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ELECTRONIC RELAY

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Fig. 1.

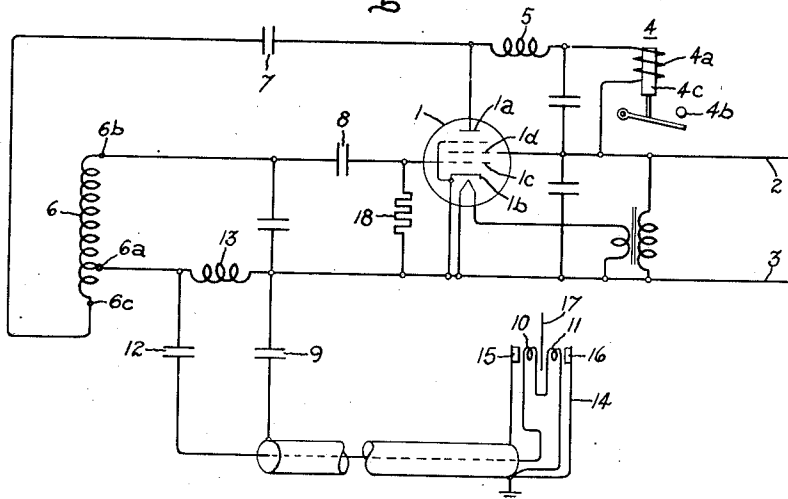


Fig. 2.

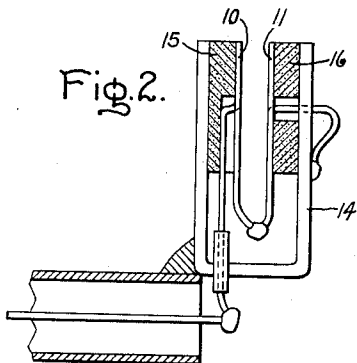


Fig. 3.

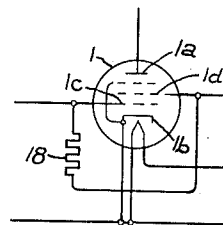
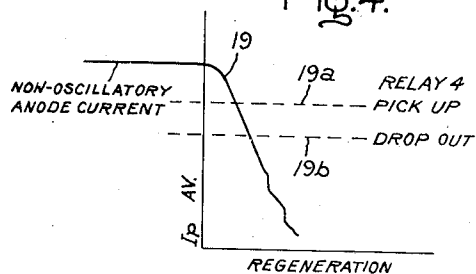


Fig. 4.



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ELECTRONIC RELAY

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This invention relates to control apparatus and has for an object the provision of a simple, reliable, inexpensive and improved device of this character.

Another object of the invention is the provision of an improved apparatus for enabling an electric valve oscillator to control an electro-responsive device such as a relay in which operation of the relay is effected by a movement of a metallic vane between two index coils, and a further object of the invention is to minimize the space required by the index coils.

A further object of the invention is substantially to increase the ratio of maximum or "vane out" to minimum or "vane in" inductance of the two index coils in series.

Also an object of the invention is to provide a snap action of the relay.

A still further object of the invention is to increase the stability of operation by minimizing the A.-C. line frequency component of voltage which is electrostatically induced on the control grid by the screen grid or anode of the oscillator valve, and by delaying blocking of oscillation of the valve until the value of the D.-C. component of anode current is reduced to less than half the non-oscillatory value and to provide smooth variation throughout the range from full value to such reduced variation throughout the range from full value to such reduced value.

In carrying the invention into effect in one form thereof, there is provided an electric valve oscillator. The operating winding of an electromagnetic relay is connected in the output circuit of the oscillator. An inductance winding is connected between the anode of the oscillator valve and its control grid. Between the cathode and an intermediate point on the winding two spaced apart inductively related index coils are connected in series aiding. The mutual inductance of the portions of the winding on opposite sides of this intermediate tap point provide a coupling between output and input circuits which tends to establish and sustain oscillations. The connection of the index coils produces a degenerative direct coupling which tends to suppress oscillations. Normally these two feed-backs balance each other; the circuit is non-oscillatory and the relay is picked up by the relatively large D.-C. component which flows during the non-oscillatory condition. An electrically conductive metallic vane is arranged to move into the space between the index coils to decrease the mutual and self inductance of

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the index coils, thereby to reduce the oscillation "turn-off" coupling to effect the drop-out of the relay.

In a preferred form, the oscillator is fed from a source of alternating voltage. A resistor is connected between cathode and grid, and a capacitor is connected in the grid circuit. The capacitor and resistor are of such magnitude that the time constant of their combination is several times the period of the line voltage.

In a modification, the control grid is connected through the grid leak resistor to the screen grid or to another point of which the voltage is positive with respect to the cathode by a substantial amount. This produces a snap action of the relay.

The invention is applicable to electrical control systems for various purposes. It is especially applicable to installations such as weighing devices, float control devices and limit or flag switch controlled devices in which a movable member or element is provided and in which a control operation is to be effected in accordance with the movement or position of such element. The control operation may be initiated, modified in some manner, or terminated upon the arrival of the element at a predetermined position, with respect to another element which may be either movable or stationary.

For a better and more complete understanding of the invention, reference should now be had to the following specification and to the accompanying drawing of which Fig. 1 is a simple, schematic diagram of an embodiment of the invention; Fig. 2 is a detail; Fig. 3 is a simple, schematic diagram of a detail of a modification; and Fig. 4 is a characteristic curve which facilitates an understanding of the operation.

Referring now to the drawing, an electric valve 1 is supplied with alternating voltage from a suitable source which is indicated by the two supply lines 2 and 3. The valve is provided with an anode 1a, a cathode 1b, a control grid 1c, and a screen grid 1d. As shown, the output circuit of the valve is connected across the source 2, 3 and the operating coil 4a of an electroresponsive device 4, such as a relay, is included in circuit between the anode 1a and the supply line 2. The relay is illustrated as having normally open contacts 4b. A conductive impedance such as a resistor or choke coil 5 of suitable dimensions is connected in the output circuit.

One terminal of an inductance winding 6 is

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connected through a capacitor 7 to the anode and the opposite terminal of the coil 6 is connected through a grid circuit capacitor 8 to the control grid 1c. Between the cathode 1b and an intermediate point 6a on the inductance winding is a connection which comprises a coupling capacitor 9, two index coils 10 and 11 connected in series aiding and a coupling capacitor 12. In parallel with this series connection is a radio frequency choke coil 13.

The portion of the coil 6 between the point 6a and the terminal 6b is a main inductor in the parallel resonant input circuit and the portion of the coil between the point 6a and the terminal 6c serves as a tickler coil which is inductively and regeneratively coupled with the main inductor. The two index coils 10 and 11 are arranged in spaced apart relationship and in a preferred form utilize magnetically permeable outer caps and electrically conductive outer shields as indicated in the following. They are mounted in a U-shaped metal bracket 14 on any suitable supporting means which may be either movable or stationary. These index coils are wound as flat pancake helices and are firmly cemented to disks 15 and 16 respectively. These disks are made of very minutely divided or powdered iron. The powdered iron is compressed in the form of disks and held in a coherent mass by means of a suitable binder. Each disk is firmly secured to an upright of the U-shaped support by a suitable method such as soldering.

The connection of the index coil circuit between the cathode and the point 6a on the inductance winding results in a balanced feedback between output and input circuits. The mutual inductance coupling of the two portions of the inductance winding on opposite sides of the intermediate tap 6a, i. e., the coupling between the tickler coil and the main inductor, provides a regenerative feedback which tends to establish and sustain oscillations, whereas the series aiding index coils 10 and 11 constitute a direct coupling as well as a degenerative inductance which tends to suppress oscillations of the valve. These feedback couplings balance each other and normally the valve is not oscillating. Consequently, the value of the non-oscillating anode current is of sufficient magnitude to energize the operating coil 4a and pick up the relay armature 4c.

The mutual inductance between the two index coils and their self inductance is reduced by means of a metallic vane member 17. This vane may be made of any suitable electrically conducting material such as copper. When this vane is interposed between the two index coils their self inductances are reduced by proximity of its conducting surfaces, and they are electrically isolated from each other so that their mutual inductance is ultimately reduced substantially to zero. Backing the index coils with powdered iron disks increases substantially the ratio of maximum or "flag out" to minimum or "flag in" inductance of the two series aiding index coils.

A grid leak resistor 18 is connected between the control grid 1c and cathode 1b. It has a very high ohmic resistance. In a typical case it has a resistance of 10 megohms. Also, the grid circuit capacitor 8 has a very high capacitance; in a typical case it has a capacity of .01 microfarad.

The time constant of the R. C. combination of resistor 18 and capacitor 8 is several times the period of the alternating voltage of the source from which the valve is supplied. With the constants specified in the foregoing, the time con-

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stant is .1 sec. which is six times the period of an alternating voltage having a frequency of 60 cycles which is assumed in this case to be the frequency of the source 2, 3.

Returning the grid circuit through the choke coil 13 to the cathode 1b and using the high values for the grid capacitor 8 and the grid resistor 18 results in the following advantages:

1. It minimizes the A.-C. line frequency component of voltage which is electrostatically induced on the control grid 1c by the screen grid 1d or anode 1a, thus contributing to stability with respect to variations in the magnitude of the line voltage.

2. The blocking of oscillation as net regeneration is increased does not occur until the D.-C. component of the anode voltage is reduced to less than half of the non-oscillatory value and relatively smooth variations are obtained from full current down to this value as the net feedback increases from zero. This contributes to dependable relay action over a range of values of line voltage and valve anode transconductance. This condition is represented by the curve 19 in Fig. 4 in which ordinates represent values of the anode current and abscissae represent the net feedback. Abscissae on the right of the vertical axis represent positive or regenerative feedback and values on the left represent negative or degenerative feedback. The horizontal portion of the curve 19 represents the non-oscillatory anode current. The value of this component of direct current is reduced sharply when the net feedback becomes regenerative, as indicated by the portion of the curve 19 at the right of the zero axis. The values of current at which the relay 4 picks up and drops out are represented by the horizontal broken lines 19a and 19b. Two additional advantages result from the extremely high ohmic resistance of the grid resistor:

1. The average plate current depends more upon the amount of feedback and less on the value of the voltage supplied from the source.

2. Sufficient bias is developed across the resistor in the absence of oscillation by the cathode emission velocity so that the resultant dependence of the bias on line voltage and cathode emissivity tends to hold the initial or non-oscillatory average anode current constant when the line voltage changes or valves of different cathode emissivity are used.

In a practical embodiment of the invention, the coils 10 and 11 or the vane 17 or both may move. The control is responsive to the relative positions of the coils and the vane. In one application, the vane is carried on the moving element of an indicating device, such as the needle of a meter, and it is required that a controlling operation be effected when the needle reaches a predetermined position. For example, the meter may be measuring and indicating furnace temperature, and it may be required that the current supply to the furnace be discontinued at a predetermined maximum value which is represented by the position of the index coils.

With the foregoing understanding of the elements and their organization the operation will be readily understood.

With the vane withdrawn from the space between the index coils, the oscillation "turn-off" degenerative coupling of the index coil circuit balances the oscillation "turn-on" coupling between the tickler coil and the main inductance coil. Consequently, the valve is not oscillating, the anode current is large and the relay 4 is

picked up and its contacts closed. Assuming the index coils to be stationary and the vane to be mounted on the needle of a furnace temperature indicating instrument the vane will move into the space between the index coils as the furnace temperature rises to the maximum permissible value as determined by the position of the coils. This tends to isolate the coils 10 and 11 from each other electrically and destroy their mutual inductance and reduces their self inductance. As a result, the oscillation "turn-on" coupling between the tickler coil and the main inductance winding becomes more fully effective and the valve 1 generates radio frequency oscillations which are sustained by the feedback through the regenerative inductive coupling.

In consequence of the oscillations, the D.-C. component of the anode current decreases, thereby deenergizing the relay 4. In response to deenergization, relay 4 drops out and opens its normally closed contacts, thereby to effect a controlling operation such as to discontinue the supply of current to an electric furnace.

It will be noted that the system fails safe. If the valve 1 burns out or becomes non-conducting for any reason, the relay 4 becomes deenergized and drops out. In other words, the relay is operated to the position to which it is operated when the vane reaches the limiting or "turn-off" position between the index coils 10 and 11.

In order to provide snap action of the relay, the circuit is modified in accordance with Fig. 3. In this modification the grid leak resistor is returned to a point having a voltage which is positive with respect to that of a cathode such as the screen or anode supply voltage. In Fig. 3 it is shown as being connected directly to the screen grid of which the voltage is positive with respect to the voltage of the cathode. This connection results in the circuit remaining non-oscillatory as regeneration is increased until much more regeneration is present than is required to sustain oscillations once they have started. This causes the anode current to decrease abruptly through the relay drop-out value the instant that oscillation starts. Furthermore, it requires substantial reduction in regeneration from this point before the relay is picked up by a return to non-oscillatory condition. Such action is highly desirable in those applications requiring large flag displacements between relay pick-up and relay drop-out with a resulting crisp relay action which eliminates tendencies of the control to hunt and of the relay to chatter if the vane itself vibrates.

Although in accordance with the provisions of the Patent Statutes this invention is described as embodied in concrete form and the principle thereof has been explained together with the best mode in which it is now contemplated applying that principle, it will be understood that the elements shown and described are merely illustrative and that the invention is not limited thereto since alterations and modifications will readily suggest themselves to persons skilled in the art without departing from the true spirit of this invention or from the scope of the annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States, is,

1. In a control system, the combination of an electric valve oscillator having input and output circuits, a balanced feedback from said output circuit to said input circuit, a mutual inductance coupling in said feedback tending to establish

oscillations, a direct coupled inductance in said feedback tending to terminate oscillations comprising two coils connected in series relationship, means mounting said coils in spaced relationship, and means comprising an electrically conductive vane movable into the space between said coils to render said second coupling ineffective and to render said valve oscillating to deenergize said electromagnetic device.

2. In a control system, a radio frequency oscillator comprising an electric valve having an anode, a cathode and a control grid, an output circuit including said anode and cathode, a parallel resonant input circuit connected across said grid and cathode including a principal inductor, a pair of index coils mounted in spaced apart relationship and connected in series aiding between said inductor and said cathode, a connection between said anode and the junction point of said index coils and said principal inductor providing a main path for the anode radio frequency current through said index coils, a balanced feedback from said anode to said grid comprising a tickler coil included in said connection and having a regenerative inductive coupling with said main inductor tending to establish oscillation and the degenerative voltage drop produced by said radio frequency current in said index coils tending to prevent oscillation and means comprising an electrically conductive vane movable into the space between said coils to decrease said degenerative voltage drop and render said valve oscillating to deenergize said electromagnetic device.

3. In a control system, the combination of an electric valve having an anode, a cathode and a control grid, an output circuit including said anode and cathode, an input circuit including said grid and cathode, a feedback from said output circuit to said input circuit comprising a main coil having one terminal connected to said anode and the opposite terminal connected to said grid, a connection between said cathode and an intermediate point on said coil providing a mutual inductance coupling in said feedback between the portions of said coil on opposite sides of said intermediate point, a choke coil included in said connection, a pair of coupling capacitors, a pair of coils mounted in spaced apart relationship connected in series aiding and through said coupling capacitors in parallel with said choke coil to provide a degenerative direct coupled inductance in said feedback tending to terminate oscillations, and means comprising an electrically conductive vane movable into the space between said pair of coils to render said direct coupling ineffective and to render said valve oscillating to deenergize said electromagnetic device.

4. In a control system, a source of voltage, an electric valve having an anode, a cathode, and a control grid, an output circuit including a connection from said anode to one side of said source and a connection from said cathode to the other side of said source, an input circuit including said grid and cathode, a balanced feedback from said output circuit to said input circuit comprising a main coil having one terminal coupled to said anode and the opposite terminal connected to said grid and a pair of coils mounted in spaced apart relationship and connected in series relationship between said cathode and an intermediate point on said main coil to provide a mutual inductance coupling in said feedback between portions of said main coil tending to establish oscillations and a direct coupled inductance in

said feedback tending to terminate oscillations, means comprising an electrically conductive vane movable into the space between said pair of coils to render said direct coupling ineffective and to render said valve oscillating to deenergize said electromagnetic device, and a grid leak resistor connected between said grid and a point having a voltage which is positive with respect to the voltage of said cathode.

5. In a control system a source of alternating voltage, an oscillator comprising an electric valve having an anode, a cathode, a control grid, and a screen grid, an output circuit comprising a connection from said anode to one side of said source and a connection from said cathode to the other side of said source, an input circuit including said control grid and cathode, a load device in said output circuit, a connection from said screen grid to said source, a feedback from said output circuit to said input circuit comprising a main coil having one terminal connected to said anode and the opposite terminal connected to said grid, a connection between said cathode and an intermediate point on said coil providing a mutual inductance coupling in said feedback between the portions of said coil on opposite sides of said intermediate point, a choke coil included in said connection, a pair of coils mounted in spaced apart relationship connected in series aiding in parallel with said choke coil to provide a degenerative direct coupled inductance in said feedback tending to terminate oscillations, means comprising an electrically conductive vane movable into the space between said pair of coils to render said direct coupling ineffective and to render said valve oscillating to deenergize said electromagnetic device, and a connection including a grid leak resistor connected between said control grid and said screen grid.

6. In a control system, a radio frequency oscillator comprising an electric valve having an anode, a cathode and a control grid, an output circuit including said anode and cathode, a load device in said output circuit, a parallel resonant input circuit connected across said grid and cathode including a principal inductor, a pair of index coils mounted in spaced apart relationship and connected in series aiding between said inductor and said cathode, each of said index coils being wound in the form of a flat helix, a backing for each of said index coils comprising a disc formed of powdered iron, a connection between said anode and the junction point of said index coils and said principal inductor providing a main path for the anode radio frequency current through said index coils, a balanced feedback from said anode to said grid comprising a tickler coil included in said connection and having a regenerative inductive coupling with said main inductor tending to establish oscillation and the degenerative voltage drop produced by said radio frequency current in said index coils tending to prevent oscillation and means comprising an electrically conductive vane movable into the space between said coils to decrease said degenerative voltage drop and render said valve oscillating to deenergize said load device.

7. In a control system, a source of alternating voltage, an oscillator comprising an electric valve

provided with an anode, a cathode and a control grid, an output circuit including said anode and cathode connected to said source, an input circuit including said grid, a load device in said output circuit, a balanced feedback from said output circuit to said input circuit, a mutual inductance coupling in said feedback tending to establish oscillations, a coupling from said output circuit to said input circuit including a pair of coils connected in series aiding and mounted in spaced apart relationship tending to terminate oscillations, a resistor connected from said grid to said cathode and a capacitor connected in said input circuit, said resistor and capacitor having a time constant several times the period of said alternating voltage, and means comprising an electrically conductive vane movable into the space between said coils to render said second coupling ineffective and to render said valve oscillating to deenergize said load device.

8. In a control system, a source of alternating voltage, an oscillator comprising an electric valve having an anode, a cathode and a control grid, an output circuit including said anode and cathode, an input circuit including said grid and cathode, a load device in said output circuit, a balanced feedback from said output circuit to said input circuit comprising a main coil having one terminal coupled to said anode and the opposite terminal connected to said grid and a pair of coils mounted in spaced apart relationship and connected in series aiding between said cathode and an intermediate point on said main coils to provide a mutual inductance coupling in said feedback between portions of said main coil tending to establish oscillations and a direct coupling in said feedback tending to terminate oscillations, a resistor connected between said grid and cathode, a capacitor connected between said main coil and said grid, said capacitor and resistor having a time constant of several times the period of the voltage of said source, and means comprising an electrically conductive vane movable into the space between said pair of coils to render said direct coupling ineffective and to render said valve oscillating to deenergize said load device.

9. In a control system oscillator including an electric valve having an anode, a control electrode, and a cathode, and a tapped inductor connected between said anode and control electrode, a degenerative feedback control comprising a variable inductance element connected in circuit between the tap of said inductor and said cathode, so that the alternating voltage drop across said inductance element provides degenerative feedback to the oscillator in amounts which vary with the inductance of such element, whereby operation of the oscillator is subject to amplitude control by said inductance element.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,404,643	Livingston	July 23, 1946
2,411,247	Cohen	Nov. 19, 1946
2,468,138	Terry	Apr. 26, 1949