated in response to the variations of the plate circuit current caused each on code period by said electromotive force picked up by the receiving circuit.

4. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, and which train carries a 32 volt source of direct current, the combination comprising; a low voltage electron tube having a plate, a cathode and a control grid; a heater circuit for said tube connected across said current source and having a current limiting resistor interposed in the lead between said cathode and the negative terminal of the current source, a condenser and a resistor connected in multiple to form a biasing unit with a time constant longer than the off period of said code rate, a grid circuit including a winding coupled to said receiving circuit, said biasing unit and said current limiting resistor and connected across said control grid and cathode to apply to the tube a control electromotive force derived from said rail current, said current limiting resistor effective to provide a fixed negative grid bias voltage which is slightly greater than the normal value of electromotive force picked up by the receiving circuit when the train is at the entrance end of the section and the rail current is low due to the rail impedance in circuit, said biasing unit effective to provide an additional negative grid bias voltage which is proportional to the electromotive force picked up by the receiving circuit above such normal value to maintain the grid negative in potential with respect to the cathode when the train is at the exit end of the section and the rail current is high due to the rail impedance being shunted out of the circuit, a plate circuit including a winding for said tube connected across said current source, and a code following relay coupled to said plate circuit winding and operated in response to the variation of the plate circuit current caused by the electromotive forces applied to the grid of the tube.

5. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, and which train carries a 32 volt source of direct current, the combination comprising; a low voltage electron tube having a plate, a cathode and a control grid; a heater circuit for said tube connected across said 32 volt current source and having a current limiting resistor interposed in the lead between the cathode and negative terminal of the current source, a biasing unit including a condenser and a resistor in multiple and effective to retain during the off period of said code rate a voltage developed across its terminals during an on period of the code rate; a grid circuit connected across the control grid

and cathode of said tube and including said current limiting resistor, said biasing unit and a winding coupled to said receiving circuit; said current limiting resistor effective to provide a predetermined fixed negative grid bias voltage, said biasing unit effective to provide an additional negative grid bias voltage equal to the voltage developed across such unit when the electromotive force picked up by the receiving circuit is greater than said fixed bias voltage, a plate circuit for said tube connected across said 32 volt current source, and a code following relay controlled by the variation of the plate circuit current due to the electromotive forces applied to the grid of the tube.

6. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined bias voltage across such resistor, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; another resistor, a grid circuit including a winding coupled to said receiving circuit, said current limiting resistor, said biasing unit and said other resistor and connected to said control grid and said cathode, said grid circuit effective to apply a fixed negative grid bias voltage due to said current limiting resistor and to apply an additional variable negative grid bias voltage due to said biasing unit when the electromotive force picked up by said receiving circuit exceeds said fixed bias voltage because of an increased rail current brought about by the train moving toward the exit end of the section and which variable voltage is modified by the voltage drop across said other resistor due to the grid current flowing therethrough, a plate circuit including a current source and a winding for said tube, and a code following relay coupled to said plate circuit winding effectively operated by the variations of the plate circuit current caused by the electromotive forces applied to the tube by said grid circuit.

7. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a single train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined negative grid bias voltage, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; a grid circuit including a winding coupled to said receiving circuit, said biasing unit and said current limiting resistor and connected across said control grid and cathode to apply to said tube a control electromotive force derived from said track rail current and modified by the bias voltage of said current limiting resistor only when the train is at the entrance end of a section and the rail current is of relatively low magnitude and modified by both the bias voltage of said current limiting resistor and the voltage developed across said biasing unit when the train is at the exit end of the section and the rail current is of relatively high magnitude, a plate circuit including said current source and a first winding of a transformer and connected to the plate and cathode of said tube, a master code following relay connected to a second winding of said transformer through a rectifier to operate said relay in response to the electromotive forces induced in said second transformer winding, a code following repeater relay, and circuit means including said current source and a front contact of said master code following relay to control said repeater relay.

8. In combination; an electron tube having a plate, a cathode and a control grid; a heater circuit for said tube, a grid circuit connected to said control grid and cathode of the tube, means effective at times to supply to said grid circuit an alternating electromotive force of a preselected code rate, a plate circuit including a current source and a first winding of a transformer and connected to the plate and cathode of said tube, a master code following relay connected to a second winding of said transformer through a rectifier to pick up the relay in response to each on period of said coded electromotive force, another transformer having a first winding connected to a current source over a front contact of said master code following relay, and a polar code following repeater relay connected to a second winding of said other transformer to operate such repeater relay to its normal and reverse positions in response to operation of said master code following relay.

9. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; a first and a second electron tube each having a plate, a cathode and a control grid; a single train carried 32 volt source of current, a heater circuit for each tube each of which circuits includes said current source and a current limiting resistor interposed in the circuit between the cathode of the respective tube and the negative terminal of the current source, a condenser and a resistor connected to form a biasing unit having a time constant longer than the off period of said code rate; a first grid circuit including a winding coupled to said receiving circuit and said biasing unit and connected across the control grid and cathode of said first tube with the current limit-

ing resistor of the first tube heater circuit interposed therein, a first plate circuit including said current source and a first winding of a first transformer and connected to the plate and cathode of the first tube, a second grid circuit including a second winding of said first transformer and connected across the control grid and cathode of the second tube with the current limiting resistor of the second tube heater circuit interposed therein, a second plate circuit including said current source and a first winding of a second transformer connected to the plate and cathode of said second tube, and a code following relay controlled by a second winding of said second transformer.

10. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a single train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined negative grid bias voltage, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; a grid circuit including a winding coupled to said receiving circuit, said biasing unit and said current limiting resistor and connected across the control grid and cathode of said tube to apply to said tube a control electromotive force derived from said track rail current and modified by the voltage drop across said current limiting resistor, a plate circuit including a current source and a primary winding of a transformer connected across the plate and cathode of said tube, means including a first secondary winding of said transformer and a rectifier connected across said biasing unit to develop a direct voltage across the unit to modify the control of the track rail current on the tube, and a code following relay connected to a second secondary winding of said transformer to operate said relay in response to the variations of the plate circuit current effected each on period of said coded current.

11. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a single train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined negative grid bias voltage, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; a grid circuit including a winding coupled to said receiving circuit, said biasing unit and said current limiting resistor and connected across said control grid and cathode to apply to said tube a control electromotive force derived from said track rail current and modified by the bias voltage of said current limiting resistor only when the train is at the entrance end of a section and the rail current is of relatively low magnitude and modified by both the bias voltage of said current limiting resistor and the voltage developed across said biasing unit when the train is at the exit end of the section and the rail current is of relatively high magnitude, a code following relay having a first and a second winding, a plate circuit including said current source, a first winding of said relay and a first winding of a transformer and connected across the plate and cathode of said tube, and means including a rectifier to connect the second winding of said relay to a second winding of said transformer to operate the relay in response to said coded current.

12. In railway traffic controlling apparatus for use with a track section whose track rails are supplied at its exit end with alternating current coded at a preselected code rate and a receiving circuit mounted on a train to receive during each on period of such coded current an electromotive force the magnitude of which may progressively increase as the train moves from the entrance end to the exit end of the section due to the rail current increasing in magnitude, the combination comprising; an electron tube having a plate, a cathode and a control grid; a single train carried source of current, a heater circuit including said current source and a current limiting resistor to heat the tube and connected with said resistor interposed in the lead between the cathode and the negative terminal of the current source to provide a fixed predetermined negative grid bias voltage, a condenser and a resistor connected to form a biasing unit with a time constant longer than the off period of said code rate; a blocking condenser; a grid circuit including a winding coupled to said receiving circuit, said blocking condenser, said biasing unit and said current limiting resistor and connected across the control grid and cathode of said tube; a grid leak resistor connected between a selected point of the biasing unit resistor and the negative terminal of said current source to modify the electromotive force applied to said control grid by said grid circuit, a plate circuit including said current source and a first winding of a transformer connected across the plate and cathode of said tube, and a code following relay connected to a second winding of said transformer through a rectifier to operate the relay due to the variations of the plate circuit current during each on period of said coded current.

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