

Nov. 19, 1946.

T. A. COHEN

2,411,247

ELECTRIC OSCILLATOR AND OSCILLATOR CONTROLLED RELAY CIRCUIT

Filed Jan. 7, 1942

4 Sheets-Sheet 1

Fig. 1.

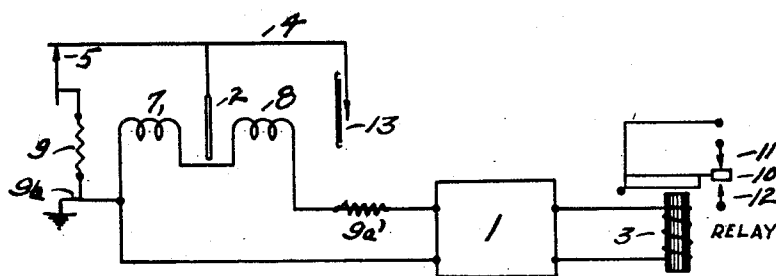
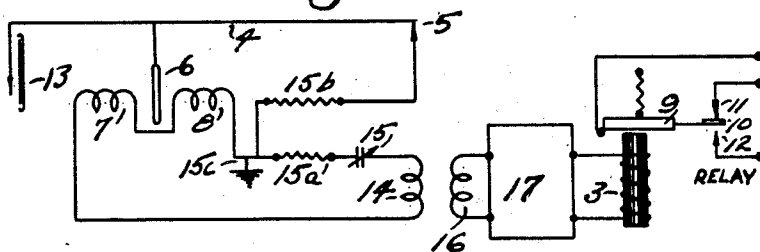


Fig. 2.



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4 Sheets-Sheet 2

Fig. 3.

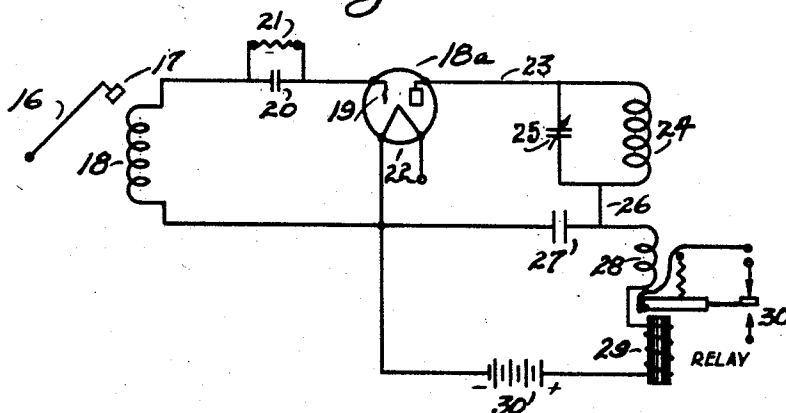
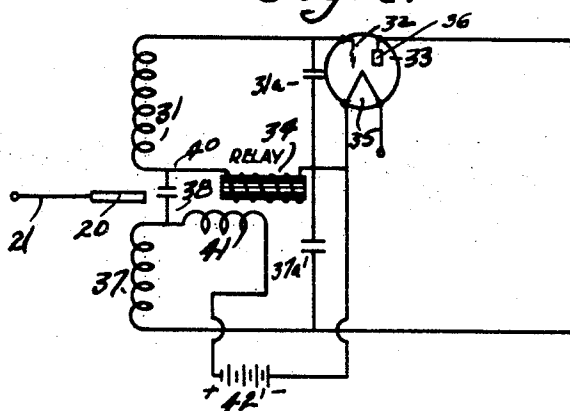


Fig. 4.



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4 Sheets-Sheet 3

Fig. 5.

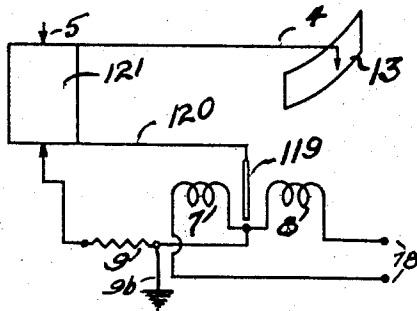


Fig. 6.

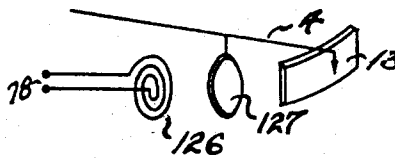


Fig. 7.

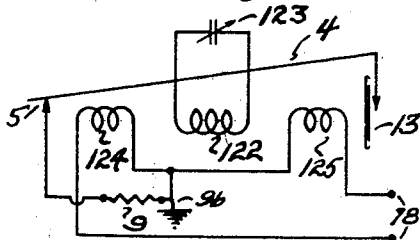
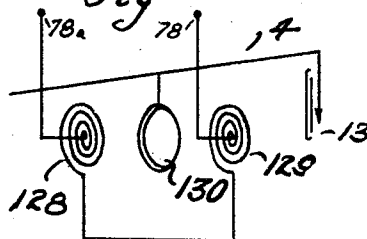


Fig. 8.



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UNITED STATES PATENT OFFICE

2,411,247

ELECTRIC OSCILLATOR AND OSCILLATOR
CONTROLLED RELAY CIRCUIT

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Application January 7, 1942, Serial No. 425,906

26 Claims. (Cl. 175-320)

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This invention relates to Electrical control apparatus and its subject matter was originally included in but subsequently divided from the application which latter matured into United States Letters Patent 2,228,163, issued January 7, 1941, to Theodore A. Cohen, for improvements in Electrical control apparatus.

One of the objects of this invention is to provide a rugged apparatus in which the contacts of a rugged relay, may be controlled by the motion of the pointer, of a sensitive measuring instrument, for example a sensitive millivoltmeter without disturbing the measuring accuracy of the measuring instrument.

A further object of this invention is to provide an apparatus in which microscopic motion of the pointer or moving part of a measuring element may effect dependable relay action.

A further object of the invention is to provide operation of such relay apparatus without disturbing the measuring accuracy of the instrument.

Other and further objects of this invention will become more apparent hereinafter as the same becomes better understood from an examination of the specification and claims, in conjunction with the accompanying drawings, wherein:

Fig. 1 is simplified schematic drawing of the control apparatus.

Fig. 2 is a modified form of the apparatus.

Fig. 3 is a detailed view of a portion of the apparatus in Fig. 1.

Fig. 4 is a modification.

Fig. 5 is a modification.

Fig. 6 is a modification.

Fig. 7 is a modification.

Fig. 8 is a modification.

Fig. 9 is a modified circuit form.

Fig. 10 is a form of the apparatus assembled in pictorial and schematic form to illustrate an actual industrial assembly.

Referring to the drawings more particularly, as shown in Figure 1, reference character 4 designates the pointer of a measuring instrument, e. g., a pyrometer, voltmeter, thermometer, or the like, actuated by the moving portion of the instrument, not shown for simplicity, for indicating upon a scale 13, the measured quantity. Such sensitive measuring instruments, particularly of the millivoltmeter variety, have operating torques of not more than 1.0 millimeter gram per 90 degrees of rotation and usually are about 0.2 millimeter gram per 90 degrees of rotation. The pointer 4 has attached thereto a light metallic flag 2, which may be of aluminum foil or the like. The pointer 4 is shown pivoted in sim-

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ple form as at 5. This may be the pivot and jewel structure as commonly used. A pair of inductances 7-8 are mounted in spaced relationship to allow passage of the flag 2, therebetween, as the pointer 4 moves around axis. The coils 7-8 form a portion of the resonant circuit of an electronic oscillator 1, in whose output circuit is connected a relay 3, having contacts 11, 12, 10. With the flag 2 withdrawn from the coil system 7-8 the oscillator is tuned to maintain the relay 3 in contact position as shown, with contacts 10-11 closed and 10-12 open. Upon the flag 2 passing within the coil system 7-8 the oscillator is detuned due to the change in inductance of coils 7-8, deresonating the oscillator 1. This causes the steady current through relay 3 to change to cause relay function and thus close relay contacts 10-12 and open relay contacts 10-11. The use of a split inductance such as 7-8 is of especial advantage as will be pointed out more specifically hereinafter.

The apparatus as shown is capable of operating a rugged relay such as is adapted for use in furnace control and the like: with a motion of the flag 2 as small as .002".

To prevent the possibility of charges collecting upon the flag which might cause disturbance of the accuracy of measurement of a sensitive instrument of which the pointer 4 is a part (by attraction or repulsion thereof), a resistor 9 is incorporated which permits grounding of the pointer 4 and at the same time, permits the placing of the flag 2 and the coil system 7-8 at the same potential. This effectively prevents disturbance of the measuring function. Another method of preventing possible disturbing effects can be accomplished by the inclusion of a resistor 9a.

Referring to Fig. 2 there is shown another form of the apparatus and circuit wherein the pointer arm 4, flag 6, scale 13 and coils 7-8 are substantially as shown in Fig. 1. In this apparatus the coils 7-8 are part of a resonant circuit including in addition the coil 14, condenser 15, and resistor 15a, which is used to control the damping and therefore broaden the tuning as desired of the circuit of which it is a part. This resonant circuit is coupled inductively to coil 16 in the control circuit of the oscillator 17. The resonant circuit is adjustable to resonate with the oscillator. The moving of the flag 6 within the coils 7-8 causes a change in tuning of the resonant circuit and a change in the absorption of the circuit, of coil 16, with a consequent change in the current passing through the relay 3 and a resultant contact operation. A disturbance pre-

vention means is shown at 15b and functions substantially as in Fig. 1.

Referring to Fig. 3 the apparatus and circuit there shown comprises the vacuum tube 18a shown as a triode whose grid 19 is connected with a grid condenser 20, and grid leak 21 the opposite ends of which are connected to the upper end of the coil 18, the other end of the coil being connected with the filament 22. In the plate circuit a conductor 23 leads to a resonant circuit including the coil 24 and condenser 25 and from this resonant circuit a conductor 26 leads to the bypass condenser 27 and thence to the filament 22. From the conductor 26 the circuit leads through the choke coil 28 and relay 29 to the positive side of the battery 30. The negative side of the battery leads to the filament 22. This type of oscillator circuit is typical of the form known as tuned plate-tuned grid oscillator in which the coupling means for the feed back of energy from the plate circuit to the grid circuit takes the form of a coupling condenser 27. A portion of the coupling is also through the plate, grid, interelectrode capacity of the tube 18a. The choke coil prevents flow of oscillating energy through relay. For oscillation to take place it is necessary that the plate tank consisting of inductance 24 and condenser 25 be resonated to the grid tank consisting of inductance 18 and the circuits' own capacity. Under the condition for maximum oscillation, a large bias is obtained across leak 21 which makes grid 19 negative and thus a resultant low plate current flows through relay 29. Should either the plate tank or the grid tank be detuned, oscillation decreases and plate current rises through the relay 29. In this apparatus, one form of detuning is shown, by means of the flag 17 on pointer 16, which may be the pointer of a measuring instrument as in Fig. 1. Upon the metal flag 17 approaching or passing within the coil 18, detuning results due to the change in inductance of 18 whereupon the plate current sharply rises to close relay contacts 30. It is obvious that the control inductance may be either the grid coil or the plate coil 24 or the flag 17 may control the amount of feed back between the grid and plate circuit as will be explained hereinafter in connection with Fig. 4. In the above described function the grid tank and plate tank have been resonated to each other in order to produce a low plate current to keep relay contacts 30 open. Upon either of the tanks being deresonated, the plate current rises to close relay contacts. In some forms of commercial apparatus, it is an advantage to have operation in the reverse manner, that is, it is desired to have the relay contacts 30 closed when flag is not at control point (plate current high) and then to have said contacts open when either tank is approached or affected by the flag 17. Such manner of operation is easily obtained by deresonating plate tank from grid tank some prechosen amount whereupon the plate current remains at an original high value which maintains contact 30 closed. Upon the approach of flag 17 within the inductance 18 (or 24) the tank is retuned to resonance whereupon plate current drops to open relay contacts 30. One advantage of such operation is in the case where tube failure occurs relay contact 30 would open to deenergize the load circuit which may be a furnace or the like.

This oscillator, although shown energized from batteries, obviously may be powered from a commercial alternating current source either by means of the usual rectifier system or in the self

rectified manner as is disclosed in the aforementioned parent Patent #2,228,163.

The inductance 18 (or 24) is preferably of the dual coil form such as described in Figures 1 and 4 to 10 hereinafter described because such split coil form permits of a maximum change in inductance with a minimum linear movement of the flag.

In an automatic control problem it is desirable to sense an immediate departure from the preset control level immediately so that compensation for the departure may be provided as rapidly as possible. Therefore relay action must be obtained with the smallest possible motion of the flag upon the measuring instrument. At the same time the relay in the oscillator apparatus should be capable of operating its contacts with the smallest possible current change. I therefore provide a relay of small differential or high throw out percentage. In this way with the sensitivity of the oscillator to flag position change together with the small differential relay microscopic motions of the flag are translated to immediate and dependable contact operations without mechanical contact between the moving measuring system such as flag 6 on pointer 4 and the mechanical portion of the system of which coils 7-8 are a part.

In Fig. 4 is shown a form involving the use of an oscillating circuit commonly known. In this circuit, the coil 31 corresponds to the coil 18 of Fig. 3. In this circuit the grid 32 of a vacuum tube 33, shown as of the triode type, is connected to the grid coil 31, a circuit leading from this coil 31 through the relay 34 and to the filament 35. A circuit leads from the plate 36 through the plate coil 37 to the condenser 38, the other side of the condenser being connected with the conductor 40, this junction leading to the relay 34 and thence to the filament 35. This places the relay in the grid circuit in position to be operated by the grid current. A circuit also leads from the plate coil through the choke coil 41 to the positive side of the plate supply battery 42. By placing the relay in the plate circuit as in Fig. 3 it may be operated by plate current change. The negative side of the battery leads to the filament 35.

All the previous description of the oscillator circuit in Fig. 4 corresponds with the previously described oscillator circuit with the exception that the control flag 20 fixed to indicating pointer 21 passes between the two inductances 31-37 and thereby controls the feed back in the oscillator circuit. This type of oscillator circuit is coupled to cause feed back by means of condenser 38 and mutual inductance between coils 31 and 37. The feed back between 31 and 37 is changed by interposing control flag 20 to thereby control the steady current flow through relay 34. The coils 31-37 are mounted so as to allow flag 20 to pass between them such as 7-8 in Fig. 1 and may take the form of mutually facing coils such as in Fig. 8.

Referring to Fig. 5 there is shown diagrammatically a form of apparatus for causing the change in tuning of the oscillator circuit in which the control flag 119 is mounted upon a secondary pointer 120 attached to the coil (not shown) or movement system which operates the indicating pointer 4. Such an apparatus may be desirable where it is essential that the indicating system not carry the control system. In this apparatus the movement system 121 may be a D'Arsonval

type meter, having the pointer 4 cooperating with the scale 13 and having the other pointer 120 attached to the bottom of the coil, forming a part of the movement system 121 and carrying the control flag 119.

Referring to Fig. 6, this figure shows still another form of pick-up construction in which a small edgewise wound spiral 126 is placed in a pick-up coil circuit such as shown in the previously described oscillator circuits of Figures 1 to 4 inclusive and cooperates with the metal flag 127 on the pointer 4 which with its movement will bring the metal flag 127 close to and in a plane substantially parallel to the plane of the spiral coil 126. The coil 126 may be the inductance 18 or 24 in Fig. 3 or the 7-8 in Fig. 1.

Referring to Fig. 7 there is shown another form of apparatus for controlling the tuning of the oscillator circuit in which the flag is replaced by a coil 122 carried by the pointer and forming part of a resonant circuit including a condenser 123 also carried by the pointer. This coil 122 cooperates with pick-up coils 124 and 125 placed in the oscillator circuit. The resonant circuit 122 and 123 carried by the pointer 4 is normally resonant to the frequency of the oscillator. Upon the approachment of the coil system 122 to the pick-up coils 124 and 125, energy is absorbed from the oscillator circuit, causing a change in plate current and a consequent operation of the relay controlled thereby.

Referring to Fig. 8 there is shown another form of pick-up coil construction involving the use of 2 spiral coils 128 and 129 lying in substantially parallel planes in which the flag 130 in its movement may pass between the spiral coils, the flag lying in a plane substantially parallel to the planes of the spirals. These coils may replace 7-8 in Fig. 1 or 18-24 in Fig. 3 or 31-37 in Fig. 4.

As previously mentioned, an important function of an automatic control system is to produce dependable contacting with the smallest change in measured quantity. It is desirable therefore to effect the greatest obtainable change in inductances with the smallest increment of flag travel since it is flag travel which eventually results in operating the load contacts. By lumping the inductance so that all portions face the flag surface the largest inductance change may be obtained with minimum pointer travel. Such a coil structure is best exemplified by the spiral pancake coil in Figs. 6 and 8.

Referring to Fig. 9 there is shown another form of apparatus and circuit including the oscillator tube 43, whose grid 44 is connected to the grid condenser 45 and grid leak 46, the circuit from the other side of the grid leak leading through the coil 47 to the filament 48. From the plate 49 a conductor 50 leads to a resonant circuit, including the coil 51 and condenser 52, the other side of the resonant circuit leading to the choke coil 53 and thence to the plate supply battery 54, the other side of the plate supply battery leading to said filament 48. A by-pass condenser 55 is connected to the choke coil 53 and filament 48. This circuit functions as the oscillator described in Fig. 3. Coupled to the plate coil 51 is a link circuit including coils 56, 57 and 58, condenser 59, and resistor 59A whose function is similar to resistor 18a of Fig. 2. Coupled to the coil 57 is a resonant circuit comprising the coil 60 and condenser 61. The controlling flag 6 on the pivoted arm 4 cooperates with the coils 58. The upper end of the resonant circuit, which includes the

coil 60 and condenser 61 is connected to the grid leak 70 and condenser 71 and thence to grid 62 of the vacuum tube 63 which acts normally as a detector, the lower side of the resonant circuit being connected to the negative end of the battery 67, and the positive end of the battery being connected to the plate of the tube 63 through a relay 66. The negative end of said battery is also connected to the filament of said tube.

The oscillator system including tube 49 functions as a tuned-plate-tuned grid oscillator as already described above for Fig. 3. The link circuit 56-57-58-59-59a is adjusted to resonate with tank 51 and 52 with the flag 6 withdrawn to a prechosen point from the coils 58 which correspond to the coils 7-8 in Fig. 1 or Fig. 2. When the resonant circuit 60-61 is resonated with the link circuit 56-57-58-59-59a such energy is detected by detector system 62-66-67-70-71-60-61. Plate current through relay 66 therefore drops to cause relay action. When flag 6 is moved into coil system 58, link circuit 56-59a, inclusive, is deresonated whereupon energy to detector 62 ceases with consequent change in plate current through relay 66 and corresponding relay action results. Although a so-called grid bend detector is illustrated using grid condenser 71 and grid leak 70 a plate bend detector may be used to give reverse operation or any variety of diode detector with appropriate bias control. The contacts for the relay 66 are not shown but may be as illustrated in previous figures. With a resistor 59a withdrawn from the circuit sharpest tuning results (narrow resonance curve) and relay 66 is operated with smallest motion of flag 6. As resistor 59a increases from zero resonant current reduces and tuning broadens requiring a larger motion of the flag 6 to produce relay action. Thus the sensitivity of control response may be adjusted. Such operation is useful for throttling control wherein the relay 66 may be, for instance, a variable reactor or a positioned fuel valve since the plate current change can be made proportional to the flag position 6 within the coils 58.

As shown in Fig. 10 one form of apparatus which may be used comprises a milli-voltmeter having a movable coil 30 and a pointer 4 pivotally mounted at 5 having an indicator 75 cooperating with an arcuate scale 13 and carrying the flag 6. The flag in its travel passes between the coils 7 and 8 to affect the tuning of the oscillator circuit. These coils 7 and 8 are mounted on a setting lever 76 which is pivotally mounted at 76a coaxially with the pointer 4. The setting lever may also carry an index finger 77 cooperating with the arcuate scale 13. The setting lever 76 may be set to any desired position by means of a suitable adjusting mechanism 78. As indicated above, when the flag 6 passes within the coils 7 and 8, the oscillator apparatus 70 will be affected causing the operation of relay 71. Such apparatus is essential in automatic control problems and is shown in connection with furnace temperature, control in which case the energy for controlling the position of the milli-voltmeter pointer 4 is produced by thermo couple 5.

The desired temperature is set upon scale 13 with pointer 77 and adjustment 78. This positions the coils 7-8 at required point. When the temperature is low in the furnace, insufficient energy is produced by the thermo couple 5 whereupon the pointer 4 and indicator 75 are below the control point 77. The flag 6 is not fully within the coils 7-8 and relay 71 remains closed, con-

facts 72 closed, energizing furnace elements 73, if electrically heated, or an electric valve if fuel fired.

As the temperature rises in the furnace the couple 5 is heated and the pointer 5 moves up scale. The flag 6 enters further between coils 7—8 changing the tuning of the oscillator and thereby opening contacts 72. The furnace now cools until flag 6 is again withdrawn below control point to cause a reenergization of the furnace. This action continues giving so-called off-on or two position control of the furnace. Because of the extreme sensitivity of the relay system, very close temperature control is obtainable. The system is easily set up to produce contact operation of 72 with a motion of the flag 6 within the coils 7—8 of less than .002".

It is important in a control mechanism of this character that the control flag 6 be incapable of passing beyond the control coils 7 and 8 because if that should take place the relay contacts 72 would then be permanently closed and the furnace element 73 would be permanently energized. The indicating pointer 75 would be deflected to the top end of the scale and all control would be lost, with resultant possible damage to furnace. A pointer stop 79 is therefore provided fixed to the lever 76 at 79A and insulated from any portion of the circuit to arrest the pointer 75 before the flag 6 can travel beyond the coil system 7—8. To prevent electrostatic charges collecting upon the flag 6 and causing erroneous indications upon the scale 13 of the pointer 75, the pointer and flag 6 are metallically connected at 6A. Such connection is usually made at a control spring mount or lead shown in simplified form at 6B. A leakage resistor 6C places the flag and pointer at the same potential as the coil system 7—8 at 7A. The line supply for the system is conventionally shown at 10. The oscillator 70 shown in simplified block form may be any of the previous oscillator systems described or one of the oscillator mechanisms disclosed in the aforementioned parent Patent #2,228,163.

It is obvious that the control apparatus may be applied to any automatic control problem such as voltage frequency, etc., with an appropriate measuring element and controlled compensator for the departed quantity.

I am aware that many changes may be made and details varied without departing from the principles of my invention and I therefore do not wish to be limited to the details shown or described.

I claim:

1. The combination with an instrument having a variable position part carrying a control element and whose position is controlled by variations in conditions to which the instrument is subjected, of a resonant circuit, a vacuum tube oscillator for exciting said circuit, a second resonant circuit coupled to said first resonant circuit, the control element whose position is controlled by said variable position part, being movable to a position in which it affects the tuning of said second resonant circuit, and a relay controlled by said oscillator, to in turn control said position of said variable position part.

2. The combination with an instrument having a variable position part, whose position is controlled by variation in conditions to which the instrument is subjected, of an oscillator circuit having an inductive portion for cooperating with said part, said part being movable to a position in which it affects said portion to thereby affect

the tuning of said oscillator circuit, and means for maintaining said part and said inductive portion at approximately the same potential to thereby prevent disturbing electrical effects upon the measuring ability of said instrument, said oscillator controlling the position of said part.

3. The combination with an instrument having a variable position part, whose position is controlled by variation in conditions to which the instrument is subjected, of an oscillator circuit having an inductive portion for cooperating with said part, said part being movable to a position in which it affects said portion to thereby affect the tuning of said oscillator circuit, and means for preventing accumulation of electrical charges upon said movable part to thereby prevent disturbing electrical effects upon the measuring ability of said instrument, said oscillator controlling the position of said part.

4. The combination with an instrument having a variable position part, whose position is controlled by variation in conditions to which the instrument is subjected, of an oscillator circuit having an inductive portion for cooperating with said part, said part being movable to a position in which it affects said portion to thereby affect the tuning of said oscillator circuit, and means for maintaining said part and said inductive portion at a predetermined potential relationship to thereby prevent disturbing electrical effects upon the measuring ability of said instrument, said oscillator controlling the position of said part.

5. The combination with a contact controlling relay, of means for controlling the operation of said relay comprising a detector circuit, an oscillator circuit, a link circuit between said oscillator circuit and detector circuit, and means for changing the tuning of the link circuit to vary the energy transferred to the detector circuit to control the operation of the relay.

6. The combination with an oscillator circuit and a variable position control element movable with respect to said circuit to change the tuning thereof, of a relay controlled by said change in tuning, said control element comprising a movable metal plate, the circuit affected by said plate comprising a spiral coil with respect to which said plate approaches and recedes in its movement, said plate and coil lying in substantially parallel planes when in proximity to each other.

7. The combination with a contact controlling relay, of means for controlling the operation of said relay comprising a detector circuit, an oscillator circuit, a link circuit between said oscillator circuit and detector circuit, a portion of which consists of a pair of spaced inductances and means for controlling the link circuit to change its tuning to vary the energy transferred to the detector circuit to control the operation of the relay, the means for controlling the link circuit comprising a control element carried by a measuring instrument and movable and in spaced relationship with said inductances.

8. The combination with an oscillator circuit and a variable position control element movable with respect to said circuit to change the tuning thereof, of a relay controlled by said change in tuning, said control element comprising a movable metal plate, the circuit affected by said plate comprising a pair of spaced spiral coils between which said plate approaches and recedes in its movement, said plate and coils lying in substantially spaced parallel planes when in proximity to each other.

9. The combination with an instrument having

a variable position part, whose position is controlled by variation in conditions to which the instrument is subjected, of a resonant circuit having an inductive portion for cooperating with said part, said part being movable to a position in which it affects said portion to thereby affect the tuning of said resonant circuit and an oscillator circuit controlled in turn by changes in tuning of said resonant circuit, said resonant circuit being provided with adjustable means for setting a predesired damping to thereby control the sensitivity of response for a given motion of said movable part.

10. In an automatic control mechanism including an instrument responsive to changes in a measured quantity, said instrument motivating a movable part, a control circuit provided with inductance for cooperating with said part in spaced relationship therewith, said inductance forming a portion of the grid tank of a vacuum tube oscillator, in the plate circuit of which is contained a tuned circuit adapted to be resonated with said grid tank, in desired degree the plate circuit also containing a relay adapted to be energized by the non-pulsating component in said plate circuit and thereby cause contact operation in another manner when said part is actuated a predetermined distance to change the tuning of said grid tank.

11. The combination with an oscillator circuit and a variable position control element motivated by a measuring instrument and movable with respect to said circuit to change the tuning thereof, of a relay controlled by said change in tuning, said control element comprising a resonant circuit including a condenser and coil, the circuit controlled by said control element including a coil with respect to which said resonant circuit approaches and recedes in its movement to in turn control the position of said variable position control element.

12. In an automatic control apparatus, the combination of a measuring instrument, having means for indicating or sensing departure from a prechosen level, such means including a movable position part, cooperating in spaced relationship with an inductance forming a portion of a resonant circuit, whereby motion of said part affects the tuning of said circuit, said circuit acting as a transmission channel for energy produced by a vacuum tube oscillator coupled therewith, such energy being transferred in greater or less degree with motional effect of said first part on said inductance, to a coupled circuit forming a portion of a detector, in whose plate circuit is incorporated a relay, adapted to function in one manner at one energy level from said oscillator in accordance with one movable part position, and in another manner when said energy level is varied in accordance with movement of said part a predetermined distance.

13. In an automatic control apparatus, the combination of a measuring instrument, having means for indicating or sensing departure from a prechosen level, such means including a movable position part, cooperating in spaced relationship with an inductance forming a portion of a resonant circuit, whereby motion of said part affects the tuning of said circuit, said circuit acting as a transmission channel for energy produced by a vacuum tube oscillator coupled therewith, such energy being transferred in greater or less degree with motional effect of said first part on said inductance, to a coupled circuit forming a portion of a detector, in whose plate circuit is incorpo-

rated a relay, adapted to function in one manner at one energy level from said oscillator in accordance with one movable part position, and in another manner when said energy level is varied in accordance with movement of said part a predetermined distance, said resonant circuit being provided with adjustable means for setting a predesired damping to thereby control the sensitivity of response for a given motion of said movable part.

14. In an automatic control system, a sensitive measuring instrument having a variable position part the position of which is controlled by variations in conditions to which the instrument is subjected, such variable position part cooperating with an inductive portion of an oscillating circuit, said inductive portion being adjustably movable over a total range of the indicating portion of the variable position part, said oscillator in turn controlling a relay which is in one position when said variable position part is below said inductive portion to control the control system in one manner and in another position when said variable position part is in prechosen relationship with said inductive portion to control the controlled system in a second manner, said inductive portion having mounted in mechanically spaced relation therewith a stop element to prevent the variable position part from assuming a position with respect to said inductive portion whereby the controlled system would become non-operative.

15. A claim such as claim 6 with the spiral coil flat.

16. A claim such as claim 8 with the spiral coils flat.

17. The combination with an instrument having a variable position part whose position is controlled by variation in conditions to which the instrument is subjected, of an oscillator circuit having spaced inductances cooperating with said part, said part in its motion affecting the inductive relationship of said inductances whereby said oscillator in turn controls the position of said part and means for maintaining said part and said inductances at a predetermined potential relationship to thereby prevent disturbing electrical effects upon the measuring ability of said instrument.

18. A claim such as claim 1 with the instrument of the millivoltmeter variety with an operating torque of not more than 1.0 millimeter grams per 90 degrees of rotation.

19. A claim such as claim 2 with the instrument of the millivoltmeter variety with an operating torque of not more than 1.0 millimeter grams per 90 degrees of rotation.

20. A claim such as claim 3 with the instrument of the millivoltmeter variety with an operating torque of not more than 1.0 millimeter grams per 90 degrees of rotation.

21. A claim such as claim 4 with the instrument of the millivoltmeter variety with an operating torque of not more than 1.0 millimeter grams per 90 degrees of rotation.

22. A claim such as claim 9 with the instrument of the millivoltmeter variety.

23. A claim such as claim 10 with the instrument of the millivoltmeter variety.

24. A claim such as claim 12 with the instrument of the millivoltmeter variety.

25. A claim such as claim 13 with the instrument of the millivoltmeter variety.

26. A claim such as claim 14 with the instrument of the millivoltmeter variety.

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