OSCILLATOR CONTROLLED RELAY

Original Filed June 22, 1944

2 Sheets-Sheet 1

FIG. 1

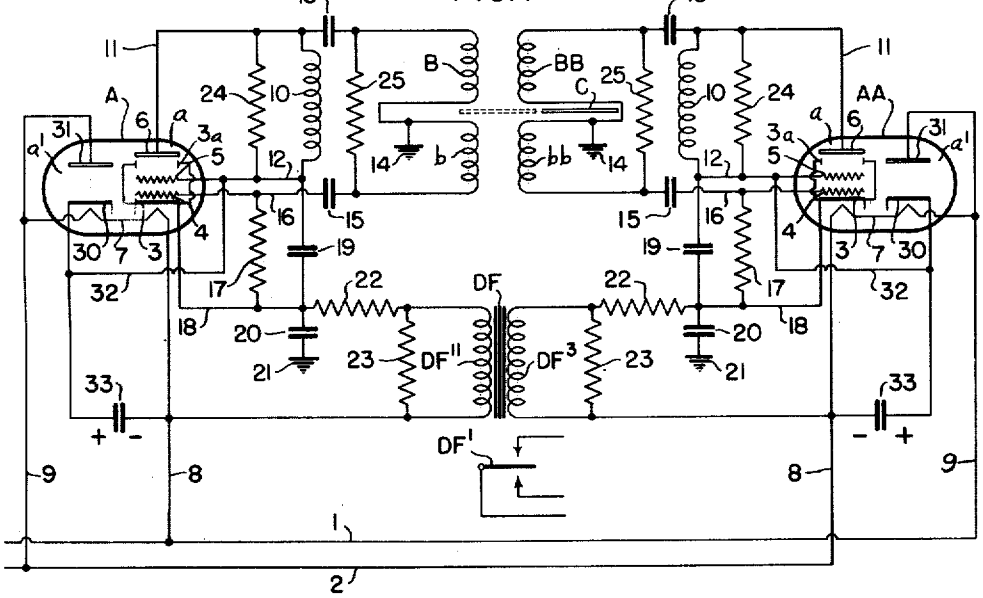


FIG. 2

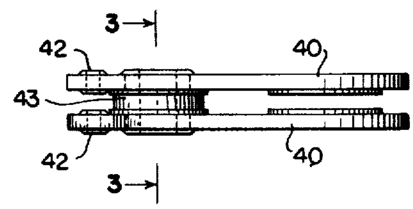


FIG. 3

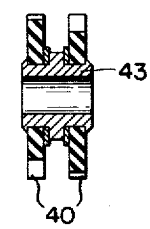
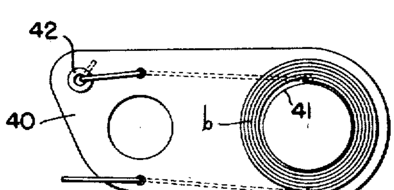


FIG. 4



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June 13, 1950 W. H. WANNAMAKER, JR 2,511,819

OSCILLATOR CONTROLLED RELAY

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FIG. 5

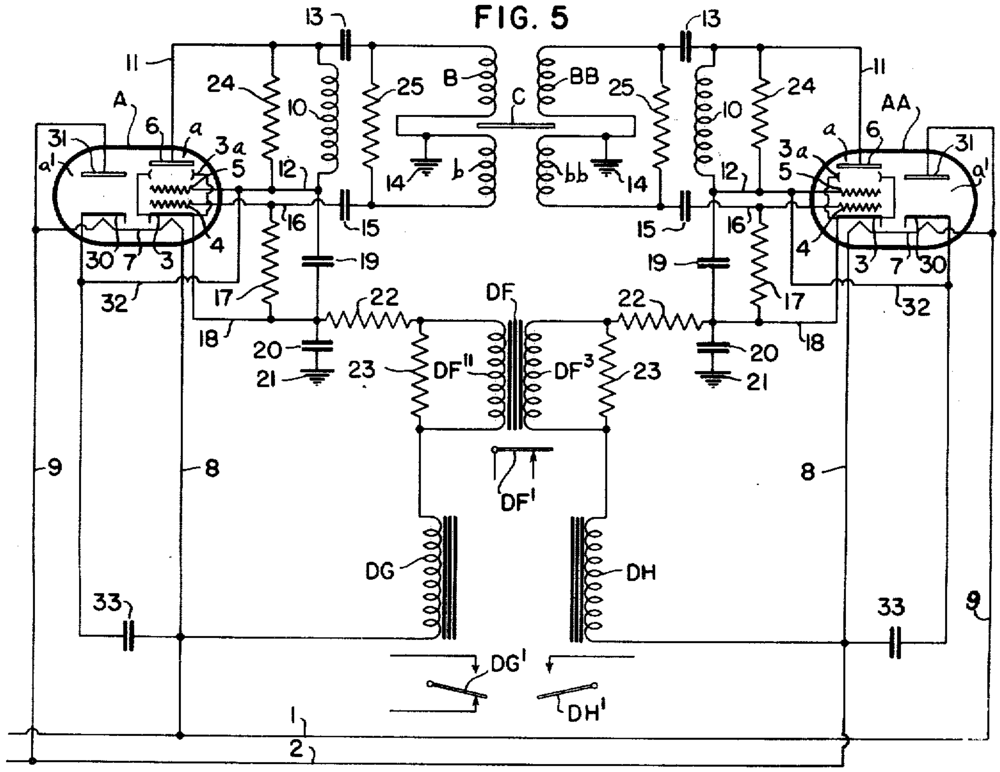
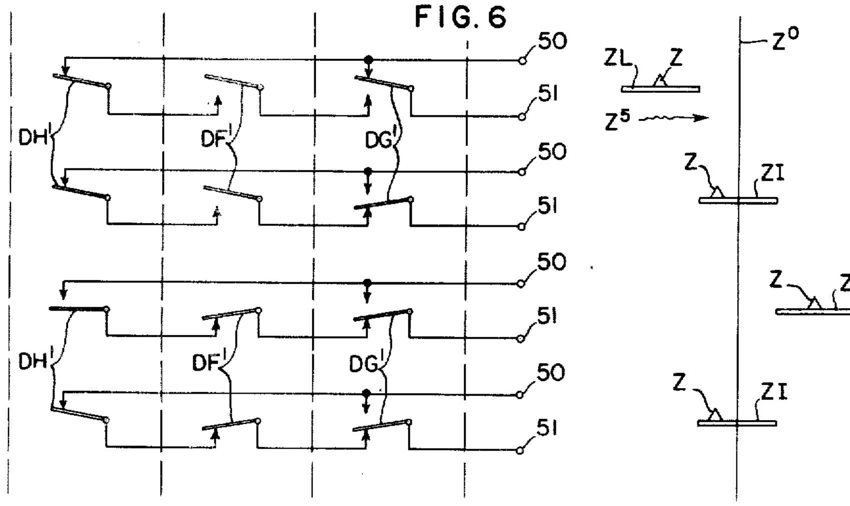


FIG. 6



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Patented June 13, 1950 2,511,819

UNITED STATES PATENT OFFICE

2,511,819

OSCILLATOR CONTROLLED RELAY

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Original application June 22, 1944, Serial No. 541,575. Divided and this application December 12, 1945, Serial No. 634,559

5 Claims. (Cl. 175—320)

1

The general object of the present invention is to provide an improved control system of the type in which control actions are effected through two electronic tubes and associated means by which each of said tubes is adapted to operate as an oscillator or not to so operate accordingly as a controlling quantity or condition has one or another value.

More specifically stated, the object of the present invention is to provide a novel control system arrangement comprising a pair of circuit units each including an electronic tube and a common control element adjustable to different positions, in accordance with variations in a control quantity, in which each, one only, or neither of said tubes is caused to oscillate, and characterized by the means through which said tubes coact to produce control effects selectively dependent on the position of said element.

A still more specific object of the invention is to provide a two-position or on-off control which permits of considerable difference between the value of the controlling condition at which a control action is initiated and the value of the condition at which that controlling action is interrupted. Such an on-off control is desirable, for example, in regulating the intermittent filling of a water reservoir from which water is withdrawn at an average rate substantially smaller than the rate of refill.

Another specific object of the invention is to combine apparatus with which the above mentioned objects of invention may be obtained with other apparatus to thereby provide a form of anticipatory control desirable in some cases.

The present application is a division of my prior application, Serial No. 541,575 filed June 22, 1944.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages, and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described preferred embodiments of the invention.

Of the drawings:

Fig. 1 is a circuit diagram illustrating a control system embodying one form of my invention;

Fig. 2 is an elevation of two associated control coils;

Fig. 3 is a section on the line 3—3 of Fig. 2;

Fig. 4 is a view taken at right angles to Fig. 2 and showing one of the coils shown in Fig. 2;

2

Fig. 5 is a circuit diagram illustrating a modification of the control system shown in Fig. 1, and

Fig. 6 is a diagram showing the control switches of Fig. 5 in different positions occupied in different conditions of operation.

The embodiment of the invention illustrated in Fig. 1 is a control system including two units, one of which comprises an electronic device A and associated circuit elements while the other unit includes an electronic device AA and associated circuit elements. Each unit may well be and as shown is a duplicate of the other, though as hereinafter explained the two units are connected differently to the supply conductors 1 and 2 by which both units are energized.

The tube A shown in Fig. 1, is a rectifier, beam power amplifier tube commonly known as the 117 N7-GT tube, comprising a tetrode valve or section a and a diode valve or section a'. The tetrode valve a comprises a cathode 3 with beam plate extensions $3a$, a control grid 4, a screen grid 5 and a plate 6. The tube A includes a filament heater 7 serving both valves a and a' and having its terminals connected by conductors 8 and 9 to alternating current supply conductors 1 and 2.

The plate 6 of the tube A is connected to the screen grid 5 by a choke coil 10 and conductors 11 and 12. The conductor 11 also connects the plate 6 through a condenser 13 to one terminal of the coil B. The other terminal of the coil B is connected to one terminal of the coil b, and the connected coil terminals have a common ground connection 14. The second terminal of the coil b is connected to the control grid 4 by a condenser 15 and conductor 16. The conductor 16 is connected to the cathode 3 by a resistance 17 and conductor 18.

The conductor 18 also connects the cathode 3 through a resistance 22 to one terminal of the energizing coil DF'' of a relay DF. The second terminal of the coil DF'' is connected to the supply conductor 1 by the conductor 8. The coil DF'' has its terminals connected by a shunt resistance 23. The conductors 12 and 18 are connected by a condenser 19. The conductor 18 is connected to ground at 21 through a condenser 20.

The conductor 12 is also connected by a conductor 32 to the cathode 30 of the diode valve a' in the tube A. The anode 31 of said valve is connected to the supply conductor 2 by the conductor 9. The cathode 30 is also connected by a condenser 33 to the conductor 8 and thereby to the supply conductor 1, thus insuring D. C. operation of the valve a of tube A. The choke coil 10 is shunted by a resistance 24, and the terminals of the coils B and *b* connected to the condensers 13 and 15, respectively, are connected by a resistance 25.

The anodes and cathodes of the valves *a'* and *a* in the tube A are connected in series in a circuit which comprises the supply conductor 2, conductor 9, anode 31, cathode 30, conductor 32, conductor 12, choke coil 10 and shunt resistance 24, conductor 11, anode 6, cathode 3, conductor 18, resistance 22, relay coil DF'' and its shunt resistance 23, conductor 8 and supply conductor 1.

In operation, the valve *a* will oscillate when the mutual inductance of the coils B and *b* is relatively great and will not oscillate when said mutual inductance is relatively small. As the conducting vane C, which is a plate of copper, aluminum or other good conductive metal, is moved from the position shown in full lines in Fig. 1 into a position in which it is directly interposed between the coils B and *b*, the mutual inductance of those coils diminishes from a maximum, causing oscillation of the valve *a* of tube A, to a minimum, small enough to interrupt said oscillation. The plate current of the valve *a* is much smaller when the valve is oscillating than when not oscillating, and in practice the coil DF'' is or is not operatively energized accordingly as the valve *a* of the tube A is not or is oscillating.

The D. C. operation of the valve *a* of the tube A, contributes to operational stability. The resistance 25 has a desirable degenerative effect and insures substantially complete stability of the oscillating system and positively prevents the valve *a* from oscillating when the vane C is fully interposed between the coils B and *b*. Its stabilizing effect is attributable in large part at least to the fact that it minimizes the effect of the capacitance of the conductor connections to the coils B and *b*. I have experimentally determined that the sensitivity of the response of a practical form of the control system shown in Fig. 1 to movement of the vane C is not affected by the use of the resistance 25 if the resistance of the latter is above 10,000 ohms. The resistance 24 increases the tolerances permissible in positioning the control coils B and *b* relative to one another and to the vane C. The resistance 24 reduces the ratio of inductance to resistance of the circuit including the choke coil 10 and this operates to limit the effective impedance of the circuit into which the anode 6 works to some value less than the value of the resistance 24. The resistance 24 may desirably have a value of 3,000 ohms.

In the desirable form shown in Figs. 2, 3 and 4 the inductance coils B and *b* are flat spirals each mounted on an individual support 40 and comprising a few convolutions only. In the form shown each coil includes five and a half convolutions, but I have obtained good results with as many as eleven and a half convolutions in each coil. In the preferred construction shown, the two supports 40 are counterparts, each being a plate-like body of insulating material deformed to provide a circular boss or projection 41 at one side, about which the corresponding coil B or *b* is wound. The terminals of each coil extend through and are anchored by cement in holes formed in the corresponding support 40, and in practice the body of each of the coils B and *b* is anchored to the corresponding support 40 by cement. One terminal of each coil passes away from the corresponding support 40 through a grommet 42 in the latter. The two coil supports 40 are advantageously connected to form a single mechanical unit by a mechanical eyelet or hub part 43 which extends through a portion of each support 40 displaced from its boss 41.

With control coils in the form of flat, closely spaced spirals, as illustrated in Figs. 2–4, the control system shown diagrammatically in Fig. 1 is characterized by its inherent simplicity, reliability and capacity for operation with high sensitivity. It is practically feasible to proportion and design such a system so that the tube A will be rendered oscillating, or non-oscillating, by a movement of the portion of the edge of the vane C adjacent the common axis of the coils B and *b* which is not greater than one-thousandth of an inch. By way of example, and not by way of limitation, it is noted that in one practical embodiment of the control system shown in Fig. 1, the capacitances of the condensers 13 and 15 are 0.00005 and 0.00007 mfd., respectively, and the capacitance of each of the condensers 19 and 20 is 0.001 mfd., though the capacitance value of neither is critical. The capacitance of the condensers 13 and 15 with the capacitance of the tube A and the distributed capacitances of the associated circuit elements provide the capacitance in the series resonant circuit portions of the system. The condensers 13 and 15 also serve as blocking condensers preventing risk of injurious current flow through the corresponding control coils, due to the normal 60 cycle, 110–120 volt potential between the supply conductors 1 and 2. The condensers 19 and 20 serve as bypass condensers.

As shown in Fig. 1, the unit including the tube AA is a duplicate of the unit including the tube A, except for differences mentioned below in the energizing connections to the two units, and in the direction of winding of the coils DF'' and DF^3. Merely to simplify the description, the two electronic tubes A and AA are identified by different symbols, and the symbols B and *b* are applied to one pair of control coils while symbols BB and *bb* are applied to the other pair of control coils. Except as above noted, corresponding parts of the two units are designated by the same reference symbol.

To avoid risk of objectionable reaction whereby either of the circuit units shown in Fig. 1 may give rise to oscillation, or interfere with oscillation, in the other unit, I advantageously arrange the two units as shown so that oscillation in each unit can occur only during the half cycles of power-line voltage which alternate with the half cycles during which oscillation in the other unit can occur. To this end the anode 31 of the tube A of Fig. 1 is connected to the supply conductor 2, and the anode 31 of the tube AA is connected to the supply conductor 1, and one terminal of the relay coil DF'' is connected to the supply conductor 1, while the corresponding terminal of the relay coil DF^3 is connected to the supply conductor 2.

The two energizing coils DF'' and DF^3 of the relay DF act additively, on the associated armature DF'. The latter is biased, as by gravitational force, to a lower position in which it engages a back contact. The relay DF is characterized by the fact that operative energization of both of its coils DF'' and DF^3 is needed to move the armature DF' out of engagement with the stationary back contact which it engages when the coils are both deenergized, but each of the coils DF'' and DF^3, when operatively energized, is adapted to hold the armature DF' in engagement with its associated front, or upper, stationary contact when the other coil is deenergized after having assisted in effecting such engagement.

The coils DF'' and DF^3 are so associated with the tubes A and AA and are so wound or connected that their magnetizing actions on the armature DF' are substantially in phase although the plate currents flowing through the tubes A and AA tend to be 180° out of phase with one another. The use of a standard relay structure is facilitated by the use with each of the coils DF'' and DF^3 of the corresponding resistances 22 and 23.

In Fig. 1 the vane member C is adapted to deflect between the position shown in dotted lines in Fig. 1 in which the vane member extends between, and substantially eliminates the mutual inductance of both pairs of control coils, and the position shown in full lines in Fig. 1 in which the vane does not significantly reduce the mutual inductance of either set of coils. While moving through a considerable portion of its arc of movement between its dotted and full-line positions, the vane C prevents the coils BB and *bb* from having significant mutual inductance, but does not significantly minimize the mutual inductance of the coils B and *b*.

In the use of the control system shown in Fig. 1 to regulate the refilling of a water reservoir as mentioned above by way of example, the controlling provisions actuated by the adjustment of the armature DF' may open a water supply valve or start a water pump into operation and thereby initiate the refilling operation when the water in the reservoir falls to a predetermined low level and thereby moves the vane C into its dotted-line position shown in Fig. 1. The refilling operation thus initiated will then continue until the water in the reservoir reaches a predetermined high level at which time the vane C will have reached its full line position, thereby permitting the armature DF' to drop into engagement with its back contact. When this occurs the supply valve is closed or the operation of the supply pump is interrupted.

As will be readily apparent, the means employed to move the vane C between its dotted-line and its full-line positions as the amount of water in the reservoir varies between a minimum and a maximum, may take various forms. For example, the hydraulic pressure in the lower portion of the reservoir may be transmitted to a Bourdon tube mechanically connected to and moving the vane as said pressure varies with the amount of water in the reservoir. Alternatively, a float in the reservoir may adjust the vane C.

A control system comprising two valve and control coil units and a controlling vane element combined with and jointly controlling a relay in the general manner illustrated in Fig. 1, may be combined with other relays to provide a form of anticipatory control, desirable in some cases. One such arrangement is illustrated by way of example in Figs. 5 and 6. The control system shown in Fig. 5 is like that shown in Fig. 1 except that the winding of a relay DG is connected in series with the relay coil DF'' controlled by the tube A, and the winding of a relay DH is connected in series with the winding DF^3 controlled by the tube AA. The armature switch members DG', DF' and DH' of the respective relays DG, DF and DH shown in Figs. 5 and 6 are adapted to collectively control the connection of control circuit terminals 50 and 51 in response to controlling condition variations, in a manner illustrated diagrammatically in Fig. 6.

The left-hand portion of Fig. 6 includes four superposed switch diagrams showing four different sets of adjustments of the switches DF', DG' and DH'. The operating condition under which the switch adjustment shown in each of the superposed diagrams is maintained, is dependent on the immediate and previous value of a controlling quantity, and is indicated in the portion of Fig. 6 at the right of the diagrams. The value of the controlling quantity is indicated in Fig. 6 by the horizontal displacement of an index Z from the vertical line Z^0 which indicates an assumed ideal or normal value of the controlling quantity. The displacement of the index Z to the right or left of the line Z^0 indicates a corresponding increase or decrease of the value of the controlling condition respectively above or below its ideal normal value.

In the control system illustrated in Fig. 5, the vane element C and control coils, B, *b*, BB and *bb* may be, and are assumed to be so relatively disposed that the three relays DF, DG and DH are all deenergized when the controlling value Z is in a high zone or range of value variation ZH, and are all energized when the controlling value Z is within a low zone or range of value variation ZL, and the relay DH and the relay winding DF^3 are operatively energized whenever the value of the controlling condition is within an intermediate zone or range of value ZI. In consequence of its previously described characteristics, the relay DF will maintain armature DF' in its elevated position when the value Z is within the intermediate zone ZI as a result of an increase in the value Z above a previous low zone ZL value, but will not lift the armature out of its low position when the value Z is within the intermediate zone ZI as the result of a decrease in the value Z from a previous high zone ZH value. As shown the zone ZI is bisected by the line Z^0.

As indicated by the portion of Fig. 6 directly to the right of its upper switch diagram, that diagram corresponds to a condition in which the controlling value Z is within the low zone ZL at the left of the intermediate zone ZI. In consequence all of the relays are then energized and each of the armature switches DF', DG' and DH' is raised and the switch DG' connects the terminals 50 and 51.

The second from the top of the series of switch diagrams shown in Fig. 6 illustrates the switch adjustments maintained when the relays DF and DH are energized and the relay DG is deenergized, and in which the switch DF' prevents the connection of the terminals 50 and 51. The operating condition maintaining this switch relation is that in which the controlling condition value Z is within the intermediate zone ZI and has entered that zone from the low zone ZL, as is indicated by the arrow Z^5.

In the switch diagram which is the third from the top of the series shown in Fig. 6, the switches DF', DG' and DH' are in their lower positions in consequence of the fact that the control condition value Z is then within the high zone ZH so that the relays DF, DG and DH are all deenergized. With all of the switches in their lower positions the switch DH' prevents the connection of the terminals 50 and 51.

In the lowermost switch diagram shown in Fig. 6, the switches DF' and DG' are in their lower positions and the switch DH' is in its elevated position and completes a connection between the terminals 50 and 51. The switch adjustments shown in the lowermost diagram result from the fact that the controlling condition value Z is within the intermediate zone ZI and has entered that zone as a result of a decrease in the value Z from a previous high zone ZH value.

As will be apparent, the kind of control illustrated diagrammatically in Fig. 6 may be used with advantage in controlling various industrial processes. For example, it is well adapted for use in controlling the heat supply to a continuous fluid heater when a small variation of the temperature of the fluid heated from the ideal normal value is not significantly objectionable. In such case heat may advantageously be supplied to the heater at a relatively high rate whenever the temperature of the fluid heated is within a low temperature zone ZL and at a relatively low rate whenever the temperature of the fluid heated is within a high temperature zone ZH. When the temperature of the fluid heated is within the intermediate temperature zone ZI, however, heat may advantageously be supplied at the relatively low rate or at the relatively high rate accordingly as the temperature of the fluid heated has previously been within the low zone ZL or within the high zone ZH, respectively. As will be apparent, when the temperature of the fluid heated is within the intermediate zone, the supply of heat at a higher rate when the temperature is decreasing than when the temperature is increasing, minimizes hunting and tends to prevent wide departures of the temperature from its desired value.

Novel features of the construction and arrangement disclosed but not claimed herein, are claimed in my above mentioned application Serial No. 541,575, or in my application Serial No. 607,034 filed July 25, 1945 as a division of said application Serial No. 541,575.

While, in accordance with the provisions of the statutes, I have illustrated and described the best form of embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims, and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. Control apparatus comprising in combination, two oscillator units each including an electronic valve having a cathode, an anode and a control grid, a relay winding, circuit means individual to each unit and including means adapted to connect the cathode and anode of the unit in series to a source of alternating current and to the relay winding of the unit and including an adjustable reactance and associated means forming coupling means reactively coupling the grid and anode of the unit to feed back energy to said grid from said anode comprising an impedance through which said grid and anode are connected and including impedance means connecting said grid to said cathode and connecting said reactance and cathode to ground and including means forming a tuned circuit including said reactance and connected to and energized by said source and controlled by the adjustment of said reactance, a controlling element operable to dissimilarly adjust the said reactances of the two units and thereby vary the aggregate magnitude of the currents flowing through the relay windings of the two units, and a relay including the two relay windings and an armature in inductive relation with two windings and biased to one position and in which the two windings subject said armature to electro-magnetic force adapted to move said armature from one position to a second position when both windings are energized and in which said windings and armature are proportioned and arranged so that when either of said windings is energized and the other in deenergized, the energized winding subjects said armature to an electro-magnetic force holding the armature from movement from one position to a second position but not strong enough to move said armature from said one position.

2. Control apparatus comprising in combination, two oscillator units each including an electronic valve having a cathode, an anode and a control grid, and a relay winding, and means through which anode current flowing through said valve energizes said winding in selective accordance with the strength of said current comprising circuit means individual to each unit and including means adapted to connect the cathode and anode of the unit to the relay winding of the unit and in series to a source of alternating current and including an adjustable reactance and associated means forming means reactively coupling the grid and anode of the unit to feed back energy to said grid from said anode and including impedance means connecting said grid to said cathode and connected to and uniting with said reactance to form a tuned circuit including said reactance and connected to and energized be said source and controlled by the adjustment of said reactance, a controlling element deflectable through a range of deflection into different positions relative to the respective reactances of the two units to thereby vary the reactive values of said reactances and the anode currents of said valves and initiate and interrupt oscillation of the valve of one unit as said element deflects through one section of its range of deflection and to initiate and interrupt oscillation of the valve of the other unit as said element deflects through a different section of its deflection range, and a relay including said relay windings and an armature in inductive relation with said windings and on which said windings act additively, each in accordance with the anode current of the corresponding valve, said armature having two positions, and means subjecting said armature to a bias force, said armature, winding and bias force means being so proportioned and arranged that said bias force holds said armature in one position when neither valve is oscillating and prevents armature movement out of said one position when only one of said windings is energized but is not strong enough to prevent said armature from moving into its second position when both windings are energized, and is not strong enough to move said armature out of said second position when either of said windings is energized.

3. Control apparatus comprising in combination two units each including an electronic valve having a cathode, an anode and a control grid, and a relay winding, circuit means individual to each unit and including means adapted to connect the cathode and anode of the unit to the relay winding of the unit and in series to a source of alternating current and including an adjustable re-

actance and associated means forming coupling means reactively coupling the grid and anode of the unit to feed back energy to said grid from said anode and including impedance means connecting said grid to said cathode and connected to and uniting with said reactance to form a tuned circuit connected to and energized by said source and controlled by the adjustment of said reactance, a controlling element adjustable into different positions relative to the respective reactances of the two units, to thereby dissimilarly vary their reactive values and establish and interrupt oscillations of said valves and vary the values of the anode currents of the valves flowing through the respective relay windings, means responsive to changes in a controlling condition for adjusting said controlling element into different positions relative to said reactances, and regulating means comprising armatures selectively responsive to the electromagnetic actions of said windings which vary as the currents flowing through said windings are varied by the adjustments of said element for effecting one or the other of two control actions accordingly as the value of a controlling quantity falls below or rises above an intermediate value and for effecting said other or said one action when said controlling quantity attains its intermediate value as a result of an increase or decrease, respectively.

4. Control apparatus comprising in combination two units each including an electronic valve having a cathode, an anode and a control grid, and two relay windings, circuit means individual to each unit and including means adapted to connect the cathode and anode of the unit to each relay winding of the unit and in series to a source of alternating current and including an adjustable reactance and associated means forming coupling means reactively coupling the grid and anode of the unit to feed back energy to said grid from said anode and including impedance means connecting said grid to said cathode and connected to and uniting with said reactance to form a tuned circuit connected to and energized by said source and controlled by the adjustment of said reactance, a controlling element adjustable into different positions relative to the reactances of the two units to thereby dissimilarly vary the respective reactive values of said reactances and thereby establish and interrupt oscillations of said valves and vary the values of the anode currents of the valves flowing through the respective relay windings, and means responsive to changes in a controlling condition for adjusting said controlling elements into different positions relative to said reactances, and a relay including one relay winding of each unit and an armature in inductive relation with the two last mentioned windings, said two windings being arranged to act additively on said armature and being adapted to move said armature from one position to a second position when both windings are energized, and to hold said armature against movement from its second position back to said one position when either of said windings is energized and the other is deenergized, and each of said two windings being inoperative to move said armature out of said one position when the other of said windings is not energized, a second relay energized by the second winding of one unit and a third relay energized by the second winding of the other unit.

5. Control apparatus as specified in claim 4, in which each of the three relays includes a two position switch, each switch occupying one or the other of its two positions accordingly as the relay including that switch is energized or deenergized, and means associated with said switches to form a control circuit which is closed when a predetermined one of said switches occupies a predetermined one, but not the other, of its two positions, and which is also closed when the last mentioned switch occupies the other of its two positions during a period in which each of the other two switches occupies a predetermined one of its two positions.

WILLIAM H. WANNAMAKER, Jr.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,838,084	Drake	Dec. 29, 1931
2,437,661	Cooke	Mar. 9, 1948