

June 1, 1948.

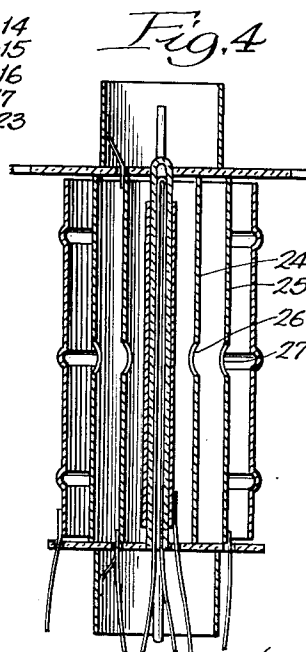
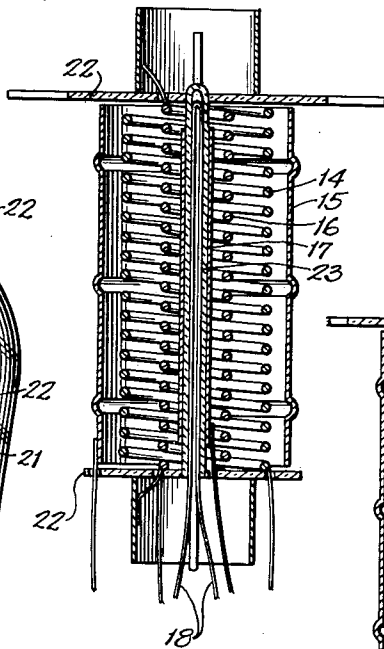
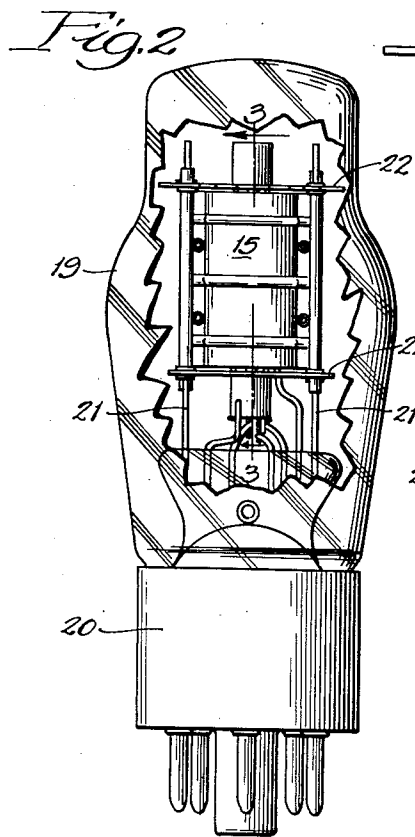
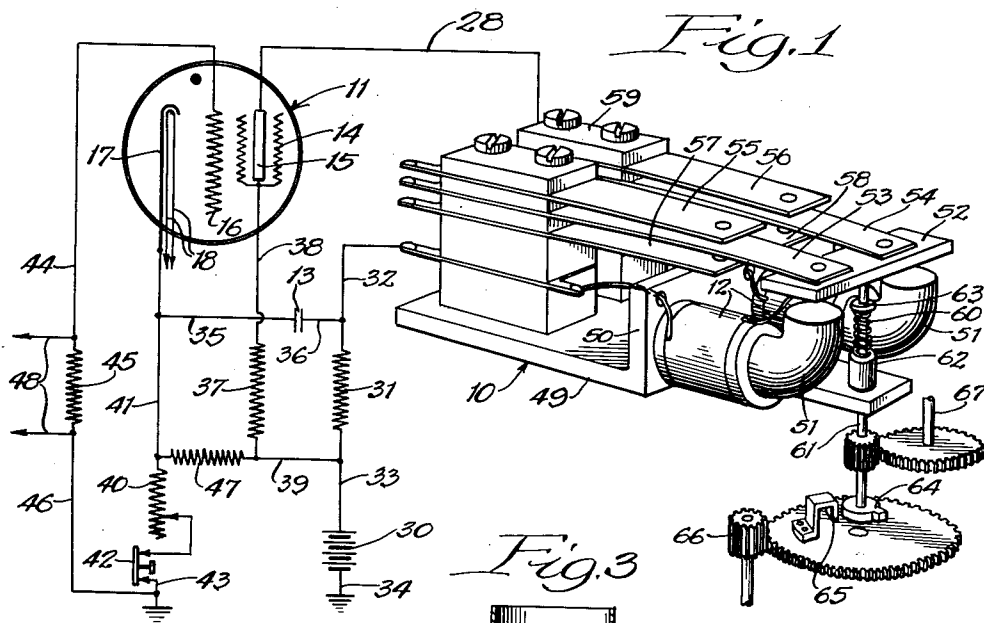
W. J. O'BRIEN

2,442,430

GAS TUBE CONTROLLED RELAY CIRCUITS

Filed April 10, 1941

3 Sheets-Sheet 1



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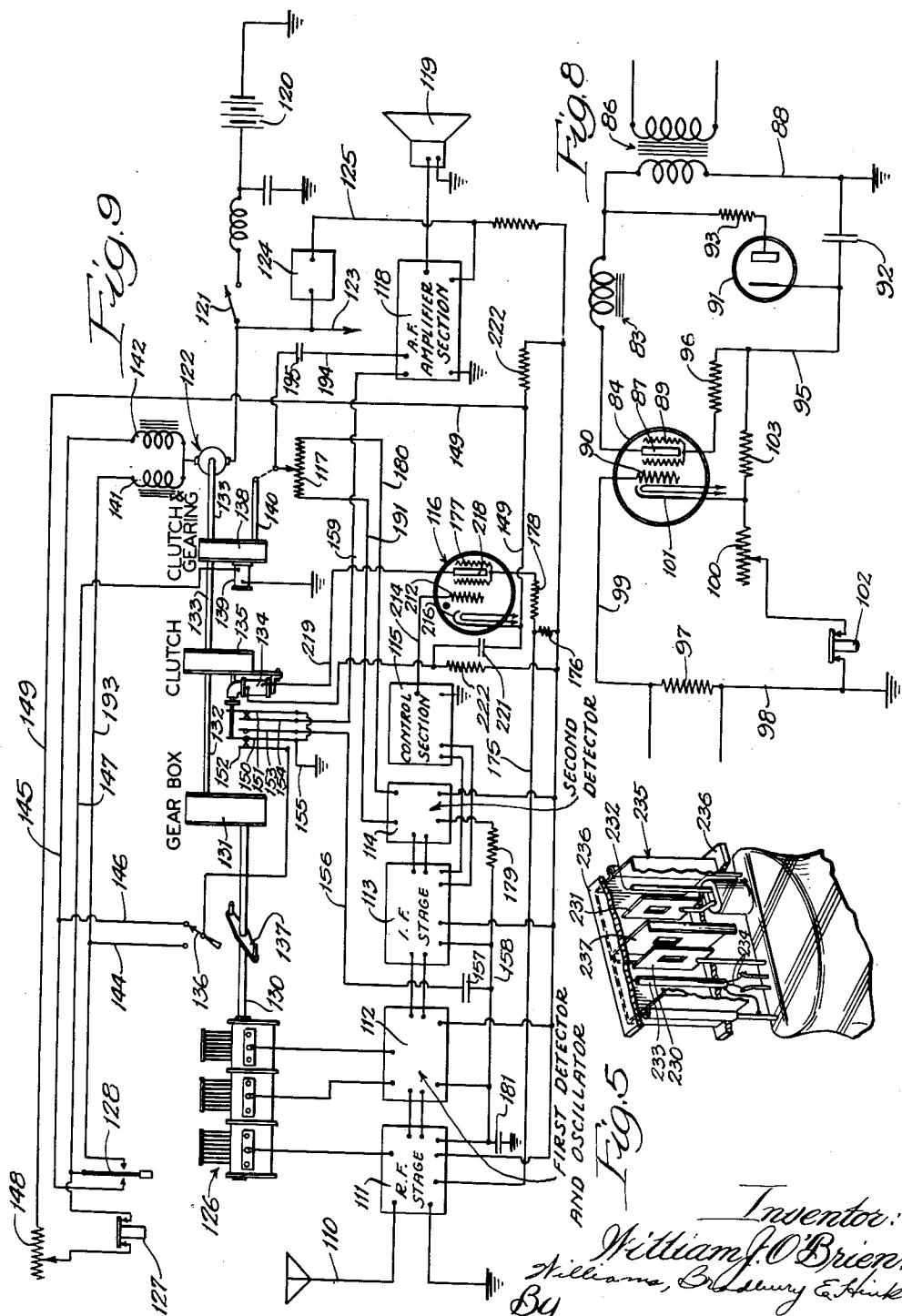
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GAS TUBE CONTROLLED RELAY CIRCUITS

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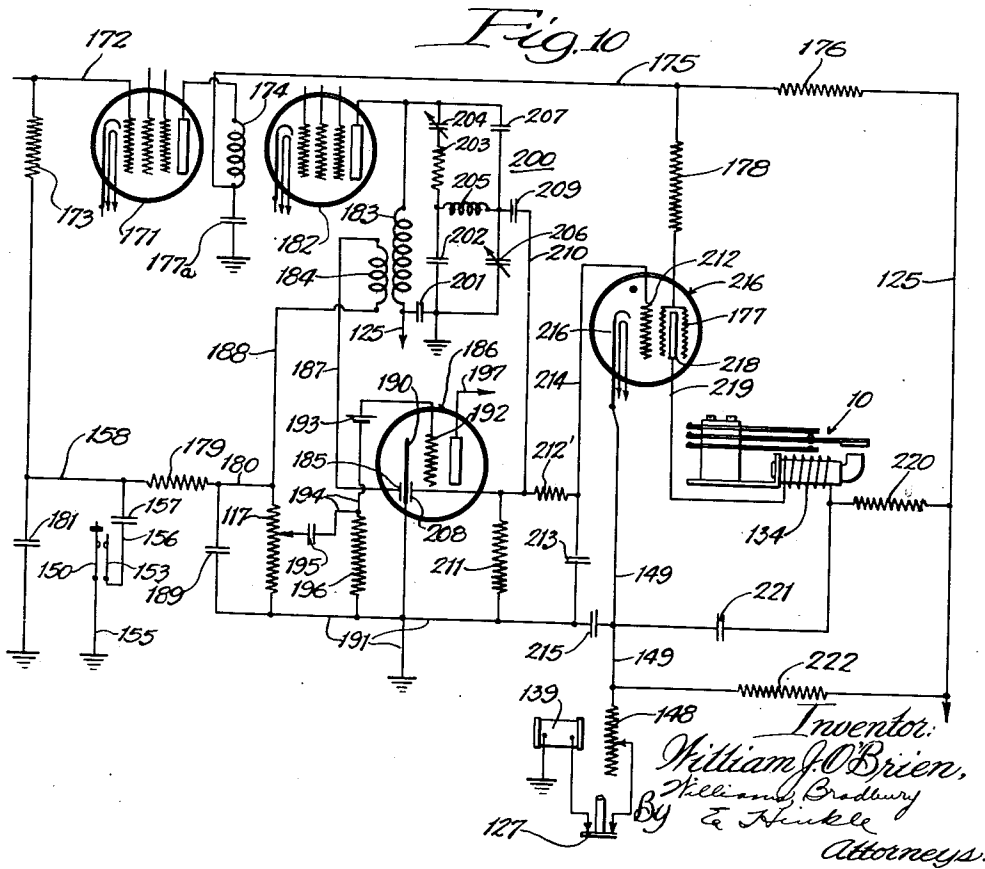
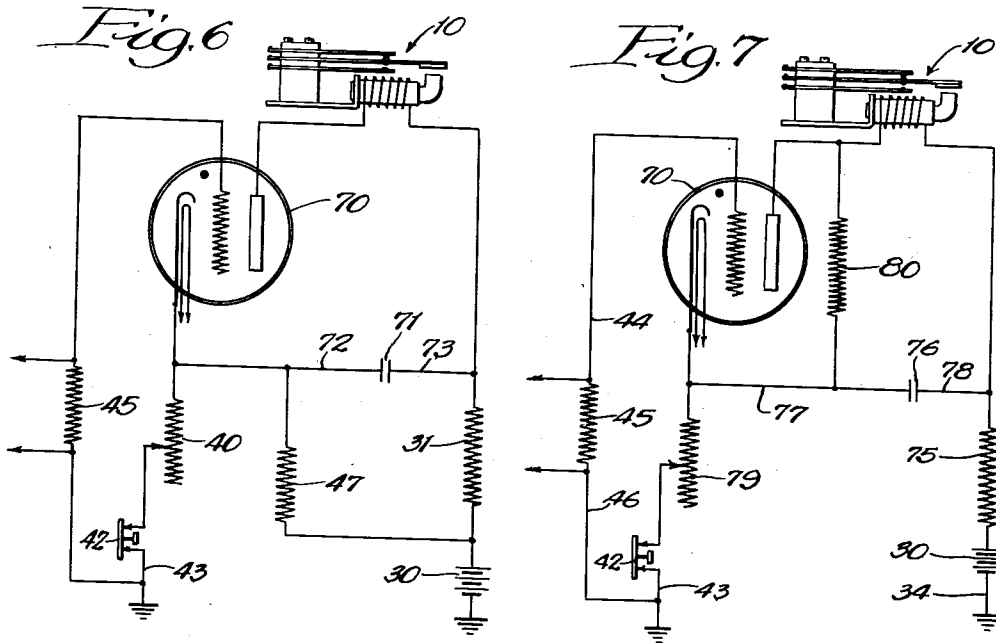
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GAS TUBE CONTROLLED RELAY CIRCUITS

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UNITED STATES PATENT OFFICE

2,442,430

GAS TUBE CONTROLLED RELAY CIRCUITS

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Application April 10, 1941, Serial No. 387,908

22 Claims. (Cl. 175—320)

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The present invention relates to improvements in circuits including fast operating, low impedance relays, and more particularly to circuits wherein said relays are controlled by means of gas tubes.

The present invention relates also to the provision of new and improved circuit arrangements for preventing deleterious effects resulting from oscillations in circuits including gas tubes, fast operating, low impedance relays, and condensers utilized to provide the relays with current impulses to increase the rapidity of operation thereof.

This invention relates also to the provision of new and improved gas tubes, and more specifically to the provision of gas tubes having an auxiliary anode by means of which the gas in the tube is maintained ionized and the tube conductive in spite of fluctuations in anode potential to values below that at which the gas would be deionized and the tube rendered non-conductive.

This invention relates also to the provision of new and improved control circuits including fast operating relays and gas tubes energized for relatively long periods of time, wherein the consumption of power is reduced without sacrificing efficiency or speed of operation of the relays.

The present invention further relates to the provision of a new and improved stop-on-carrier control for radio receivers, certain forms of which are disclosed and claimed in the Edward F. Andrews patents, Nos. 2,262,218, granted November 11, 1941, and 2,326,737, granted August 7, 1943, and my co-pending applications, Serial Nos. 387,907, filed contemporaneously herewith, 681,183, filed July 3, 1946, 683,312, filed July 13, 1946, and 754,194, filed June 12, 1947, of which the latter is a division of the present application.

The present invention is illustrated in connection with special types of gas tubes with an auxiliary anode, which tubes are also disclosed and claimed in my copending application Serial No. 754,194, filed June 12, 1947.

Other aspects and advantages of the present invention will become apparent from the ensuing description, in the course of which reference is had to the accompanying drawings, in which:

Fig. 1 is a diagrammatic representation of a control circuit for a fast operating relay embodying the present invention;

Fig. 2 is a side elevational view, partly broken away, of a gas tube which may be used in the circuit of Fig. 1;

Fig. 3 is a fragmentary vertical cross-sectional view taken along the line 3—3 of Fig. 2;

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Fig. 4 is a view similar to Fig. 3 of another embodiment of the tube;

Fig. 5 is a fragmentary perspective view of a further embodiment of a tube;

Figs. 6 and 7 are views similar to Fig. 1 of other embodiments of the present invention wherein gas tubes of conventional construction are utilized;

Fig. 8 is a view similar to Fig. 1 illustrating a further embodiment of the invention;

Fig. 9 is a diagrammatic representation of a standard automobile superheterodyne receiver, in connection with which the present invention has been utilized; and

Fig. 10 is a diagram showing the details of a portion of the circuit of Fig. 9.

The circuit arrangement illustrated in Fig. 1 comprises a relay 10 whose energization is controlled by a gas tube 11. In order to effect fast operation of the relay, it is constructed to have a low impedance and low inductance winding so that with a given voltage a large current flow through it will be established in a short length of time. The low impedance and inductance are obtained by utilizing low resistance wire and a winding having relatively few turns. Reduction of the number of turns reduces the actuating force exerted by the relay as the number of ampere turns is reduced (assuming the voltage supplied to the relay to remain the same), and to compensate for this reduction and to obtain fast operation the relay winding, indicated by reference character 12, is supplied with a considerable current impulse upon energization by means of a condenser 13 discharging through the winding when tube 11 is rendered conductive, the discharge flowing through the tube. This discharge of a large current by the condenser occurs rapidly because of the low impedance of the relay winding and of the gas tube, thereby to effect fast operation of the relay. However, the circuit including the relay winding, tube and condenser has a tendency to oscillate because of its low resistance, and the oscillations reduce the anode potential of the tube and are likely to cause deionization of the gas in the tube and to render the tube non-conductive. These fluctuations are prevented from deionizing the gas in accordance with the present invention, as illustrated in Fig. 1, by providing the tube with an auxiliary anode supplied with a potential sufficient to maintain ionization of the gas in spite of fluctuations in anode potential.

In addition to the auxiliary anode, indicated by reference character 14, the tube is provided with an anode 15, a grid 16, an indirectly heated cathode 17, and a cathode heater 18. The physi-

cal construction of the tube may take various forms, three forms being shown in Figs. 2 and 3, 4, and 5. In the embodiment of Figs. 2 and 3 the tube is shown with the usual glass envelope 19 and base 20. The envelope surrounds the previously enumerated elements of the tube and contains an ionizable gas. The anode 15 is cylindrical in shape and is supported in conventional manner by a pair of spaced posts 21 between insulating plates 22. The cathode 17 is cylindrical in shape and supported concentrically with respect to the anode by a refractory post 23 in which the cathode heater 18 is embedded. The grid 16 is a helical wire located in proximity to the cathode and concentrically arranged with respect to both the cathode and anode. The auxiliary anode 14 is also a helical wire, it being located in this embodiment in proximity to the anode and concentric with respect to the other tube elements. Suitable leads are brought from the tube elements to prongs on the tube base 20. All the tube elements are of substantially the same length in order that the tube may operate in its intended manner, as will be described shortly in connection with Fig. 1.

The tube illustrated in Fig. 4 is similar to that just described except that the grid and auxiliary electrode are constituted by metallic cylindrical members 24 and 25 provided with two or more aligned apertures 26 and 27, respectively.

The tube illustrated in Fig. 5 differs from those previously described mainly in that the grid and auxiliary anode are constituted by apertured flat structural elements 230 and 231, respectively, and the anode by a cylindrical wire 232. These elements and the cathode 233 and cathode heater 234 are surrounded by a grounded metallic shield 235, the open ends of which are closed by insulating plates 236. The shield comprises an apertured partition 237 located between the grid and auxiliary anode, thus defining two compartments, one for the cathode, cathode heater and grid and a second for the auxiliary anode and anode. The apertures in the grid, partition and auxiliary anode are in alignment with each other and the cathode and anode. A tube of this construction may be constructed simply and economically and possesses a high control factor.

Returning now to a further detailed description of the circuit of Fig. 1, it may be seen that the relay winding 12 is composed of two series connected coils. One terminal of the winding is connected directly to anode 15 by conductor 28 and the other to the positive terminal of a source of potential, such as battery 30, through a current limiting resistor 31 and conductors 32 and 33. The battery thus serves as a source of anode potential for the tube and as a source of energizing current for the relay. The other terminal of the battery is grounded through conductor 34.

The power consumption of the relay is reduced by the resistor 31 which is chosen to have a value such that once the relay is energized, the current flow therethrough is only sufficient to maintain the relay in its operated position.

The current impulse supplying condenser 13 is connected to the cathode by conductor 35 and to a point intermediate the relay and resistor 31 by a conductor 36. It is thus connected so as to be charged by battery 30 when the tube is non-conductive and to discharge through the tube and relay when the tube is conductive.

The auxiliary anode is supplied with a potential sufficient to maintain the gas ionized and the tube conductive in spite of fluctuations in anode

potential from a suitable source, preferably the battery 30, through a current limiting resistor 37 and conductors 38, 39 and 33.

Grid-bias voltage is obtained through the use of an adjustable resistor 40 connected between the cathode and ground. This resistor is connected to the cathode by conductor 41 and to ground through switch 42 and ground connection 43. The grid is connected to ground through conductor 44, resistor 45 and conductor 46. A grid-bias voltage sufficient normally to maintain the tube non-conductive is obtained by connecting the cathode end of bias resistor 40 to the battery through a bleeder resistor 47.

The tube is rendered conductive by rendering the grid more positive and this can be accomplished as by applying a positive signal voltage across the terminals of resistor 45 by means of conductors 48.

The relay may be utilized to control circuits or mechanisms and the like. In stop-on-carrier controls it is utilized to control circuits and a clutch, as indicated in Fig. 1. The relay may also take various forms, that shown in Fig 1 being of a novel construction requiring but little space. It comprises a metallic base 49 having an upturned flange 50 at its front end. The coils 12 together with their cores 51 are secured to the flange. The cores have upturned ends above which is supported an armature 52 mounted at the ends of contact carrying switch blades 53 and 54. The switch blades are biased upwardly normally to complete circuits through fixed switch blades 55 and 56 and are movable downwardly upon energization of the relay to complete circuits through switch blades 57 and 58, respectively. The switch blades as well as the terminals to which conductors 28 and 32 are attached are mounted at the rear of base 49 by spacer blocks 59 and suitable bolts. The spacer blocks are made of insulating material to insulate the terminals and switch blades from one another.

Switch blades 53 and 54 are biased upwardly by a spring 60 that serves also to maintain the clutch engaged whenever the relay is deenergized. The biasing is effected through a combined clutch operating and power transmitting rod 61 slidably and rotatably mounted in a supporting bearing 62 forming part of the base member. The spring is held between the bracket and a washer 63 secured to the rod above the bracket.

The clutch comprises a pair of selectively engageable elements 64 and 65, the former of which is secured to rod 61 and the latter of which is driven from a suitable source of motive power, such as an electric motor, by gear 66. When the clutch is engaged, as indicated, rod 61 is rotated to impart movement to a driven gear 67 used to drive tuning condensers in stop-on-carrier controls, as will be explained more fully in connection with Figs. 9 and 10. It should be understood, however, that while the circuit described above is particularly adapted for stop-on-carrier controls for radio receivers, it may be used for other purposes, as may be noted from the following description of the operation of the relay and its control circuit.

In the description of the operation it is assumed that the tube is non-conductive by reason of the bias applied to grid 16 and that, as a result, relay 10 is deenergized. At this time the grid is biased negatively by reason of current flow through resistors 40 and 47, which are connected across the battery 30 through conductors 33 and 39, switch 42 and ground connections 34 and 43.

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The condenser 13 is fully charged by reason of its connection to the battery and battery potentials are applied to auxiliary anode 14 and anode 15.

The tube is rendered conductive and the gas therein ionized when a positive signal of sufficient strength is applied across resistor 45, after which the grid 16 becomes ineffective to exert further control. Immediately the tube is rendered conductive, current flows through the relay windings 12 and fast operation of the relay is insured by reason of its low resistance and impedance and the discharge of condenser 13 there-through. The low resistance series circuit including the condenser, tube and relay winding has a tendency to oscillate with the result that the potential applied to anode 15 may be periodically reduced to a value below the potential required to maintain ionization. In the ordinary three element gas tube the result would be the de-ionization of the tube, but in the described apparatus, the gas in the tube is maintained ionized by the auxiliary anode 14, which is connected to the battery through resistor 37 and which is not affected by the oscillatory circuit.

The relay is supplied with current sufficient to maintain it energized through a circuit including the battery, ground connections 34 and 43, the tube and resistor 31. Resistor 31 is so proportioned that it limits the relay current to the desired value. Resistor 37 is so proportioned that only a very limited amount of current flows through it, thereby reducing power consumption by preventing any substantial flow of current through it and the auxiliary anode in excess of that required to maintain ionization.

When it is desired to deenergize the relay and to render the tube non-conductive, it is necessary only momentarily to open switch 42. Opening of this switch results in the opening of both the anode and auxiliary anode circuits as the switch is in series with the tube and battery.

In the modification of Fig. 6 there is illustrated a somewhat different arrangement for preventing deionization of a conventional three element gas tube as a result of any tendency of the circuit to oscillate. This arrangement employs an electrolytic condenser which has a rectifying characteristic—that is, it permits substantial current flow in one direction and substantially prevents current flow in the opposite direction.

Referring now to Fig. 6, it may be noted that the three element gas tube is indicated by reference character 70. Its anode is connected to the battery 30 (the same reference characters are used to indicate elements of this embodiment corresponding to those in the embodiment of Fig. 1) through the winding of relay 10 and current limiting resistor 31. Grid bias voltage is obtained through the use of the bias resistor 40 which is connected between the cathode and ground and to the positive terminal of the "B" supply battery 30 through bleeder resistor 47. The grid is connected to ground through resistor 45 just as in the embodiment of Fig. 1.

The electrolytic condenser, indicated by reference character 71, is connected between the cathode and a point intermediate resistor 31 and the winding of relay 10 by conductors 72 and 73. The condenser thus connected will discharge through the tube and relay winding when the tube is rendered conductive. This connection comprises connecting the anode, which is ordinarily the oxide coated electrode of the condenser, to conductor 75

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73, and the metallic portion, ordinarily aluminum, to conductor 72.

When the condenser is connected as indicated and the tube rendered conductive by the application of a positive signal across resistor 45, the condenser immediately and rapidly discharges through the tube and relay winding, thus effecting rapid operation of the relay. However, when a reversal of current through the circuit comprising the condenser 71 and the low impedance relay 10 occurs as a result of its tendency to oscillate, a positive potential is impressed on the cathode of the condenser, i. e., the terminal connected to conductor 72, and a negative potential is impressed on the anode of the condenser, i. e., the terminal connected to conductor 73. Under these circumstances the condenser acts as a resistor having a low resistance. Direct current flows through the condenser and large losses occur which damp out the oscillation which tends to reduce the potential applied to the anode of tube 70. Thus, as a result of the unidirectional or rectifying characteristic of the electrolytic condenser, deionization of the gas tube after its original ionization by reason of the tendency of the series circuit including the condenser, tube and relay winding to oscillate, is prevented.

For use in connection with stop-on-carrier radio receivers, such as illustrated in Figs. 9 and 10, the condenser would have a capacity in the order of $\frac{1}{2}$ mf. It is desirable that the power factor of the condenser be as high as possible, and it should be formed to withstand, without breakdown, the anode potentials applied to tube 70. It has been found that a condenser of $\frac{1}{2}$ mf. capacity, having an effective resistance of 250 ohms at 120 cycles per second, operates satisfactorily, although a still lower resistance would be desirable. These values, it should be understood, are merely illustrative and not limitative of the invention.

The embodiment illustrated in Fig. 7 is somewhat similar to that illustrated in Fig. 6 in that it, too, employs the conventional three element gas tube. The condenser employed in this arrangement, however, is an ordinary paper condenser instead of an electrolytic condenser.

Referring now specifically to Fig. 7, it may be seen that the three element tube 70 has its anode connected to the positive terminal of battery 30 through the winding of relay 10 and resistor 75. The paper condenser 76 is connected by conductors 77 and 78 to the cathode and to a point intermediate resistor 75 and the relay winding. The grid of the tube is provided with biasing potential by reason of current flowing through an adjustable biasing resistor 79 and a bleeder resistor 80, the grid being connected as in the previously described embodiments to ground connection 43 through resistor 45 and conductors 44 and 46. The normally closed switch 42 is interposed between resistor 79 and ground connection 43. The grid is normally biased negatively with respect to the cathode by reason of current flowing from the positive terminal of battery 30 through resistor 75, winding of relay 10, resistor 80, conductor 77, resistor 79, switch 42, and ground connections 43 and 34.

In this embodiment the resistance of resistor 75 (which corresponds to resistor 31 of the previously described embodiments) is reduced, so that the flow of current through the relay winding when the tube is ionized is greater than the corresponding current flow in the embodiment of Fig. 6.

By thus reducing the value of the resistor 75, the flow of current through the relay when the tube is ionized is increased. Thus, if the tendency for the circuit, including the relay 10, the condenser 76, and the tube 70 to oscillate, is not too great, this tendency will not reduce the plate current sufficiently to bring the plate voltage below ionizing potential. The current which flows through the resistor 47 in the circuit of Fig. 6, will flow through the tube 70 in the arrangement of Fig. 7, thus providing a larger plate current and requiring a current reversal resulting from oscillation of a higher value in the circuit of Fig. 7 before the voltage on the plate falls below the ionization voltage. When the tube is deionized, a sufficient flow of current through the resistor 79 is maintained through the resistor 75 and the resistor 80, which together have approximately the same value as the resistor 47 in the previous embodiment. It will thus be seen that by the location of the resistor 80 in Fig. 7 and lowering the resistance of resistor 75, the tendency to deionize can be resisted to a greater extent, with the same total bleeder current, than in the circuit of Fig. 6, where oscillation is prevented by means of the rectifying characteristic of the electrolytic condenser.

The relay may be released by opening switch 42, which serves to disconnect the relay winding entirely from the battery 30, i. e., it breaks the circuit through both tube 70 and resistor 80.

In Fig. 8 is illustrated a further embodiment of the present invention in which an alternating current relay 83 is controlled by a gas tube 84 corresponding to the tube 11 of Fig. 1, but in which the source of energy is an alternating current source rather than a battery. The alternating source (not shown) is connected to the primary winding of transformer 86. The secondary winding has one terminal connected to the anode 87 of the tube through the relay and its other terminal to ground through conductor 88.

The auxiliary anode 89 is provided with a substantially constant positive potential to maintain the tube ionized after initial ionization has been effected as by application of a suitable signal to grid 90. This potential is supplied from a rectifier tube 91 having a filter condenser 92 connected thereacross. The anode of tube 91 is connected to the secondary through resistor 93, while the cathode is connected to the auxiliary anode 89 of tube 84 through conductor 95 and resistor 96. The grid 90 is connected to ground through resistor 97 and conductors 98 and 99. The grid bias voltage is obtained through the use of an adjustable bias resistor 100 connected to the cathode 101 and to ground through normally closed switch 102. The cathode end of the resistor is connected to the positive terminal of the rectifier through a bleeder resistor 103 and conductor 95.

Prior to the application of a positive signal voltage across resistor 97, tube 84 is maintained in a non-conductive condition by reason of the voltage drop across bias resistor 100. The voltage drop results from current flow through the resistor 100 which is connected across the rectifier tube 91 and filter condenser 92, conductor 95, resistor 103, resistor 100 and ground. At this time a substantially constant potential is applied to the auxiliary anode 89 and an alternating potential to the anode 87.

When a positive signal is applied across resistor 97 to decrease the negative bias on grid 90, the

tube is rendered conductive and the gas therein ionized. The tube is maintained conductive and the gas ionized, even though an alternating potential is applied to anode 87, by reason of the maintenance of a substantially constant positive potential on auxiliary anode 89. As a result, each half-cycle that a positive potential is applied to anode 87, current flows through relay 83 to maintain it in its operated position.

When it is desired to render the tube non-conductive and release the relay, it is necessary only momentarily to open switch 102.

The present invention is particularly adapted for stop-on-carrier radio receiver control. The use of a gas tube provided with an auxiliary anode results in a reduction of the number of tubes required. For instance, when used in a control of the type disclosed in my copending application one tube is eliminated. An application of the tube to this type of control is illustrated in Figs. 9 and 10. Referring now more particularly to Fig. 9, it may be noted this figure illustrates in block diagram form a standard automobile superheterodyne receiver to which the elements of the present invention have been added. For the most part the receiver and control circuits are those disclosed and claimed in my copending applications Serial Nos. 387,907, (now U. S. Patent No. 2,426,580), 681,183, 683,312, and 754,194, of which the latter is a division of this application and consequently only the portion of the circuit associated with the operation of the novel gas tube of the present invention will be described in detail hereinafter.

The receiver comprises an aerial 110, a radio frequency stage 111, a first detector and oscillator section 112, an intermediate frequency stage 113, a second detector section 114, a balanced bridge circuit section 115 forming part of the stop-on-carrier control and illustrated in greater detail in Fig. 9, a gas tube 116 also forming part of the stop-on-carrier control, a volume control potentiometer 117, an audio frequency amplifier section 118, and a loudspeaker 119.

Energy is supplied by a battery 120 adapted to be connected by a switch 121 to a tuning means operating motor 122 of the reversible type, a cathode heater circuit 123, and through an interrupter, step up transformer and "B" supply unit 124 to a "B" supply line 125. The "B" supply line leads to the various receiver portions and the stop-on-carrier control in a manner to be considered in greater detail hereinafter. The switch 121 is illustrated as a manually operable switch, but it may be operated by the motor 122, as set forth in my copending application.

The receiver is provided with the usual tuning condensers 126 which are actuated by motor 122. The tuning and receiver volume are controlled from a remote point, such as the dashboard of an automobile, by means of a tuning control switch 127, which is normally closed, and a volume control switch 128, which is selectively operable from a normal circuit breaking position (into which it is biased as by springs) to the left to increase the volume and to the right to decrease the volume.

Before describing in detail the various control means and control circuits, it may be well to review briefly the mode of operation of stop-on-carrier radio receiver control. In so far as tuning is concerned, the tuning is initiated manually at the remote point by momentary opening of switch 127. This sets the motor in operation to rotate the tuning condensers through a clutch

until the receiver is tuned to the carrier frequency of a station received with a certain intensity. The motor operates first in one direction over the entire range of movement of the condensers and then in the other, the direction of rotation of the motor being controlled by limit switches cooperatively associated with the condenser shaft. The same motor is used to control the volume but, when so used, it is selectively operable in either direction upon operation of switch 128 to either of its two positions. The volume control also includes a clutch through which the motor is selectively connected to the movable portion of the potentiometer 117 heretofore referred to.

Referring again to Fig. 9, it may be noted the condensers 126 are mounted for rotation with a shaft 130 connected by gears 131 to a shaft 132. The latter is adapted to be connected to a shaft 133 driven by motor 122 whenever a relay 134, associated with the stop-on-carrier control, is deenergized or released, at which time the clutch 135 is engaged. The relay and clutch may be constructed in accordance with those illustrated in Fig. 1, i. e., the relay is of the fast acting type and the clutch is operable by the relay armature. The energization of the relay is controlled by gas tube 116 and when it is energized, shafts 132 and 133 are disconnected to prevent further driving of the condensers whenever a station received with a certain intensity is tuned in. As already indicated, the tuning condensers are rotated first in one direction and then the other, the direction of rotation being reversed at the limits of their movement by a limit switch 136 operated by two arms or the like 137 suitably secured to condenser shaft 130.

The volume control includes a clutch 138 operable by a relay 139 and adapted whenever the relay is energized to interconnect shafts 133 and 140. The latter is operatively connected to the movable member of potentiometer 117.

The motor 122 has a pair of windings 141 and 142 selectively energizable to rotate the motor in opposite directions. Winding 141 is connected by conductors 143 to the right contact of volume control switch 128 and by branch conductor 144 to one of the two contacts associated with limit switch 136. Winding 142 is connected by conductor 145 to the left contact of the volume control switch and by a branch conductor 146 to the other contact of the limit switch. The movable blade of volume control switch 128 is connected by conductor 147 to one terminal of clutch operating relay 139, the other terminal of which is grounded. Thus, when switch 128 is operated to either of its two positions, the motor is energized simultaneously with energization of the relay, and, as a result, the movable member of the potentiometer is operated in one direction or the other to increase or decrease the volume of reception. The energizing circuit is completed in both cases through the armature of motor 122, switch 121, battery 120 and ground.

The remote tuning control switch 127, which is opened to initiate the tuning of another station, has one of its fixed contacts connected to conductor 147, this conductor serving, as will appear more fully hereinafter, as a ground connection, and its other fixed contact connected to adjustable resistor 148. A conductor 149 connects the latter to the cathode of gas tube 116 whereby the switch and resistor are included in the plate circuit of the stop-on-carrier gas tube 116.

The energization of motor 122 during tuning

is controlled by relay 134 which actuates switch blades 150 and 151. Switch blade 150 has associated with it a pair of relatively fixed switch blades 152 and 153, while blade 151 has associated with it a relatively fixed blade 154. Blades 150 and 151 are connected to ground by conductor 155. Blade 152 is connected to limit switch 136. Blade 153 is connected by conductor 156 and an AVC delay condenser 157 to an AVC conductor 158. Blade 154 is connected by conductor 159 to the grids of the tubes of the last stage of audio amplification, as in my copending application.

Thus, when relay 134 is deenergized, as it is during the actual tuning operation, the condensers 126 are connected to the motor shaft through clutch 135 and one or the other of the two motor windings is energized, the energizing circuit extending from the battery, through the motor armature, one or the other of windings 141 or 142 depending upon the position of limit switch 136, switch blades 152 and 151, and ground connection 155 back to the battery. At the same time conductor 156 and condenser 157 are disconnected from ground to provide fast acting AVC (as described in my copending application), while conductor 159 is connected to ground through switch blades 151 and 154 and conductor 155. Connection of conductor 159 to ground serves to connect the grids of the amplifier tubes of the last amplifier (audio-frequency) to ground to mute the loudspeaker during tuning. When the relay is energized by tube 116 becoming conductive, as now about to be described, the condensers are declutched from the motor and the latter deenergized. The motor is deenergized by reason of the opening of its energizing circuit by disengagement of blades 150 and 152. The AVC delay condenser 157 is simultaneously rendered effective to increase the time delay applied to the AVC voltage to a value necessary for proper reception during normal reception. Furthermore, the ground is removed from the audio-frequency amplifier tubes to condition these for normal operation.

The primary function of gas tube 116 is to control the energization of relay 134 so that it is substantially instantaneously operated when the receiver is tuned to the carrier frequency of a broadcast station. A further function of this gas tube, which is provided with an auxiliary anode 177, is to employ the high positive control voltage impressed on the auxiliary anode to prevent premature deionization of the tube as a result of oscillations in the plate circuit after it has been ionized. To fulfill this function, the gas tube 116 operates in a manner somewhat similar to that described in connection with Fig. 1. The relay is energized when the tube is rendered conductive and the latter is rendered conductive whenever the condensers 126 are rotated to tune the receiver to the carrier frequency of a broadcast station. To insure the tube being rendered conductive when the station is exactly tuned in, the tube is controlled in response to the tuning. In brief, the tube 116 is controlled by two potentials, one acting upon the auxiliary anode 177 and the other upon a grid 212. These potentials vary with the tuning of the receiver and render the tube conductive when the station is substantially exactly tuned to a carrier frequency.

Referring now more particularly to Fig. 10, this figure illustrates in greater detail certain portions of the apparatus illustrated diagram-

matically in Fig. 9. These portions are those from which the control potentials for the gas tube are obtained. Corresponding elements of Figs. 9 and 10 are indicated by like reference characters.

The radio frequency section 111 of Fig. 9 is shown to comprise a tube 171. Its control grid is coupled in conventional manner to the antenna by conductor 172 and connected to the AVC conductor 158 through resistor 173. Its anode is connected to the primary winding 174 of a coupling transformer which has not been illustrated in full but which is utilized to connect tube 171 to the first detector and oscillator section 112, which likewise has not been illustrated in Fig. 9. The terminal of winding 174 remote from the anode is connected to the "B" supply conductor 125 through conductor 175 and resistor 176 and to the auxiliary anode 177 of the gas tube through conductor 175 and a resistor 178. The same terminal is also by-passed to ground through condenser 177a.

The automatic volume control includes a resistor 179 connected between conductor 158 and a conductor 180 leading to a source of AVC voltage to be referred to later. It also includes a very small radio frequency by-pass condenser 181 connected between conductor 158 and ground and the previously mentioned AVC time delay condenser 157 that is controlled by switch blades 150 and 153 operated by relay 134.

The output from the radio-frequency section 111 is, as already described, supplied to the first detector and oscillator section 112 and thence to the intermediate frequency section 113. A portion of the output from the latter is supplied to the second detector stage 114 and a portion to the balanced bridge circuit and stop-on-carrier control section 115.

The intermediate frequency section comprises a tube 182, the anode of which is connected to one terminal of the primary winding 183 of a closely coupled transformer, the other terminal of which is connected to "B" supply conductor 125. A portion of the output of tube 182 is supplied to the detector stage through the secondary winding 184 of the transformer. One terminal of winding 184 is connected to the detector anode 185 of a multi-function tube 186 through conductor 187, and the other terminal by conductor 188 to volume control resistor 117, which is shunted by condenser 189 and together with the detector diode section of tube 186 serves also as the source of AVC voltage. The other terminal of resistor 117 is connected to the cathode 190 of tube 186 by a grounded conductor 191.

Tube 186 also serves as the first stage of audio-frequency amplification. Its control grid 192 is connected to the movable member of the volume control potentiometer through a suitable source of grid biasing potential, such as battery 193, conductor 194 and condenser 195. The grid is further connected to ground by a grid leak resistor 196. The amplified audio-frequency output is supplied to the succeeding stage of amplification through the anode connection 197. From the foregoing description it may be noted that the circuit of Fig. 10 does not correspond exactly to the block diagram of Fig. 9, in that in the latter the second detector and audio-frequency amplifier sections have been entirely separated. However, in a practical installation the tube 186 may well perform the dual function of a detector and amplifier, and it has been illustrated as doing this in Fig. 10. As a matter of

fact, and as will appear shortly, tube 186 is utilized also as a rectifier to provide a second control potential for gas tube 116.

The second control potential for gas tube 116 is obtained by means of a balanced bridge circuit 200 so constructed and arranged that it is critically responsive to the tuning of a station, as fully described in my copending applications Serial Nos. 387,907 and 683,312. This circuit comprises a first tank circuit including primary winding 183, condenser 201, condenser 202, resistor 203, and an adjustable condenser 204, whereby this circuit may be tuned to resonance at the intermediate frequency. The circuit also comprises a second tank circuit including condenser 202, inductance coil 205 and an adjustable condenser 206 for tuning this tank circuit to resonance at the intermediate frequency. The common connection of condensers 201, 202 and 206 is grounded. The common side of winding 183 and condenser 204 is connected to the common side of inductance 205 and condenser 206 through condenser 207.

The "output" from the bridge circuit is led to the anode 208 of the second diode rectifier section of tube 186 through a condenser 209 and conductor 210, and the rectified output appearing as a voltage drop across resistor 211 is supplied to the control grid 212 of gas tube 116 through a time delay circuit including the resistor 212' and condenser 213. The resistor 212' is in series with the grid lead 214 connecting the grid to the anode end of resistor 211. A radio frequency by-pass condenser 215 is connected across ground conductor 191 and the previously referred to conductor 149 leading to the cathode 216 of gas tube 116.

The relay 134 is connected to anode 218 of tube 116 by conductor 219 and the "B" supply is connected to the anode through the relay winding and current limiting resistor 220. A current impulse is supplied to the relay winding when the tube is rendered conductive by a condenser 221 having one terminal connected to the cathode 216 through conductor 149 and its other terminal connected to a point intermediate relay winding 134 and resistor 220. A bleeder resistance 222, connected at one end to the "B" supply and at the other end to the cathode lead 149, provides proper bias of the grid 212 when the tube is non-conductive, current flowing therethrough and the previously mentioned bias adjusting resistor 148.

The operation of the system of Figs. 9 and 10 is as follows:

The receiver is put into operation by closure of switch 121 which completes an energizing circuit for motor 122 extending from the battery 120, switch 121, the armature of motor 122, winding 142, conductors 145, 146, limit switch 136, switch blades 152, 150, and back to the battery through ground connection 155. Since clutch 135 is engaged when relay 134 is deenergized, as it is at this time, the motor rotates the condensers 126 first in one direction and then the other as the windings 141 and 142 are alternately energized by operation of limit switch 136 from one position to another by the arms 137 mounted on condenser shaft 130. This rotation of the condensers in alternate directions continues until the various tubes are heated and a broadcast station received. When a station is received, the gas tube 116 is rendered conductive and relay 134 immediately operated to declutch the condensers from the motor shaft and to deenergize the motor.

The gas tube is rendered conductive by the ap-

plication of an increased positive potential on the auxiliary anode 177 and by a reduction of the negative voltage impressed on the grid 212 from the diode 208. The auxiliary anode is made more positive as a result of the application of automatic volume control voltage to the grid of radio frequency tube 171. This control voltage is obtained from the second detector section of tube 186 and is applied to the grid of tube 171 through a circuit including conductor 180, resistor 179, conductor 158, resistor 173, and conductor 172. As a result of the application of this control voltage on the grid of tube 171, the plate current of this tube is decreased, with the further result that the voltage drop across resistor 176 is decreased and an increased positive potential is applied to the auxiliary anode 177, which is connected to the anode side of resistor 176. This connection is through resistor 178 which serves to limit current flow through the auxiliary anode. The voltage applied to the auxiliary anode rises rapidly as a station is being tuned in and is at a maximum when a station is exactly tuned in, as described at considerable length in my copending applications Serial Nos. 387,907 and 683,312.

The voltage thus applied to the auxiliary anode 177 when ionization occurs is considerably in excess of the ionizing potential, and remains so until the next station is tuned in by manually operating push button switch 127, to deionize tube 116. Thus, even though oscillation in the circuit, including tube 116, relay 134, and condenser 221, may reduce the voltage of the plate 218 below ionizing potential, ionization is maintained regardless of the potential on the plate by the potential on the auxiliary anode 177, which remains continuously above the ionizing potential until the switch 127 is again opened.

The balanced bridge circuit 200 supplies a signal to the diode 208 which increases as resonance with the station is approached until it is within about one kilocycle of resonance. From this point the amplitude of this signal falls rapidly, substantially to zero. Thus, a negative direct current voltage from the diode 208 is applied to the grid 212 of the gas tube 116, which increases as resonance is approached to a maximum negative value around one kilocycle from resonance, and then falls steeply substantially to zero at resonance. The reduction of this negative signal on the grid 212 when the station is correctly tuned in, together with the previously described increase in the positive voltage applied to the auxiliary anode 177, effects ionization of the tube 116 and stopping of the condensers 126 at a position correctly to tune in the station.

The primary winding 183 of the transformer associated with the intermediate frequency tube 182, condenser 204, resistance 203, condenser 202, and the mutual reactance of condenser 207 constitute a tank circuit tuned to the intermediate frequency. Condenser 202, inductance 205, condenser 206, together with the mutual reactance of condenser 207, also constitute a tank circuit tuned to the intermediate frequency. This circuit is excited through condensers 202 and 207. The coupling of these tank circuits through condenser 202 is inversely proportional to the frequency, while the coupling through condenser 207 energizing the inductance 205 is proportional to the frequency. Due to these opposing couplings and the parameters of the elements of the two tank circuits, the potential appearing across condenser 206 is substantially zero when a signal of exactly intermediate frequency is placed across the pri-

mary winding 183. In other words, the effect of the coupling occurring through condenser 207 produces a voltage drop across the inductance 205 which is equal and opposite to the voltage drop across condenser 202 at resonance. The value of resistance 203 is selected so as to bring the voltage across the condenser 202 180° out of phase with the voltage across inductance 205. Under these conditions there is substantially zero voltage across condenser 206 at resonance. In one aspect the arrangement of the coupled circuits may be considered as a balanced bridge circuit or a circuit providing zero coupling at resonance.

On the other hand, if the signal across the primary winding 183 is slightly out of resonance, there is no longer a balance between the opposing couplings—that is, the effect of one coupling is greater than that of the other, and a potential varying with the departure from resonant frequency exists across condenser 206. When the condensers 126 are approaching exact tuning, that is, one or two kilocycles away from exact tuning, a very large alternating current voltage is applied to the anode 208 of the rectifier section. The output of the rectifier appears as a voltage drop across resistor 214 and this voltage is applied through resistor 212' to the grid 212 of tube 216. The greater the voltage applied to the anode 208 of the rectifier, the more negative the grid 212.

The normal negative bias of the grid 212 due to the biasing resistor 148 and the bleeder resistance 222 is such as to render the tube conductive when the negative bias applied to the grid 212 from the balanced bridge circuit and rectifier approaches a minimum value (which occurs at resonance) so that when a station is exactly tuned in, the tube is rendered conductive by the conjoint actions of the less negative grid and more positive auxiliary anode 177. When the tube 116 is ionized, the plate to cathode resistance of the tube drops to a relatively low value. The condenser 221, which accumulates a high charge through its connection to the "B" supply through resistor 220 during the non-conductive period of tube 216, now discharges rapidly through the low impedance winding of relay 134, with the further result that the relay is instantly operated to declutch the condensers from the motor shaft and to deenergize the motor, thus stopping the condenser exactly on the carrier frequency as previously explained. The steady flow of current through the resistor 220, relay winding and tube, which are connected in series across the "B" potential, is sufficient to hold the relay in its operated position once it has been operated by the discharge of condenser 221.

As heretofore explained, the operation of the switch of relay 134 results also in the disconnection of conductor 159 from ground, thereby removing the ground connection from the last stage of audio-frequency amplification, and the output of the receiver can be heard through loudspeaker 119. The relay also effects connection of switch blades 150 and 153, with the result that condenser 157 is connected to ground to render it effective to increase the time delay applied to the automatic volume control voltage necessary for proper quality reception during audible reception of the signal.

When it is desired to tune in a different station, switch 127 is momentarily opened, thereby effectively breaking the plate circuit of the gas tube which results in the deenergization of relay 134. The motor is thereby energized and the

condensers are connected to the motor shaft. The tuning operation described above will be repeated and the motor again deenergized, and the condensers declutched upon reception of another signal exceeding a certain strength. The signal strength at which the tuning means will operate may be adjusted at will by means of the adjustable resistor 148 which serves to control the normal negative bias of the grid 212 of the gas tube.

The volume may be adjusted at any time by moving the volume control switch 128 either to the right or left, as indicated in Fig. 9. When moved into either of its circuit making positions, the one or the other of motor windings 141 or 142 is energized simultaneously with the energization of clutch operating solenoid 139. The energization of the solenoid results in the clutching of the volume control shaft 140 to the motor shaft 133, with the result that the movable member of the volume control potentiometer 117 is operated in the direction selected by operation of the volume control switch 128.

When it is desired to turn the receiver off, it is necessary only to open the power switch 121 which effectively cuts off the power to the radio receiver proper and to the various controls.

Although the invention has been disclosed in connection with specific details of preferred embodiments thereof, it must be understood that such details are not intended to be limitative of the invention except in so far as set forth in the accompanying claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a gas tube comprising a cathode, anode, grid, and an auxiliary anode, means for supplying said auxiliary anode with potential sufficient to maintain the ionization of the gas in said tube once the tube has been ionized, and means for supplying control potentials to both said grid and auxiliary anode for ionizing the gas in said tube.

2. In combination, a gas tube comprising a cathode, anode, grid, and an auxiliary anode, a source of anode potential, means for normally supplying said grid with a negative potential sufficient to prevent ionization of the gas in said tube, a source of positive potential for said auxiliary anode for maintaining ionization of the tube once it has been ionized, and means for varying both the grid and auxiliary anode potentials to ionize the gas in said tube.

3. In combination, a gas tube comprising a cathode, anode, grid, and an auxiliary anode, a source of anode potential, means for normally supplying said grid with a negative potential sufficient to prevent ionization of the gas in said tube, a source of positive potential for said auxiliary anode, and means for varying both the grid and auxiliary anode potentials to ionize the gas in said tube, the source of positive potential for said auxiliary anode being such that said auxiliary anode maintains ionization of the gas irrespective of variations in potential of said anode potential.

4. In combination, a low inductance relay, a gas tube comprising a cathode and anode in circuit with said relay, a source of anode potential connected to the anode of said tube through said relay, means for ionizing the gas in said tube to energize said relay, means including a condenser dischargeable through said relay and tube upon ionization of said tube for effecting quick opera-

tion of said relay, and means for thereafter maintaining said relay energized even though the anode potential decreases below a value sufficient to maintain ionization.

5. In combination, a fast acting relay of the type comprising a low impedance winding of relatively few turns of wire, a gas tube comprising an anode and cathode, a source of direct current having its positive terminal connected to said anode through said relay winding and its negative terminal connected to said cathode, a current limiting resistor in circuit between the positive terminal of said source and said winding, a condenser connected across said cathode and a point intermediate said resistor and relay winding, said condenser and relay comprising together with said tube a low resistance oscillatory circuit, means for ionizing the gas in said tube to discharge the condenser through said relay, and means for maintaining said relay energized despite fluctuations in anode potential caused by oscillation in said oscillatory circuit.

6. In combination, a fast acting relay of the type comprising a low impedance winding of few turns, a gas tube comprising an anode, cathode, grid, and auxiliary anode, said grid and auxiliary anode being spaced apart and located in proximity to said cathode and anode, a direct current source of anode potential, a circuit including a resistor and said relay winding connecting the positive terminal of said potential source to said anode, said resistor limiting the current flow through said winding to a value sufficient to maintain the relay in operated position after initial operation thereof, a circuit from the negative terminal of said potential source to said cathode including a grid biasing resistor, a condenser connected across said cathode and a point intermediate the source and relay winding for effecting initial operation of the relay by a current impulse when said tube is ionized, said condenser, relay winding, and tube constituting an oscillatory circuit, means associated with said grid for ionizing the gas in said tube, means including a connection from the positive terminal of said potential source to said auxiliary anode having interposed therein a current limiting resistor for preventing the oscillation in said oscillatory circuit from deionizing the gas in said tube, and means for deionizing the gas in the tube including a switch in circuit with said potential source.

7. In combination, a fast acting relay of the type comprising a low impedance winding of relatively few turns of wire, a gas tube comprising an anode, cathode, and grid, a direct current source of anode potential, a circuit including a resistor and said relay winding connecting the positive terminal of said potential source to said anode, said resistor limiting the current flow through said winding to a value sufficient to maintain the relay in operated position after initial operation thereof, a circuit from the negative terminal of said potential source to said cathode, an electrolytic condenser connected across said cathode and a point intermediate said relay winding and the positive terminal in such manner that when the tube is ionized it discharges through the tube and winding to effect initial operation of the relay and damps oscillation in the circuit including the tube, relay winding, and condenser, thus preventing deionization by reduction of anode potential due to oscillation, and means associated with said grid for ionizing said tube.

8. In combination, a fast acting relay of the

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type comprising a low inductance winding, a gas tube comprising an anode, cathode and grid, a direct current source of anode potential, a circuit including a resistor and said relay winding connecting the positive terminal of said potential source to said anode, said resistor providing a current flow through said winding above a value sufficient to maintain the relay in operated position after initial operation thereof, a circuit from the negative terminal of said potential source to said cathode including a grid biasing resistor, a condenser connected across said cathode and a point intermediate said relay winding and the positive terminal for effecting initial operation of the relay by a current impulse when said tube is ionized, said condenser, relay winding, and tube constituting an oscillatory circuit, a bleeder resistor connected between said cathode and a point intermediate said relay winding and anode, said resistor providing grid biasing current during deionization of said tube, means associated with said grid for rendering said tube conductive, and means including a switch in circuit with said potential source for deionizing said tube.

9. In combination, a gas tube comprising a cathode, anode, grid, and auxiliary anode, said grid and auxiliary anode being spaced apart and located in proximity to said cathode and anode, a relay winding, an alternating current source of anode potential, a circuit including said relay winding connecting said source to said anode and cathode, means including said grid for ionizing the gas in said tube, means including a direct current source, the positive terminal of which is connected to said auxiliary anode, for maintaining ionization of said tube, and a current limiting resistance in series with said auxiliary anode and said direct current source.

10. In combination, a gas tube comprising a cathode, anode, grid, and auxiliary anode, said grid and auxiliary anode being spaced apart and located in proximity to said cathode and anode, a relay winding, an alternating current source of anode potential, a circuit including said relay winding connecting said source to said anode and cathode, means including said grid for ionizing the gas in said tube, means including a direct current source, the positive terminal of which is connected to said auxiliary anode, for maintaining ionization of said tube, a current limiting resistance in series with said auxiliary anode and said direct current source, and means including a switch in circuit with said alternating current source for deionizing said tube.

11. In combination, a gas tube comprising a cathode, anode, grid and auxiliary anode, an alternating current source of anode potential connected to said anode, means including said grid for ionizing said tube, and means including an auxiliary anode for maintaining ionization of said tube when the alternating current potential applied to the anode is insufficient to do so.

12. In combination, a fast acting relay of the type comprising a low impedance winding, a gas tube comprising an anode, cathode, grid and auxiliary anode, said grid and auxiliary anode being spaced apart and located in proximity to said cathode and anode, a direct current source of anode potential, a circuit including a resistor and said relay winding connecting the positive terminal of said potential source to said anode, said resistor limiting the current flow through said winding to a value sufficient to maintain the relay in operated position after initial operation thereof, a circuit from the negative terminal of said

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potential source to said cathode including a grid biasing resistor, a condenser connected across said cathode and a point intermediate the source and relay winding for effecting initial operation of the relay by a current impulse when said tube is ionized, said condenser, relay winding and tube constituting an oscillatory circuit, means for impressing control potentials upon said grid and auxiliary anode for ionizing said tube, and means including a connection from the positive terminal of said potential source to said auxiliary anode having interposed therein a current limiting resistor for preventing the oscillation in said oscillatory circuit from deionizing said tube.

13. In combination, a fast acting low inductance relay, a gas tube comprising an anode and a cathode, a resistor, a source of current connected across the anode and cathode of said tube and having in series therewith the resistor and relay winding, a condenser connected across said cathode and a point intermediate said resistor and relay winding, whereby said condenser is adapted to discharge through the tube and relay upon ionization of the tube to effect quick operation of the relay, and said condenser, relay and tube comprising an oscillatory circuit, means for ionizing the gas in said tube to discharge the condenser through said relay, and means for maintaining said relay energized despite fluctuations in anode potential subsequent to the energization of said relay.

14. In combination, a fast acting low inductance relay, a gas tube comprising an anode, cathode, and grid, a direct current source of anode potential, a circuit including a current limiting resistor and said relay winding connecting the positive terminal of said potential source to said anode, a circuit from the negative terminal of said potential source to said cathode, an electrolytic condenser connected across said cathode and a point intermediate said relay winding and the positive terminal so that it discharges through the tube and relay winding when the tube is ionized, and means for ionizing said tube.

15. In combination, a gas tube comprising a cathode, anode, grid and auxiliary anode, an alternating current source of anode potential connected to said anode, means including said grid for ionizing said tube, and means including a rectifier energized from said alternating current source and having its output connected to said auxiliary anode for maintaining ionization of said tube when the alternating current potential applied to the anode is insufficient to do so.

16. In combination, a gas tube comprising a cathode, anode, grid and auxiliary anode, an alternating current source of anode potential connected to said anode, means including said grid for ionizing said tube, and means including a half-wave rectifier and filter condenser connected to said alternating current source for supplying said auxiliary anode with direct current to maintain ionization of said tube when the alternating current potential applied to the anode is insufficient to do so.

17. In combination, a gas tube comprising a cathode, anode, grid, and an auxiliary anode, a source of anode potential, means for supplying said grid with a negative restraining potential sufficient to prevent ionization of the gas in said tube, a source of relatively high positive potential for said auxiliary anode, and means for reducing the negative potential supplied to the grid and for increasing the positive potential applied to said auxiliary anode to ionize the gas in said tube.

18. In combination, an electron tube having an output circuit and a grid, resistance means in said output circuit, means connected to the grid of said tube for rendering the grid more negative and thereby making the anode end of said resistance means more positive, a gas tube comprising a cathode, anode, grid and auxiliary anode, a relay in the anode circuit of said gas tube, a source of anode potential connected to the anode of said gas tube through said relay, means for normally biasing the grid of said gas tube negatively to a potential sufficient to prevent ionization of the gas in said tube, and means including a connection from the plate end of said resistance means to the auxiliary anode of said gas tube for supplying a positive potential to the auxiliary anode and increasing the positive potential applied to the auxiliary anode to control the ionization of said tube.

19. In combination, a gas tube comprising a cathode, anode, grid and auxiliary anode, a source of alternating current anode potential in the anode-cathode circuit of said tube, a utilization device in said anode-cathode circuit, means including said grid for ionizing said tube to operate said utilization device, and means including a rectifier energized from said alternating current source and a filter including impedance means in its output circuit for connecting the positive output terminal of the rectifier to the auxiliary anode for maintaining ionization of said tube during that part of the cycle when the alternating current potential applied to the anode is insufficient to do so and for restricting the power supplied from the rectifier.

20. In combination, a gas tube comprising a cathode, anode, grid and auxiliary anode, a source of alternating current anode potential in the anode-cathode circuit of said tube, a utilization device in said anode-cathode circuit, means including said grid for ionizing said tube to operate said utilization device, a rectifier and filter energized from said alternating current source, means for supplying a positive, filtered direct current voltage from the rectifier and filter to the auxiliary anode for maintaining ionization of said tube during that part of the cycle when the alternating current potential applied to the anode

is insufficient to do so, means for deionizing said tube, and impedance means between the cathode and grid of said tube and between the cathode and said rectifier and filter to bias the grid of said tube so that it tends to maintain the tube deionized.

21. In combination, a gas tube comprising a cathode, anode, grid, and an auxiliary anode, a source of anode potential, means for supplying said auxiliary anode with positive potential, means for supplying said grid with negative ionization restraining potential, and means supplying variable control voltages to the grid and auxiliary anode for varying the grid and auxiliary anode potentials to ionize the gas in said tube.

22. In combination, a gas tube comprising a cathode, anode, grid, and an auxiliary anode, a source of anode potential, means for supplying said auxiliary anode with positive potential, means for supplying said grid with negative ionization restraining potential, and means for varying the grid and auxiliary anode potentials to ionize the gas in said tube, said last mentioned means including means for increasing the positive potential of the auxiliary anode and means for increasing and then decreasing the negative potential of the grid.

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