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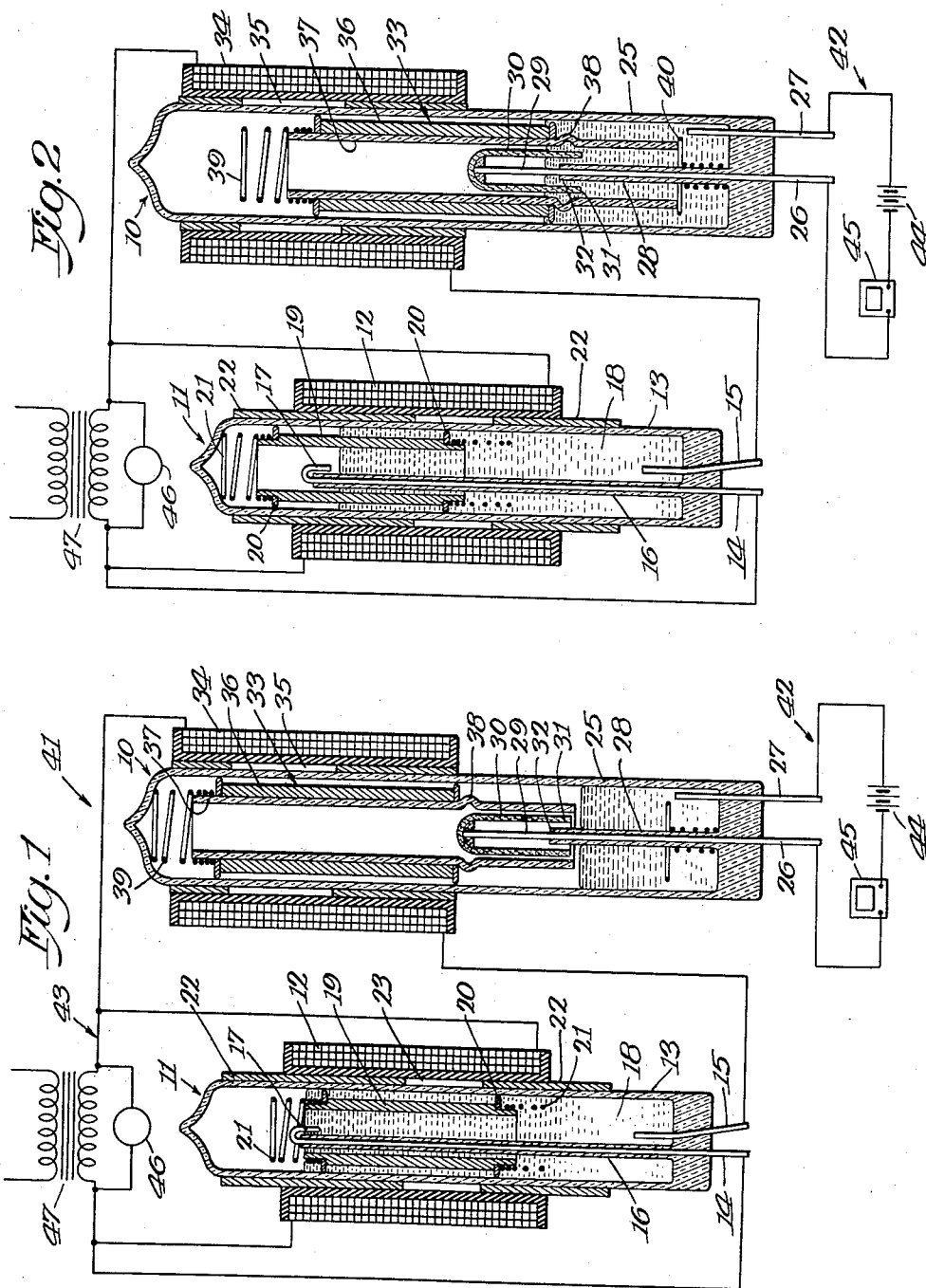
U. C. HEDIN ET AL

2,208,271

MERCURY SWITCH RELAY AND CIRCUIT

Filed Feb. 24, 1937

3 Sheets-Sheet 1



Inventors
Uno C. Hedin
Carl H. Larson
By Gillson, Mann & Co. Attys.

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Fig. 4

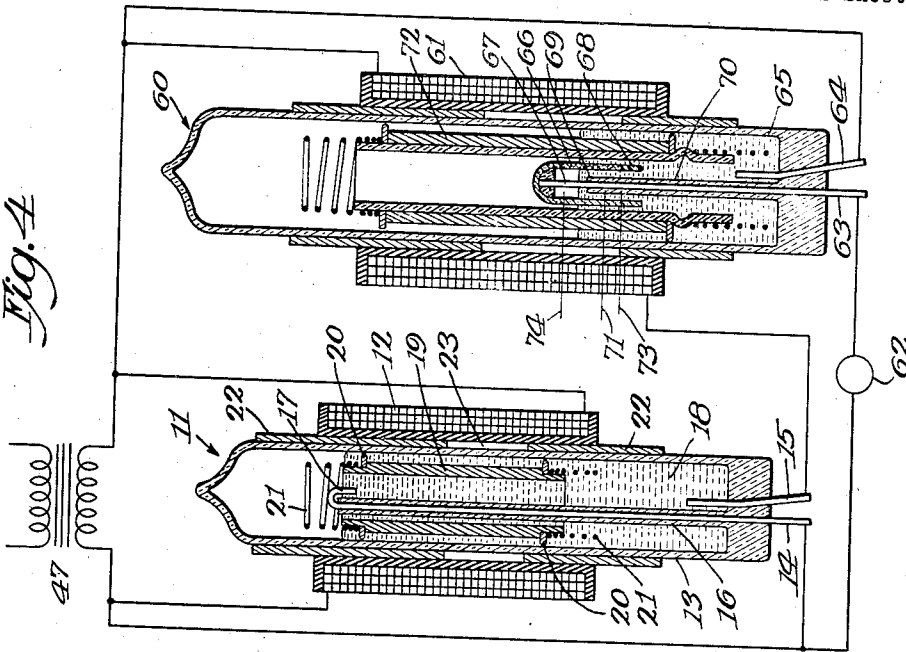
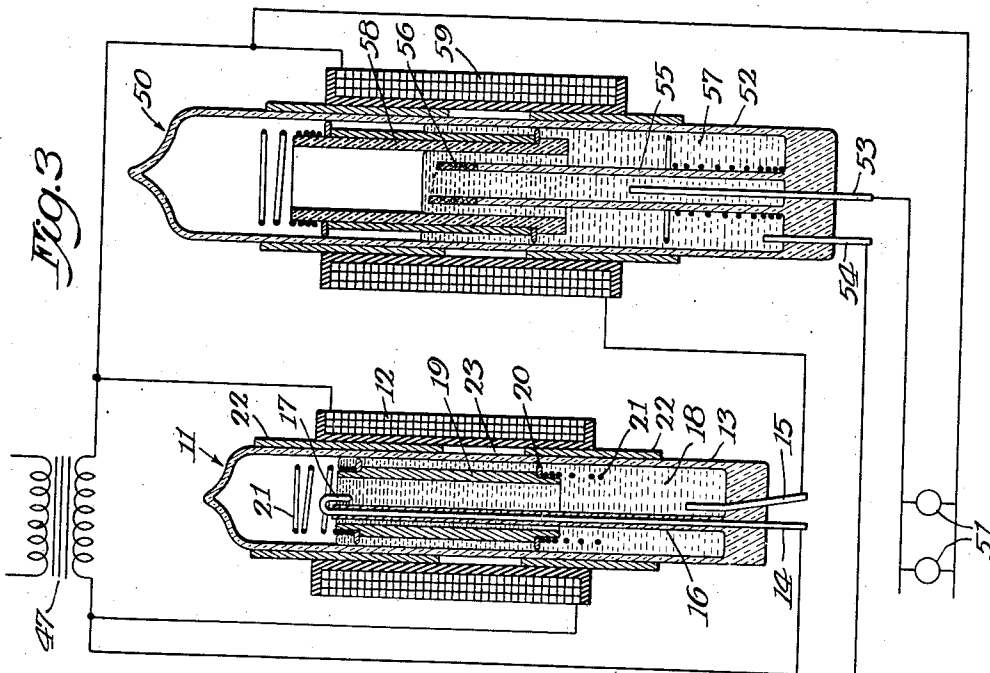


Fig. 3



Inventors
Uno C. Hedin
Carl H. Larson
By *Gilson, Mann & Coys.*

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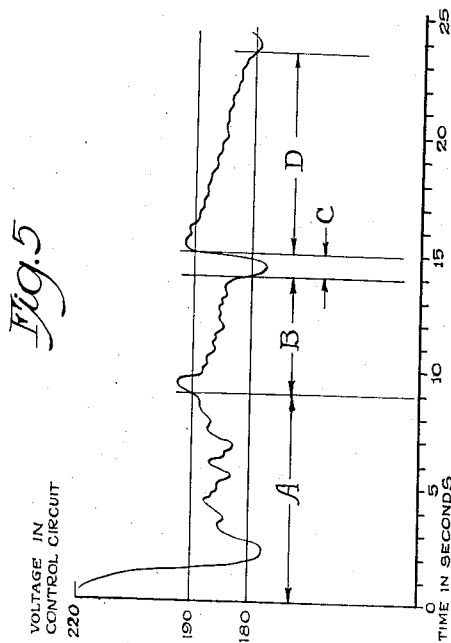
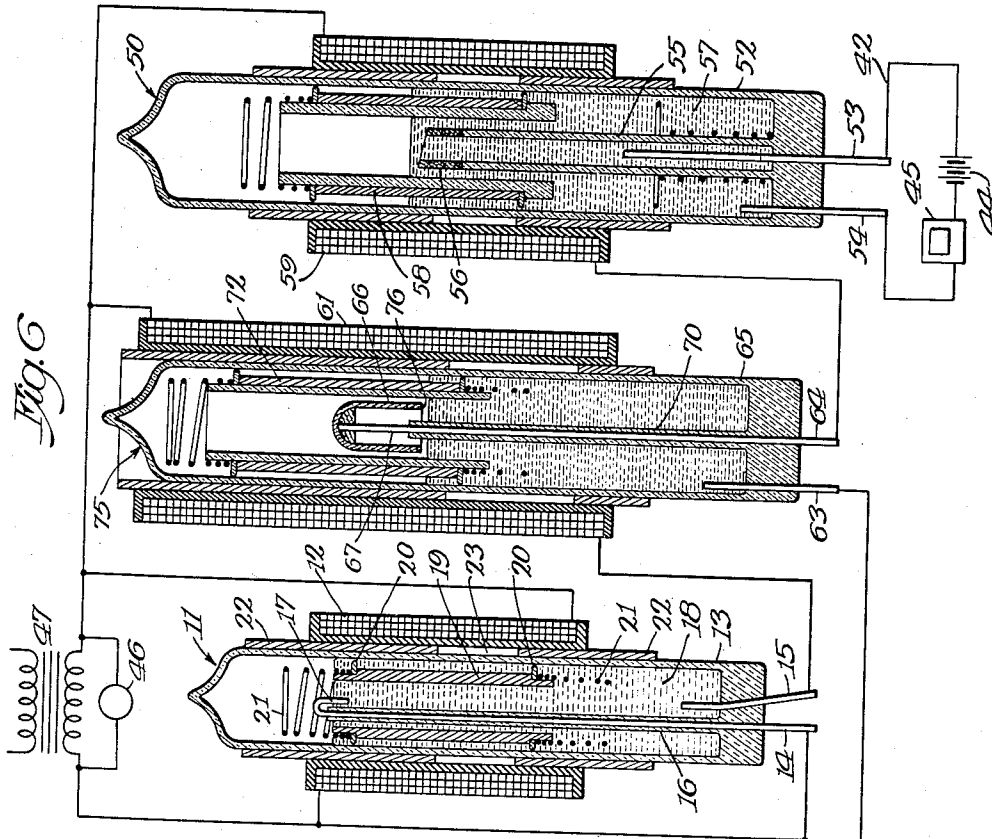
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MERCURY SWITCH RELAY AND CIRCUIT

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3 Sheets-Sheet 3



Inventors:
 Uno C. Hedin
 Carl H. Larson
 By *Hedman, Mann & Co.*
Attys.

UNITED STATES PATENT OFFICE

2,208,271

MERCURY SWITCH RELAY AND CIRCUIT

Uno C. Hedin and Carl H. Larson, Elkhart, Ind.,
assignors to The Adlake Company, a corporation of Illinois

Application February 24, 1937, Serial No. 127,390

10 Claims. (Cl. 175—320)

It is common practice to control a load relay by means of a pilot relay, but ordinarily the operating coil for the load switch is energized from a different source than that used by the pilot relay.

In most mercury switch relays, and to some extent, in electromechanical relays, the span between the pickup and drop away values of the relay is directly proportional (as distinguished from inversely proportional) to the load carried by the relay, i. e. if the relay is to handle a heavy load, it is very difficult, if not impossible, to obtain a small span between the pickup and drop away values of the relay, yet many times this relationship between load and voltage span is highly desirable.

It is one of the objects of this invention to provide means for operating a heavy load relay on small differences of voltage.

The relay and circuit of this invention also has another important application and use, and that is in cases where it is desirable to have the condition of the circuit controlled by the load switch changed only after there has been a continuous, as distinguished from a momentary, change in the voltage of the control circuit.

These and other objects and advantages will become apparent as the disclosure proceeds and the description is read in conjunction with the accompanying semi-diagrammatic drawings, in which

Fig. 1 shows a relay which is adapted to change the condition of a load circuit only after the control circuit has dropped below a predetermined minimum voltage for a specified length of time, the load switch being shown in its open circuit position;

Fig. 2 is a view of the relay shown in Fig. 1 with the load switch in its closed circuit position;

Fig. 3 is a view of a relay which is used for heavy loads;

Fig. 4 is a view showing a relay in which the load switch has a time delay element which acts both upon opening and closing of the associated electrical circuit;

Fig. 5 is a diagram in which the voltage of the control circuit is plotted against time; and

Fig. 6 shows a modified form of the invention.

The illustrative embodiments of the invention shown in the drawings and hereafter described are chosen for the purpose of complying with Sec. 4888 of the Revised Statutes, but the appended claims should be construed as broadly as the prior art will permit.

The relay shown in Figs. 1 and 2 is used where an electrical circuit is to be closed whenever the circuit to be controlled falls below a predetermined voltage for a specified length of time. The relay is particularly useful in cases where the control or primary circuit is subject to comparatively gradual rises and falls in potential, or where that circuit is likely to fluctuate between rather narrow limits of voltage near the critical voltage of the relay. It is not desirable to close the load or secondary circuit unless the primary circuit has definitely fallen below a predetermined minimum value for a definite period of time and the relay of Figs. 1 and 2 is intended to accomplish this object.

The load switch is indicated at 10 and the control switch at 11, the former being of the mercury displacement type disclosed in Larson 1,967,946, and the latter being of the mercury displacement type disclosed in Larson Patent No. 1,967,247. The load switch is a slow make, quick break switch, i. e. the circuit which it controls is not closed until a predetermined length of time has elapsed after the operating coil has been de-energized, whereas the circuit is opened immediately whenever the associated operating coil is energized. The control switch 11 is of the fast acting type, i. e. it has no time delay element to introduce a lag between the operation of the associated operating coil and the circuit which the switch controls.

The control switch 11 is operated by a coil 12 and comprises briefly a switch envelope 13 through the base of which electrodes 14 and 15 are suitably sealed, the former being insulated to a point adjacent to its top by a sleeve 16 with the bared end 17 of the electrode bent over to form a suitable contact surface. The switch envelope has a mercury fill 18, the level of which is changed by a magnetically responsive displacer 19 operating under the influence of the coil 12. The displacer is guided in its movement by suitable guides 20, and springs 21 at the top and bottom of the displacer protect the ends of the switch envelope against breakage.

Magnetic pole sleeves 22 telescoped over the switch envelope 13 fix the position of the air gap 23 which influences the movement of the displacer 19.

The load switch 10 comprises a switch envelope 25 through the base of which electrodes 26 and 27 are sealed, the former having an insulating sleeve 28 surrounding it for a portion of its height, leaving the upper part of the electrode 26 bare, as indicated at 29. A thimble 30

of ceramic material or other porous material (an impervious thimble with a single restricted gas opening may be used instead) is secured to the bared end 29 of the electrode 26 with its lower edge 31 extending below the top 32 of the insulating sleeve 28.

A magnetically responsive displacer generally indicated at 33 is normally held in suspended position by an operating coil 34, the air gap for the iron circuit associated with the coil being indicated at 35. The displacer in this case consists of an outer shell 36 of magnetic material and an inner tube 37 of glass or ceramic material, the former seating upon a ledge 38 formed on the tube 37, and the two being frictionally held together by a spring 39 telescoped over the projecting end of the glass tube 37. The bottom end of the tube 37 projects downwardly over the thimble 30, the latter constituting the time delay element of the switch. When the coil 34 is de-energized, the displacer 33 is released from its suspended position and displaces a sufficient quantity of mercury to raise the outside mercury level above the top 32 of the sleeve 28, but the mercury level within the thimble 30 rises at a rate which corresponds to the seepage of the entrapped gas within the thimble through the pores of the wall. After a predetermined period of time has elapsed subsequent to the releasing of the displacer from its suspended position, the mercury level within the thimble 30 will rise above the top 32 of the insulating sleeve 28, thereby closing the circuit between the electrodes 26 and 27, and this time interval is the same for every lowering of the displacer 33 providing the latter always starts from its original suspended position.

The closed circuit position of the load switch is shown in Fig. 2 with the tube 37 resting upon a spring 40, frictionally secured to the insulating sleeve 28 associated with the central electrode 26, and when the coil 34 is again energized, the displacer 33 is lifted by magnetic force to the position shown in Fig. 1 with the result that the mercury level immediately falls to the position in which it is shown in Fig. 1, thereby breaking the electrical circuit between the electrodes 26 and 27 without delay. The switch, therefore, operates as a slow make, quick break switch.

Let it be assumed that the entire relay, which for convenience will be designated generally 41, is to close a secondary circuit, generally designated 42, whenever the primary circuit generally designated 43 falls below a predetermined standard for a period of time corresponding to the time delay action of the thimble 30 of the load switch 10. The load or secondary circuit may include a source of electromotive force 44 and a relay 45 which may be used to ring an alarm or energize other relays for connecting the load 46 of the primary circuit to some other source of electromotive force.

The load 46 of the primary circuit is shown connected across the secondary of a transformer 47 which may be considered as the source of electromotive force for the primary circuit. The operating coil 12 of the control switch and the operating coil 34 of the load switch are likewise connected across the secondary of the transformer 47, but the latter coil is connected in series with contacts 14 and 15 of the control switch so that its action is dependent upon the control switch.

It will be convenient to illustrate the action of the relay 41 by assuming definite voltage con-

ditions in the source 47 of the electromotive force and assigning suitable pickup and drop away values, all of which are capable of being obtained, to the load and control switches 10 and 12. For example, let it be assumed that the source 47 is normally 220 volts, and that the secondary circuit 42 is to be energized whenever the voltage of the source falls below 180 volts for a period of say three seconds; also that the secondary circuit is to be de-energized whenever the source 47 is restored to 190 volts or higher. Under such circumstances, the control switch coil 12 will be wound so that the control relay represented by the switch 11 and coil 12 will have a drop away value of 180 volts and a pickup value of 190 volts. The load switch relay represented by the coil 34 and the switch 10 should then have a somewhat lower range of pickup and drop away values, for example, a drop away of 110 volts and a pickup of 140 volts, and the time delay element of the load switch 10 should have a time factor of three seconds.

If now the source gradually falls in potential below 180 volts, the coil 34 of the load relay will be de-energized at the instant when the control switch 11 opens the circuit between the electrodes 14 and 15, i. e., when the voltage drops below 180 volts. As soon as the coil 34 is de-energized, the displacer 33 falls to the position shown in Fig. 2 and the mercury level will start to rise in the thimble 30 to close the circuit through the electrodes 26 and 27 after a three second interval. Should the voltage of the source 47 be restored to normal within that period, or at least rise above 190 volts, the coil 35 will again be energized and the mercury will fall away from the thimble 30 before it has had an opportunity to reach the bared end 29 of the electrode 26. It is, therefore, obvious that in the arrangement shown in Figs. 1 and 2, the voltage in the source 47 must drop below 180 volts for a period of at least three seconds (for the conditions assumed) before the secondary circuit 42 is closed through the electrodes 26 and 27.

If a control switch 11 had not been used, and the load switch 10 had been directly responsive to the voltage condition of the source 47, the gradual fall in potential would have resulted in the displacer 33 slowly being lowered within the switch envelope, thereby causing some mercury to enter the thimble 30 before the drop in voltage had reached a critical value of the relay. Upon reaching this value, the displacer 33 would fall to the position shown in Fig. 2, but the secondary circuit 42 would be closed within a shorter interval than three seconds because of the mercury that had entered the thimble 30 before the voltage had fallen to the drop away of the relay. Obviously this is an undesirable condition which the circuit arrangement and relays of this invention overcome.

The control relay also tends to prevent fluctuations of voltage near the critical drop away value of the relay from operating the load switch 10 for if the load relay were to be used alone, a momentary drop in voltage would drop the displacer of the load switch and start the time interval running for closing the secondary circuit, even though the primary circuit immediately returned to a voltage above the drop away value of the relay, but below the pickup value of the relay.

Furthermore, it would be very difficult, if not impossible, to have a switch of the type shown in Fig. 2 operate on a ten volt difference between 75

pickup and drop away values for a source normally operating at 220 volts.

In Fig. 3, the control switch 11 is identical with the corresponding switch in Figs. 1 and 2, and its operating coil 12 is similarly connected across the source 47. The same reference characters will, therefore, be used for corresponding parts.

The load switch 50 in this case is a fast acting, heavy duty switch adapted to control a high amperage load represented by lamps 51. The switch comprises a switch envelope 52 through the base of which electrodes 53 and 54 are suitably sealed, the former being enclosed within a tube 55 of insulating material, preferably of glass, to the top of which a tube 56 of ceramic material is fused, or otherwise secured. The mercury fill 57 of the switch occupies the space within the coaxial tubes 55 and 56, as well as the space outside, and the mercury level is shifted by a displacer 58 in response to a coil 59 to make or break a circuit through the electrodes 53 and 54, according to the condition of the coil 59. The switch 50 is commonly known as a fast acting mercury to mercury contact heavy duty circuit breaker.

A mercury to mercury circuit breaker of this type necessarily requires a rather wide span between pickup and drop away values for operation and yet there are circuits in which conditions necessitate closer regulation.

A switch of the type indicated at 11 is capable of operating on small differences between pickup and drop away values so that by using the switch 11 as a control for the operating coil 59 of the load switch as shown in Fig. 3, the load switch is actually operated on much smaller changes in voltage than would otherwise be possible. To do this, however, the operating coil 12 for the control switch should be wound to provide the desired pickup and drop away values of the entire relay and for illustration, it may be assumed that the circuit through the electrodes 14 and 15 of the control switch should be closed whenever the voltage in the source 47 is 190 volts or more, and should be open whenever the source of voltage is 180 volts or less. For these values, the coil 59 may be wound so that it will pick up at 140 volts and drop away at 95 volts.

The reason for having the load relay operate on substantially lower pickup and drop away voltages than are used for the control relay is because this relationship between the operating characteristics of the two relays makes certain (with a relatively large factor of safety) that whenever the control relay drops away, the load relay will likewise drop away, and whenever the control relay picks up, the load relay will likewise pick up.

It will be understood, however, that the relationship between the operating characteristics of the two relays may vary within rather wide limits.

The relay and circuit combination shown in Fig. 4 is similar to the one shown in Figs. 1 and 2, the principal difference being that the load switch 60 is a slow-make, slow-break front contact switch instead of a slow-make, quick-break back contact switch. The relay and circuit arrangement is advantageously used for controlling the operation of a motor running under a heavy load, since it is desirable to shut off the motor whenever the voltage falls below a predetermined standard, say 180 volts, for a specified period, for example three seconds, and for the motor to be turned on again whenever the voltage is restored

to some higher value, say 190 volts, for a specified period, for example three seconds.

The control switch 11 has its contacts 14 and 15 connected to the operating coil 61 of the load switch 60 as in Figs. 1, 2 and 3, and both of the operating coils for the switches 11 and 60 are connected across the secondary of the source 47. The load, which in this case is a motor, is indicated at 62 and it also is connected across the secondary of the source 47 but in series with contacts 63 and 64 sealed through the base of the switch envelope 65 of the switch 60.

The ceramic thimble 66 which caps the bared end 67 of the central electrode 63 is similar in all respects to the thimble 30 shown in Figs. 1 and 2 with the exception that its lower margin 68 is substantially below the top 69 of the insulating sleeve 70 surrounding the central electrode and is also substantially below the normal level of the mercury indicated at 71 (i. e. the level of the mercury when the coil 61 is deenergized and the mercury is at equilibrium). By this proportioning of the parts, a time delay is introduced into both the closing and opening of the electrical circuit through the electrodes 63 and 64, since the displacer 72 never lowers the mercury level sufficiently to allow the outside mercury level to fall below the bottom 68 of the thimble 66, and, consequently, the energization and de-energization of the coil 61 merely establishes a difference of mercury level within and outside of the thimble 66, after which, equilibrium can be established only by the retarded flow of gas through the pores of the thimble 66.

By properly locating the top 69 of the insulating sleeve 70, the normal mercury level 71 and the lower margin 68 of the thimble 66 and by regulating the stroke of the displacer 72 (which can be done by varying the air gap in the magnetic circuit), the relationship between the time relay for closing the circuit and that for opening the circuit may be varied within fairly wide limits.

To assist in explaining the operation of the relay and circuit shown in Fig. 4, the control and load relays may be assumed to have the same pickup and drop-away values as those assumed for the corresponding relays in Figs. 1 and 2; i. e., the control relay may have a pickup value of 190 volts and a drop-away value of 180 volts and the load relay may have a pickup value of 140 volts and a drop-away value of 110 volts. If now, the voltage of the source falls from its normal of 220 volts to below 180 volts, the circuit through the electrodes 14 and 15 will be opened causing the coil 61 of the load relay to become de-energized. As soon as this occurs, the displacer 72 rises by its buoyancy, causing the outside mercury level to fall to a position such as indicated by the line 73. The inside mercury level, i. e., the level within the thimble 66, will gradually recede, the decline being determined by the porosity of the thimble 66. After a predetermined interval, which, for the purpose of illustration, may be three seconds, the circuit through the electrodes 63 and 64 will be opened, thereby shutting off the motor 62.

If now, the voltage of the source 47 is restored to 190 volts or more, the coil 61 is again energized, causing the displacer 72 to be lowered and the mercury level on the outside of the thimble 66 to be raised to a position such as that indicated by the line 74. The equilibrium in the mercury is established only after a predetermined period of time has elapsed to permit the

mercury within the thimble 66 to rise from the level indicated at 71 to the top 69 of the insulating sleeve 70. When this happens, the circuit through the motor 62 is again closed.

The advantage of having a time delay between the restoration of the voltage of the source and the starting of the motor is to allow the voltage in the source to become more or less constant in value and to allow the wild fluctuations, which often occur upon restoration of voltage, to level off.

The relay and circuit of Fig. 6 combine the advantages of the time delay load switch of Figs. 1 and 2 with the heavy duty load switch of Fig. 3. The control relay 11 is identical with the one shown in Figs. 1 and 2 and the load switch 50 is identical with the load switch of Fig. 3. The intermediate switch 75 is identical with the load switch 60 of Fig. 4 with the exception that the bottom edge 76 of the time delay element 66 is slightly above the mercury level when the relay is de-energized, so that the switch operates as a slow make, quick break front contact switch.

The circuit employed in Fig. 6 for the purpose of illustration is similar to that of Figs. 1 and 2, the intermediate or dampening switch 75 having its coil 60 connected across the transformer 47 in series with the electrodes of the control switch 11 and the operating coil 59 of the load switch being likewise connected across the transformer 47, but in series with the electrodes of the dampening switch 75.

If desired, the dampening switch may be made to provide a time interval both when the control relay 11 picks up and drops away and in such a case, the time delay element 66 would be extended further into the mercury in the manner shown in Fig. 4. In this case, the load circuit of Fig. 4 may be used in place of the independent load circuit indicated by 42 (Figs. 1, 2 and 6).

Throughout this specification, it has been convenient to use such expressions as "voltage dropping below 180 volts for a given period of time" and "voltage rising above 180 volts for a given period of time," but it should be understood that while the voltage changes in the control circuit will ordinarily respond literally to the language quoted above, there are some types of fluctuation in the control circuit which will cause the load relay to operate even though the voltage in the control circuit is not maintained for a specified period above or below the value which initially causes operation of the control relay. For example, the voltage fluctuation of the control circuit indicated by the portion A of the curve in Fig. 5 illustrates the situation in which a momentary drop of the control circuit voltage below 180 volts causes the load relays of Figs. 1, 2 and 4 to become de-energized but the load relays cannot again pickup because the voltage, while it rises above 180 volts, does not reach the pickup value of 190 volts of the control relay until after say 9 seconds have elapsed, and within this period, the three second time delay of the load switches has allowed the load circuits to be completed (Figs. 1, 2 and 4).

A similar situation occurs when the control circuit voltage surges momentarily above 190 volts after having been below that value and then continues to fluctuate between 190 and 180 volts for a period longer than the time delay provided in the load switches. This situation is illustrated by the portion B of the curve in Fig. 5 and the action of the load relay in Fig. 4, for once the control relay has picked up, the time delay ele-

ment of the load switch will permit the closing of the load circuit after a predetermined time interval has elapsed, unless the control relay again drops away within that period of time.

The portion of the curve in Fig. 5 indicated by C shows a type of voltage fluctuation which the control relay effectively handles without causing operation of the load switches of Figs. 1, 2, 4 and 6.

The portion D of the curve in Fig. 5 indicates the manner in which a gradual fall in voltage immediately prior to the dropping away of the control relay will effect an accurate timing of the closing of the load circuit whereas such a result could not be obtained if the voltage were applied directly to the coil of the load switch.

Because of the situations illustrated by A and B on the curve of Fig. 5, it is obvious that the relay and circuit of this invention give more accurate regulation than could be obtained without the use of a pilot relay, for the greater the span between the pickup and drop away values of the relay, the more aggravated is the inaccuracy caused by the voltage conditions represented by A and B in Fig. 5.

In all forms of the invention, the action of the load switch is characterized by positive "on" or "off" action as distinguished from the action of a control switch in which the position of the displacer is substantially proportional to the voltage in the operating coil, or, stated in other words, the relatively low pickup and drop-away values of the load relay make the relay insensitive to fluctuations in line voltage other than those which are sufficiently sustained to make positive operation of the load relay desirable.

All specific voltage and time delay values referred to herein are merely illustrative, and do not impose limitations on the appended claims.

We claim:

1. In combination, a source of electromotive force that is subject to comparatively gradual rises and falls in potential and/or rapid fluctuations of voltage within rather narrow ranges of potentials, a mercury switch relay connected to said source and adapted to close an electrical circuit whenever the source of electromotive force has fallen below a specified value for a predetermined period of time, said relay comprising a load switch of the back contact time delay mercury displacement type, a coil connected to said source for operating the load switch, a control switch having its contacts in series with the coil of the load switch and an operating coil for the control switch connected to said source.

2. In combination, a source of electromotive force that is subject to comparatively gradual rises and falls in potential and/or rapid fluctuations of voltage within rather narrow ranges of potentials, a mercury switch relay connected to said source and adapted to close an electrical circuit whenever the source of electromotive force has fallen below a specified value for a predetermined period of time, said relay comprising a load switch of the back contact time delay mercury displacement type, a coil connected to said source for operating the load switch, a control switch having its contacts in series with the coil of the load switch and connected to said source, and an operating coil for the control switch connected to said source, the pickup and drop away values of the load switch coil being less than the corresponding values for the control switch coil.

3. In combination, a source of electromotive

force, a relay for changing the condition of an electrical circuit whenever the source has fallen below a specified voltage for a predetermined length of time, said relay including a load switch having a time delay element, a coil for operating the load switch, a control switch having its contacts connected in series with the load switch coil and the source, and an operating coil for the control switch also connected to the source, said series connection operating to continuously maintain the load switch in its desired position until the source has fallen below said specified voltage for said specified period of time, and then return the load switch to said position whenever the voltage rises above said specified voltage.

4. In combination, a source of electromotive force, a relay for changing the condition of an electrical circuit after the source potential has varied by some given amount, said relay including a load switch having an operating coil, a control switch having its contacts connected in series with the coil of the load switch and the source, and an operating coil for the control switch also connected to said source, said series connection operating to continuously maintain the load switch in its desired position until the source has varied by said given amount and then return the load switch to said position whenever the voltage returns to its normal value.

5. In combination, a source of electromotive force, a relay for changing the condition of an electrical circuit after the source potential has varied by some given amount, said relay including a load switch having an operating coil, a control switch having its contacts connected to the coil of the load switch and to the source, and an operating coil for the control switch also connected to said source, the control switch having pickup and drop away values relatively close to one another and the load switch having pickup and drop away values substantially lower, respectively, whereby the load switch may function in response to the pickup and drop away values of the control switch.

6. In combination, a source of electromotive force, a relay for changing the condition of an electrical circuit after the source potential has varied by some given amount, said relay comprising a load switch of the mercury displacement type in which the intermittently immersed electrode has a form which inherently adapts the switch to high load, but effects a relatively large span between the pickup and drop away values of the switch, an operating coil for the load switch, a control switch having its contacts connected to the coil of the load switch and to the source and being of a type which is inherently capable of operating on a relatively small span between pickup and drop away values, and an operating coil for the control switch also connected to the source.

7. In combination, a source of electromotive force that is subject to comparatively gradual rises and falls in potential and/or rapid fluctuations in voltage within rather narrow ranges of potential, a mercury switch relay connected to said source and adapted to change the condition

of an electrical circuit whenever the source potential has exceeded or fallen below predetermined maximum and minimum values, respectively, for a specified length of time, said relay comprising a load switch of the slow make, slow break mercury displacement type, a coil for operating the load switch, a control switch having its contacts in series with the coil of the load switch, and an operating coil for the control switch connected to said source.

8. In combination, a source of electromotive force, a relay for changing the condition of an electrical circuit after the source potential has varied by some given amount, said relay including a load switch, a control switch, and operating coils for each, and means for connecting the coil of the control switch to the source, and the coil of the load switch to the source but in series with the contacts of the control switch whereby the load switch coil is energized only when the control switch contacts are closed and the load switch though controlled by the same source which operates the control switch is characterized by positive "off and on" action in its operation, said series connection operating to continuously maintain the load switch in its desired position until the source has varied by said given amount and then return the load switch to said position whenever the voltage returns to its normal value.

9. In combination, a source of electromotive force, a relay for changing the condition of an electrical circuit whenever the source has fallen below a specified voltage for a predetermined length of time, said relay including a load switch, a coil for operating the load switch, a control switch adapted to operate the load switch, an operating coil for the control switch connected to the source, and means for delaying the changing of the condition of the electrical circuit through the load switch until after the source has fallen below a specified voltage for a predetermined length of time, said means including a time delay element associated with the load switch whose action begins when the voltage falls below the specified value and which immediately resets itself whenever the voltage rises above the pickup value of the control switch.

10. In combination, a source of electromotive force, a relay for changing the condition of an electrical circuit after the source potential has varied by some given amount, said relay comprising a fast acting load switch of the mercury displacement type in which the intermittently immersed electrode has a form which inherently adapts the switch to high load, but effects a relatively large span between the pickup and drop away values of the switch, an operating coil for the load switch, a control switch having its contacts connected to the coil of the load switch and to the source and being of a type which is inherently capable of operating on a relatively small span between pickup and drop away values, and an operating coil for the control switch also connected to the source.

UNO C. HEDIN.
CARL H. LARSON.