May 24, 1932. A. CARPE 1,859,498

VACUUM TUBE CONTROL SYSTEM

Filed Oct. 2, 1928 2 Sheets-Sheet 1

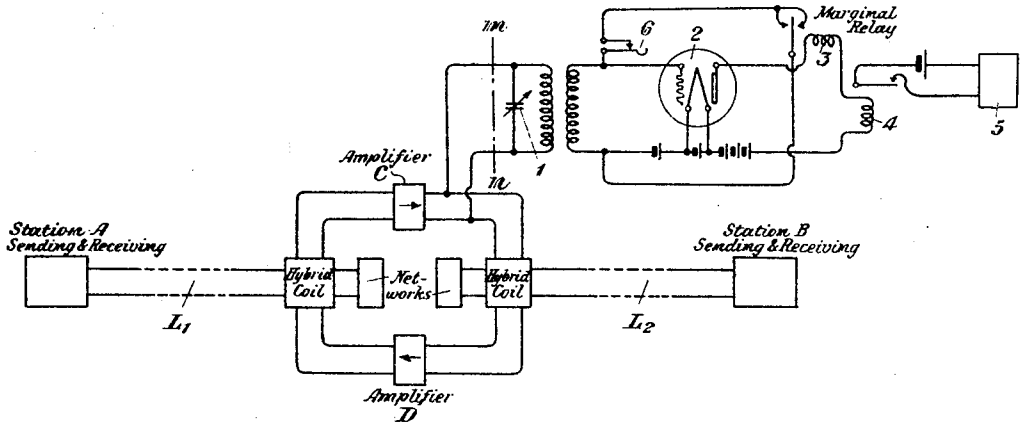


Fig. 1

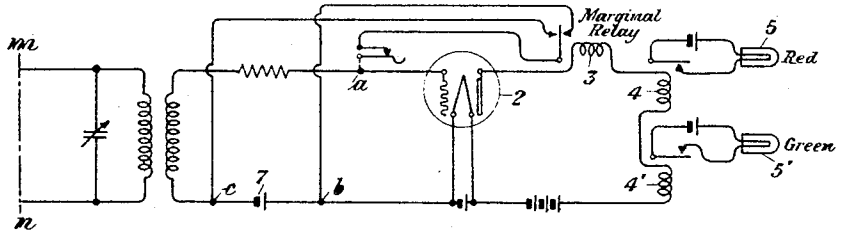


Fig. 2

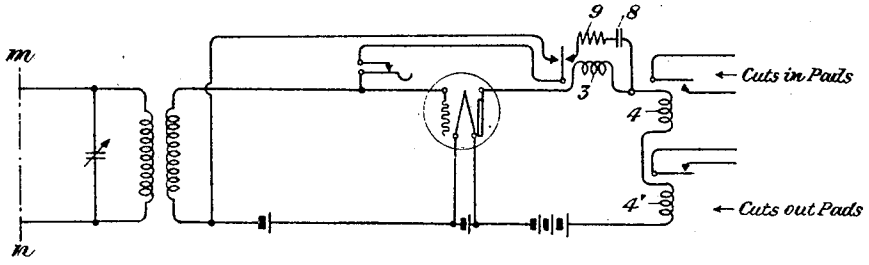


Fig. 3

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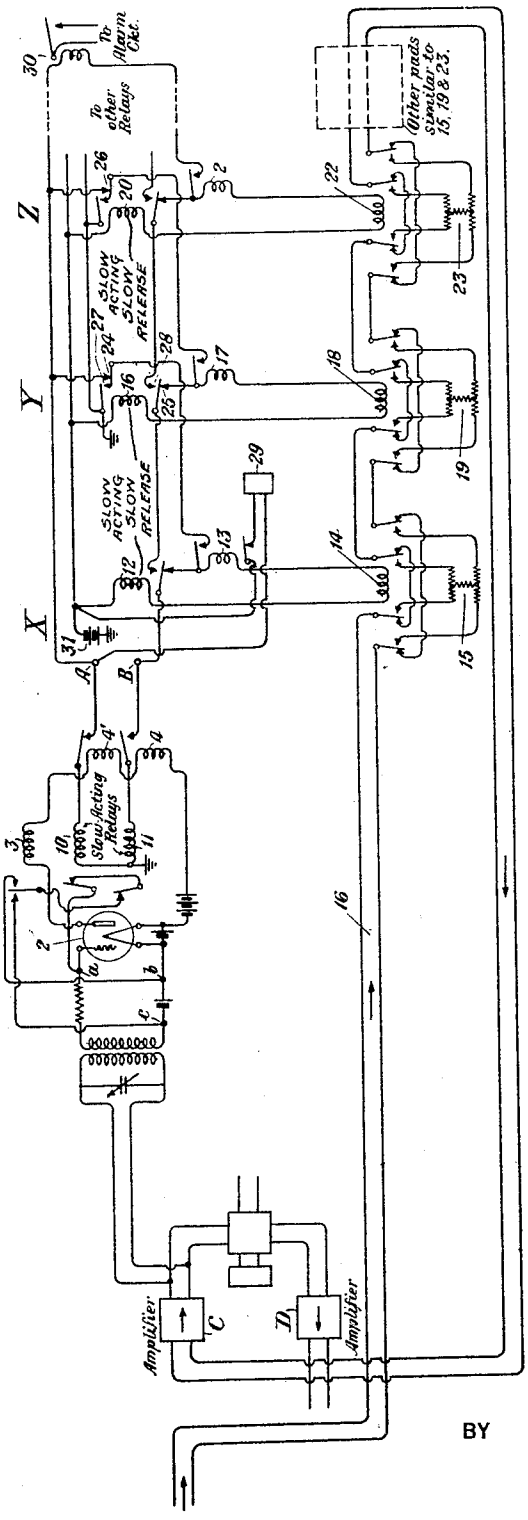


Fig. 4

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UNITED STATES PATENT OFFICE

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VACUUM TUBE CONTROL SYSTEM

Application filed October 2, 1928. Serial No. 309,750.

The invention resides in a vacuum tube control system which, when connected with some form of input circuit, will respond to slight variations from normal of the input current, and will produce much greater changes in the output current of the tube, which will operate devices that would not respond directly to the slight variations of the input current itself.

This invention may, for example, be applied to alternating current signaling systems, and particularly to means for indicating variations from normal of the current of a pilot channel transmitted over such systems.

In the operation of carrier or radio signaling systems employing one or more repeaters between the terminals thereof, it is customary to transmit a single frequency wave together with the signaling waves, the single frequency wave being known as a pilot channel. The pilot channel serves as an index of line conditions that affect the transmission of signals. The frequency of the pilot channel is so chosen with respect to the frequency of the signaling waves that any variation of line conditions that affect it will, in like manner, affect the signaling channels operating simultaneously with the pilot channel over the said line. As is well known, the signaling waves in a carrier system are sidebands produced by the modulation of a carrier frequency by the low frequency signal that it is desired to transmit. The pilot channel may be either of a frequency that is above all the signaling frequencies or it may be one of the carrier frequencies. This invention is applicable either to a carrier system in which the pilot channel lies above or below the range of signaling frequencies or to a system in which the one of the carrier frequencies has been chosen as the pilot channel, which carrier frequency, however, must not be employed for the transmission of signals between stations of the system.

This invention resides in part in a method and means for indicating variations from normal of the current of the pilot channel, the said method being characterized by the employment of slight variations in the space current of a vacuum tube indicating device to change the connections of the input circuit of the said tube, thereby producing a greater change in the said space current which, in turn, effects the operation of an indicating device to show that the level of transmission has exceeded certain predetermined limits.

Other objects of this invention will be apparent from the following description, when read in connection with the attached drawings, of which Figure 1 shows schematically the simplest form of embodiment of the invention; Figs. 2 and 3 are variations of the scheme shown in Fig. 1; and Fig. 4 shows a variation of the arrangement in Fig. 2, together with control apparatus whereby the gain of the amplifier may be automatically varied.

In Fig. 1, stations A and B represent terminals of a line which is made up of sections L_1 and L_2, which sections are connected with a repeater, which, in the form shown, is adapted to amplify separately the oppositely traveling currents. It is to be understood that the terminal stations are adapted to send and receive carrier signals. While a 22-type repeater has been shown involving hybrid coils and balancing network in addition to the amplifiers, it is to be understood that any well known type of repeater may be employed.

The pilot channel indicating circuit, which is shown connected across the output of the amplifier C, comprises a tuned circuit or filter 1 that is selective to the pilot frequency. This tuned circuit is coupled to the grid circuit of the vacuum tube rectifier 2. The plate circuit of this rectifier includes the windings of the marginal relay 3 and of the relay 4 which controls an alarm 5. The armature of relay 3 is connected with one side of the secondary winding of the input transformer of the tube 2 and both of the contacts of that relay are connected with the other side of the same winding of the said transformer. The latter connection includes a switch 6, by means of which the circuit may be opened at will.

The manner in which the circuit of Fig. 1 operates is as follows:

Let it be assumed that the pilot channel current is being transmitted from station A to station B over the line L_1—L_2. This current will be amplified by C and a portion of the energy thereof will pass into the indicating circuit. This current will be impressed upon the grid of the tube 2 and will cause a variation of the plate current of the tube. If the pilot channel current, when amplified by C, is of normal amplitude, the armature of relay 3 will remain midway between its contacts and the armature of relay 4 will also be unaffected. If, due to circuit conditions, the pilot channel current when amplified is above its normal level, the current in the plate circuit of tube 2 will be increased. Relay 3, however, is a sensitive marginal relay that will respond to a small marginal change of the plate current so as to attract its armature to its right-hand contact. This puts a short circuit across the secondary winding of the input transformer and causes a substantial reduction in the plate current. Relay 4, which is energized by the normal plate current, will be released when the current falls to a predetermined value. Thereupon, the plate current will fall and relay 4 will be sufficienty deenergized to release its armature and close the circuit of the alarm 5. The fall in current in the plate circuit also permits the armature of relay 3 to fall back, which removes the short circuit across the input of the tube. That will permit the restoration of the plate current to normal and will cause relay 4 to attract its armature. If the signal voltage still remains high, the same cycle of operation is repeated, that is, relay 3 attracts its armature, establishes a short circuit across the input of the tube which reduces the plate current and thus permits the armature of relay 4 to fall back and close the circuit of the alarm 5. The result is that for an over-voltage or high signal level, the alarm 5 acts as a buzzer.

If the voltage of the signal falls below normal, the marginal relay 3 will cause its armature to touch its left-hand contact, thereby short-circuiting the input of the tube and causing the armature of relay 4 to fall back, thereby closing the circuit of the alarm 5. If the voltage of the signal continues to be subnormal, the condition just described will continue and a steady indication will be given by the alarm 5. That is, the shunting of the secondary winding would cause a falling off in the current through relay 4, which would produce an indication by 5. It is important to note that in this invention the slight change in space current, due to variations in level of the pilot current, operates a trigger-like relay, which, by altering the grid potential, causes a greater space current which is capable of operating the relay of an alarm circuit. Such an arrangement requires the contacts of relay 3 to carry very little current.

As soon as the repeater attendant receives the signal, he makes an adjustment of the gain of the amplifier C and at the same time opens the circuit of the armature and contacts of relay 3 by means of the switch 6. This effects a restoration of the signal, and if the adjustment made by him is sufficient, the signal will not be operated again when the switch 6 has been closed. Improper adjustment will cause another operation of the signal 5 and lead the attendant to carry out again the cycle of operations just described.

Fig. 2 represents another form of indicating circuit having certain features not disclosed in Fig. 1, which circuit is capable of being connected at the points *m*—*n* of the repeater circuit shown in Fig. 1. In Fig. 2, the contacts of the marginal relay 3 are not connected together as in Fig. 1 but are separately connected with the input circuit of the vacuum tube 2 upon opposite sides of the source of grid potential 7. The plate circuit contains two relays, 4 and 4′, each of which controls an indicating device or a pad selecting network. For the purpose of illustrating the invention, indicating devices, such as lamps, have been chosen, which lamps are preferably of different colors.

The relays are so adjusted that, when the plate current is of normal value, relay 4′ will be energized and its armature will be attracted, while relay 4 will remain in its released position. A predetermined decline in value of the plate current releases relay 4′, and, in like manner, a predetermined rise in value operates relay 4.

When the arrangement of Fig. 2 is connected with the repeater circuit of Fig. 1, and the pilot current exceeds a predetermined limit, relay 3 will be operated so that its armature closes its right-hand contact. This connects the grid of the tube directly with the filament thereof and causes a large increase in the plate current of the tube. This current will energize relay 4, thus attracting its armature, and at the same time holding the armature of relay 4′. The attraction of the armature of 4 closes the circuit connected with the lamp 5 and indicates a predetermined rise in level above normal. The holding of the armature of 4′ keeps open the circuit of the lamp 5′, so that no indication is given thereby. If, on the other hand, due to circuit conditions the pilot current falls below its normal value, the space current of the tube 2 will likewise decrease and the armature of relay 3 will close its left-hand contact. This effectively shunts the secondary winding of the input transformer and permits the source 7 to cause a greater reduction of space current than normal. This reduction causes the release of relay 4′ which closes the circuit connected with its armature and

contact, and causes the lighting of the lamp 5′, which indicates to the attendant that the level has fallen to a fixed limit.

The arrangement shown in Fig. 3 differs from those of the preceding figures in that it provides a feed-back circuit between the plate and the grid whereby oscillations are set up under a certain circuit condition and an increase of the plate current is obtained thereby. In the arrangement shown in Fig. 3 (which is adapted to be connected with the repeater circuit of Fig. 1 at the points *m*—*n*) an increase in the pilot current will cause relay 3 to attract its armature, thereby connecting the plate circuit with the grid circuit through the condenser 8 and the resistance 9. This causes the tube to oscillate, and increases the plate current. The armature of relay 4 will then be attracted, thus closing the circuit of the alarm device. If, on the other hand, the pilot current drops below a predetermined level, the armature of relay 3 will touch its left-hand contact, thereby shunting the secondary winding of the input transformer. This will cause a reduction in the plate current, thereby releasing relay 4′ and giving an indication of the condition that exists.

In the arrangements heretofore shown, a manually operated key is employed in the circuit of the marginal relay to open the circuit controlled by the said relay each time an adjustment of the repeater has been made, so that the indicating device will be in condition to show whether such adjustment is of sufficient magnitude to restore the pilot current to normal. In the arrangement shown in Fig. 4, not only are the shunt-circuits controlled by the marginal relay 3, opened automatically but also the gain of the repeater is adjusted automatically by means of the relay combinations and the pads shown at the right-hand side of the figure. In the figure, the contacts of relay 3 are connected with the input circuit of tube 2 in the same way as in Fig. 2. The armature connection, however, is effected through the contacts and armatures of the slow-acting relays 10 and 11. The purpose of the latter relays will be apparent when the operation of the system is described. The plate circuit of the tube includes the relays 4 and 4′ which function to control the operation of the pad-selecting system shown at the right-hand side of the drawing. This selecting equipment is represented by 3 groups of relays, designated X, Y, and Z, but it is to be understood that any number of groups may be employed, depending upon the degree of refinement desired in adjusting the gain of the repeater. Group X comprises the relays 12, 13, and 14, the latter of which controls the connection of pad 15 with the circuit 16 over which current is flowing toward the amplifier C; the group Y includes the relays 16 to 18, inclusive, and the pad 19; and the group Z includes relays 20 to 22, inclusive, and the pad 23.

When the pilot current, impressed upon the input of tube 2, is of normal magnitude, the current flowing in the plate circuit of that tube will energize relay 4′, and will partly energize relay 3 but not relay 4. The armatures of those relays will be in the positions shown in the drawing. If the pilot current increases to a predetermined value, relay 3 will be fully energized, causing its armature to touch its right-hand contact, thus establishing a shunt across the input circuit of the tube between the points *a* and *b*, the said shunt including the contacts of relays 10 and 11 and also the right-hand contact of relay 3. This produces a large increase in the plate current which operates relay 4. The closing of the contact of that relay establishes a circuit that includes battery 31 and the windings of relays 12, 14, 13, and 11. Relay 14, by its operation, connects the pad 15 across the input of the amplifier C, thereby tending to reduce in magnitude the currents of all channels passing through C. The operation of relay 13 locks up the other relays of group X over a circuit extending from battery 31, over the upper contact of relay 13, contact 24 of relay 16, and the contact of relay 4′. Relay 12, which is slow acting, then removes the first ground from the relays of group X, and connects the relays of group Y to point B by a path that includes the lower contact 25 of relay 16, contact of relay 12, and contact of relay 4, thereby preparing the way for the connection of another pad with the input of the amplifier C.

After the group of relays, designated X, have operated, relay 11 will be energized, thereby opening the shunt that has previously been established between points *a* and *b* of the input circuit of the tube 2. The opening of this shunt path restores the circuit to normal, and if the pad 15 is sufficient to reduce the pilot current to its normal value the armatures of relays 3 and 4 will be opened. The opening of relay 4 causes the armature of relay 11 to drop back. If, however, the pilot current remains above normal, relay 3 will continue to attract its armature to its right-hand contact, thereby reestablishing the shunt between *a* and *b* when the armature of relay 11 falls back. The relay 4 will again be energized by the resulting increase of plate current and a circuit will be established from battery 31 to the ground on the winding of relay 11, the circuit including the windings of relays 16, 18, 17, contact 25 of relay 16, the upper contact of relay 12, the contact of relay 4, and the winding of relay 11. Relay 18 will connect the pad 19 across the input of the amplifier C with

which the pad 15 is also connected. Relay 17 will lock up the relays of the group Y over a circuit that includes the contact of relay 17, contact 26 of relay 20, contact of relay 4′, and the winding of relay 10. When relay 16 operates, its armature opens contact 24 and closes contact 27, thereby connecting relay 13 to ground over a path that includes contact 27. The lower armature of relay 16 closes contact 28, thereby establishing a path to point B for the relays of group Z. Upon the completion of the operation just traced, relay 11 will be energized, thereby opening the shunt between the points *a* and *b*, and if the pilot current has been reduced to normal relay 3 will be only partly energized, so that its armature will return to a position midway between its contacts. Relay 4 will be deenergized, which opens the circuit of relay 11, thus permitting its armature to fall back. The relays of the groups X and Y continue to be energized and the pads 15 and 19 remain connected across the input of the amplifier C.

If the pilot current drops below normal to a predetermined extent, the plate current of the tube 2 will diminish, thus permitting the armature of relay 3 to touch its left-hand contact. This establishes a shunt across the points *a* and *c*, and results in a further reduction of the plate current, which causes the armature of the relay 4′ to fall back. The releasing of the relay 4′ opens the circuit of the relays of group Y, thereby removing the pad 19 from the input of the amplifier C. The relays of group X will not be released until relay 16 of group Y operates to open contact 27, which will not occur as soon as 17 and 18 operate because relay 16 is of a slow release type.

After the pad 19 has been removed from the input circuit of the amplifier it is desirable to open the shunt across the points *a* and *c* of the tube 2 in order to determine whether such removal has been sufficient to bring the pilot current up to its normal value. The releasing of relay 4′ opened the circuit of relay 10 and permitted its armature to drop back. This opened the shunt across the points *a* and *c* so that when the pad 19 has been removed from the input circuit the indicating device is in a position to again test the sufficiency of the change. If the pilot current is now of satisfactory magnitude, relay 4′ will now close, thereby establishing ground through contact 24 of relay 16 whenever this relay releases, and no further operations will take place. If, however, the pilot current is still below normal, relay 3 will remain deenergized, thereby shunting the input circuit between the points *a* and *c*. It will be remembered that while this shunt path was open the normal space current flowed through the winding of relay 4′ thus causing it to close and causing relay 10 to attract its armature. As soon as the shunt has been reestablished, due to the continued abnormally low pilot current, the plate current will be again reduced, thus releasing relay 4′. By this time relay 16 will have released, thus establishing the ground of the relays of group X through the contact 24. The releasing of relay 4′ in turn releases the relays of group X and removes the pad 15 from the circuit. The releasing of relay 13 will cause the operation of the alarm 29, and, in like manner, after all of the pads have been cut into the circuit, an alarm 30 will be operated. In order to maintain battery on relay 10 when relay 13 releases, so that the circuit may remain in operative condition, point A is connected through the alarm device 29 to battery 31 by the release of the lower armature of relay 13.

The arrangement shown in Fig. 4 automatically controls the connection of the pads with the input side of the amplifier, whereby the level of transmission may be controlled. The pads herein referred to would preferably be artificial line or equalizer elements the attenuation of which would vary with respect to frequency. While the form of the marginal relay control device shown in Fig. 4 is the same as that shown in Fig. 2, with the arrangement for automatically opening the shunt path, it will be apparent that the other forms of marginal relay devices may also be used with the said modification for the purpose of automatically controlling the connection of the pads shown in Fig. 4.

Although the invention has been shown in certain forms, it is to be understood that such showing is purely schematic and that it is capable of embodiment in other forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In an electrical controlling system, the combination with a vacuum tube of an output circuit including a source of plate voltage and a marginal relay, an input circuit including a source of negative biasing current and a source of alternating current, and a plurality of shunts, controlled by the said marginal relay, and adapted for connection across the said input circuit, to shunt one or both of said sources of current.

2. In an electrical controlling system, the combination with a vacuum tube rectifier having input and output circuits, of a marginal relay connected with the output circuit of the said rectifier, a plurality of sources of potential connected with said input circuit, and a plurality of shunts adapted to be effectively connected across the input circuit of said rectifier by the said relay to shunt one or both of said sources of potential.

3. In an electrical controlling system, the combination with a vacuum tube rectifier having an input circuit including a source of

negative biasing current, a source of alternating current to be rectified, an output circuit having a source of plate voltage, and means also connected with the said plate circuit to effectively shunt the said source of alternating current alone, or the said source of alternating current together with the source of negative biasing current.

4. In an electrical controlling system, the combination with a vacuum tube rectifier having an input circuit including a source of negative biasing current, a source of alternating current to be rectified, an output circuit having a source of plate voltage, means also connected with the said plate circuit to effectively shunt the said source of alternating current alone, or the said source of alternating current together with the source of negative biasing current, and means also connected with the said plate circuit responsive to the maximum current created by the shunting of the said source of alternating current together with the source of biasing current, or to the minimum current resulting from the shunting of the said source of input current alone.

5. In an electrical controlling system, the combination with a vacuum tube rectifier having an input circuit containing a source of negative biasing current, and an output circuit containing a source of plate voltage, a source of alternating current, the level of which may vary with time, coupled with the said input circuit, a marginal relay connected with the plate circuit, and means controlled by the said relay either to effectively shunt the said source of alternating current alone or to shunt that said source together with the source of negative biasing current.

6. In an electrical controlling system, the combination with a vacuum tube rectifier having an input circuit containing a source of negative biasing current, and an output circuit containing a source of plate voltage, a source of alternating current, the level of which may vary with time, coupled with the said input circuit, a marginal relay connected with the plate circuit, means controlled by the said relay either to effectively shunt the said source of alternating current alone or to shunt that said source together with the source of negative biasing current, and relays connected with the plate circuit responsive to currents representing the upper level and the lower level, respectively, of the said plate current resulting from the shunting operations.

7. In a pilot channel control system, the combination with a vacuum tube rectifier having a source of negative biasing current for the grid thereof and a source of plate voltage connected with the plate thereof, a source of alternating current representing a pilot channel also connected with the said grid, the said source having an amplifier connected therewith, a marginal relay connected with the plate circuit of the said tube, the said relay governing the establishment of a shunt across the said source of alternating current alone, or across that said source together with the source of negative biasing current, control relays connected with the plate circuit, one of which responds to the upper level of the plate current resulting from the shunting of the source of alternating current together with the source of negative biasing current, and the other relay responding to the lower level of plate current resulting from the shunting of the source of alternating current alone, a plurality of relays governed by the said control relays to cut in or cut out pads across the input of the said amplifier, and a relay individual to and connected with each control relay to open the shunt across the input of the said rectifier each time the pad selecting relays have operated.

8. In a system such as set forth in claim 3, the method which consists in utilizing a slight fall in the plate current resulting from the fall in level of the input current to automatically shunt the source of input current to produce a much greater decrease in the plate current of the rectifier.

9. In a system such as that set forth in claim 3, the method which consists in utilizing a slight rise in the plate current resulting from an increase in level of the input current to automatically shunt the source of input current together with the source of biasing current to produce a greater increase in the plate current of the rectifier.

10. In a system such as that set forth in claim 3, the method which consists in utilizing a slight fall in the plate current resulting from the fall in level of the input current to automatically shunt the source of input current to produce a greater decrease in the plate current of the rectifier, and in utilizing a slight rise in the plate current resulting from an increase in level of the input current to automatically shunt the source of input current together with the source of biasing current to produce a greater increase in the plate current of the rectifier.

11. In an electrical controlling system, the combination with a vacuum tube rectifier having input and output circuits, of a marginal relay connected with the output circuit of the said rectifier, a plurality of sources of potential connected with the said input circuit, and a shunt adapted to be effectively connected across the input circuit of the said rectifier by the said relay to shunt one of the said sources of potential.

12. In an electrical controlling system, the combination with a vacuum tube of an output circuit including a source of plate voltage and a marginal relay, an input circuit including a source of negative biasing current and a

source of alternating current, and a shunt controlled by the said marginal relay adapted to shunt the source of alternating current whenever the latter relay operates.

In testimony whereof I have signed my name to this specification this 29th day of September, 1928.

ALLEN CARPE.