

Sept. 11, 1951

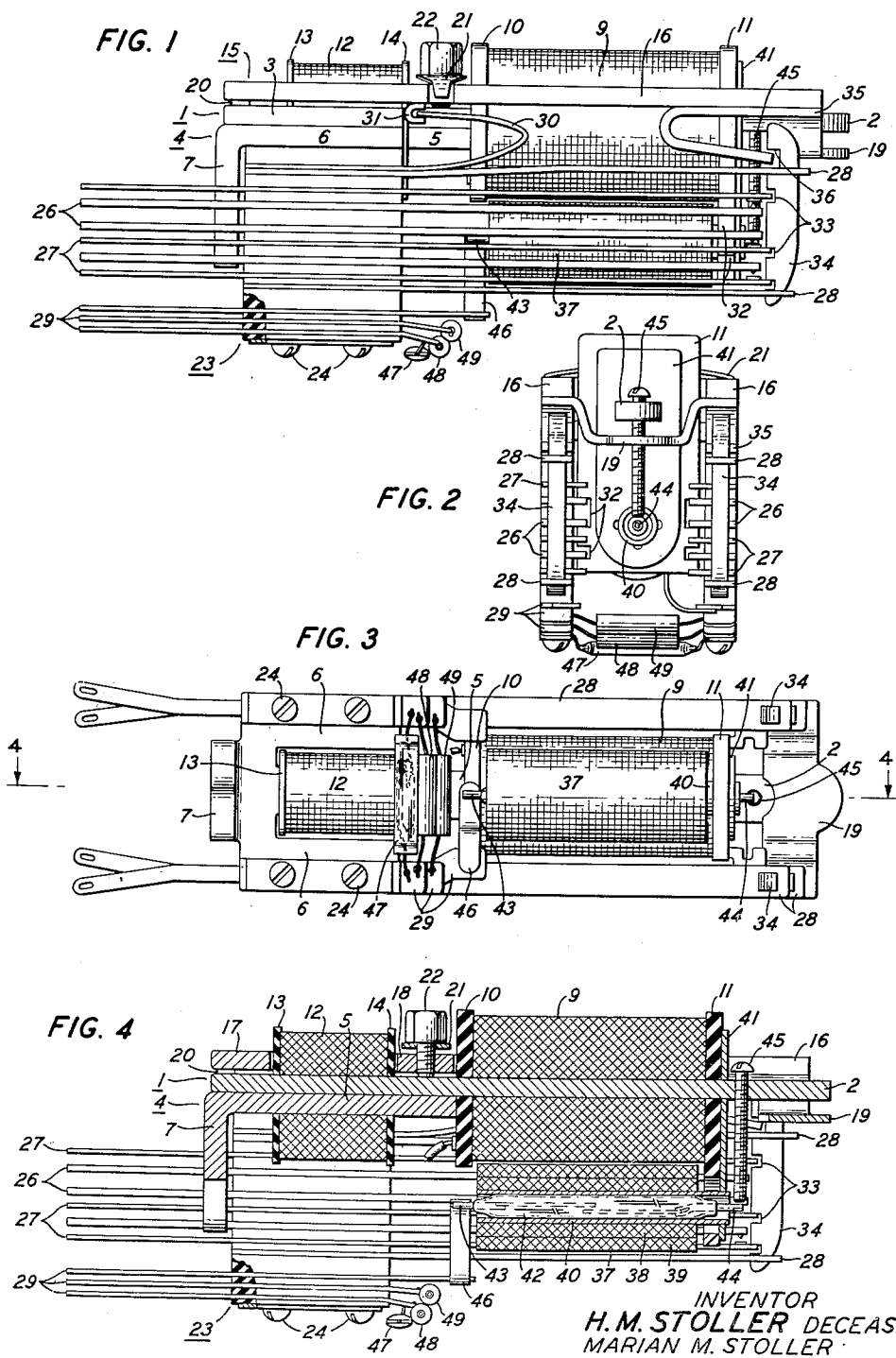
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2,567,827

TIME DELAY RELAY

Filed March 12, 1948

3 Sheets-Sheet 1



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TIME DELAY RELAY

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3 Sheets-Sheet 2



BY

Sept. 11, 1951

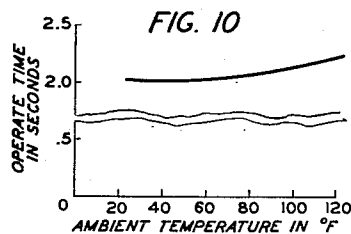
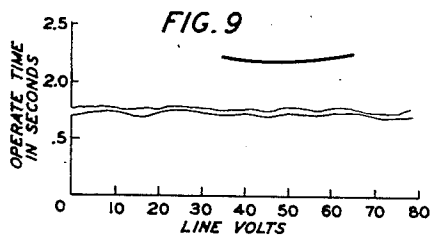
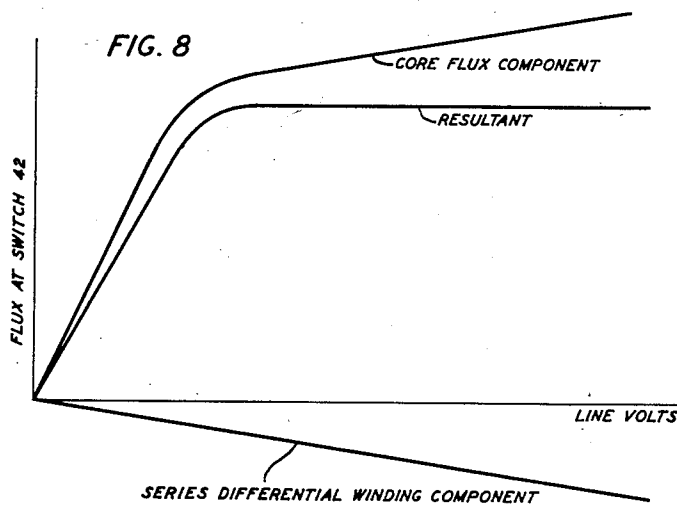
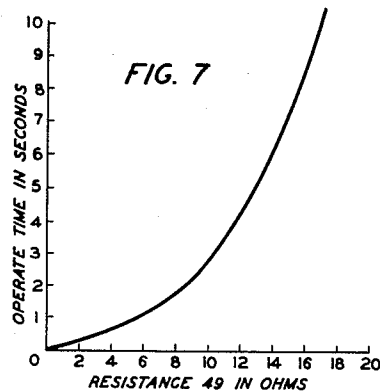
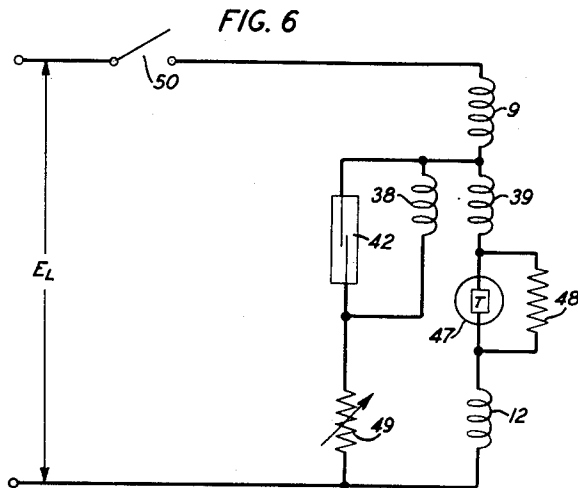
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TIME DELAY RELAY

Filed March 12, 1948

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,567,827

TIME DELAY RELAY

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Application March 12, 1948, Serial No. 14,597

8 Claims. (Cl. 175—335)

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This invention relates to electromagnetic devices and more particularly to improvements in relays of the slow-to-operate type.

In order to meet requirements for relays which will operate after a relatively long time delay, i. e., of the order from one-half of a second to several minutes, industry has generally been forced to resort to unduly expensive arrangements such as mercury relays or to expensive and cumbersome combinations of relays, vacuum tubes, and condenser-resistance time delay networks. A variety of improvements and alternate schemes have been proposed, and many of these have been directed at the utilization of a resistor having a high temperature coefficient of resistance in various circuit combinations with a standard fast-operating relay. Most such arrangements have found limited application industrially in view of the appreciable variations in delay intervals arising from variations in ambient temperature, line voltage, or frequency of operation. On August 18, 1925, Patent 1,550,155 was granted to A. S. Fitzgerald which disclosed a solution to certain of these difficulties through the use of both the heating and cooling period of a temperature sensitive resistor to provide a reasonably constant time delay interval.

The applicant has met the demand for an efficient, compact, reliable time-delay relay for utilizing the full cycle of heating and cooling of a resistor, the resistance of which changes greatly with changes in temperature, by employing a series-make magnetically operable switch, and by providing other circuit elements, all in combination with an improved relay structure. The resulting design provides a unitary structure, substantially eliminates variations in the time delay interval resulting from normal variations in line voltage or ambient temperature, and effectively abates the memory characteristics of most prior circuits, i. e., it provides a high degree of constancy of delay whether the relay is repetitively operated or whether there is an appreciable lapse of time between consecutive operations.

In general the invention comprises a relay structure having a main energizing winding and a secondary energizing winding wound upon a common core. A suitably shaped armature is associated with the core in such a fashion that two opposing air gaps between the core and the armature are provided: a hold gap across which a flux is induced primarily by the secondary winding, and an appreciably larger main gap across which a flux is induced primarily by the main winding of the relay. Since the hold gap

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and main gap are on opposite faces of the core, and since they are located at different distances from the hinge, opposing moments on the armature will be produced when the magnetic circuit is energized. Basically, the main winding, the secondary winding and a temperature sensitive resistor, which shall hereinafter be referred to as a "thermistor" and which in the embodiment herein presented has a large negative temperature coefficient of resistance, are connected in circuit with a source of electrical energy. A series-make contact operable, primarily, by the flux induced by the main winding, and a resistance are placed in shunt of the secondary coil and of the thermistor. Closure of a line switch will complete the series circuit through the main coil, thermistor, and secondary coil, and the parameters of the magnetic and electrical circuits are such that the moment exerted by the force across the hold gap is sufficiently greater than the opposing moment exerted by the force across the main gap that the relay will be prevented from operating. As the thermistor heats due to the current passing therethrough, the resistance of that element gradually decreases and, as a result, the current through the series-connected main coil, thermistor, and secondary coil increases; but since the flux induced by the secondary coil increases in proportion to the flux generated by the main coil, the relay will not operate. When the current through the series circuit reaches a certain value, the flux induced by the main coil will be sufficient to operate the magnetically operable series-make contact and a portion of the current previously flowing through the thermistor and secondary windings will be by-passed through the aforementioned resistor, thereby permitting the thermistor to start cooling. At the beginning of this cooling period, sufficient current flows through the secondary winding to prevent the operation of the relay, but as the resistance of the thermistor gradually increases, a critical point is reached at which the force exerted upon the armature across the hold gap as a result of the flux induced by the secondary winding is reduced to the point where the force exerted across the main gap is sufficient to operate the relay.

The use of series and shunt differential coils to secure time elements that are stable despite variations of line voltage or ambient temperature, the shunting of the thermistor with a resistance to provide a maximum threshold value for the thermistor, and the provision of means for varying the time delay will all be discussed

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in detail hereinafter with reference to the accompanying drawings in which:

Fig. 1 is a top view of the relay and associated circuit elements embodying features which constitute the invention, the relay being shown in the unoperated position. The wiring in this and subsequent drawings has been omitted for purposes of clarity;

Figs. 2 and 3 are end and side views, respectively, of the relay shown in Fig. 1;

Fig. 4 is a top view in section of the relay and associated elements;

Fig. 5 is a partially exploded perspective of the relay with certain parts broken away, and with the relay inverted relative to the drawing of Fig. 1;

Fig. 6 is a circuit diagram showing the electrical interrelationship of the various elements;

Fig. 7 is a curve showing the change of delay time interval with changes in the value of the resistance in series with the magnetically operable switch;

Fig. 8 depicts the effect of the series differential coil on the flux at the magnetically operable switch; and

Figs. 9 and 10 show the results of tests demonstrating the high degree of constancy of time delay with variations in line voltage or ambient temperature.

The major structure of the relay proper and particularly the relationship of the core and armature and the provision of opposing air gaps therebetween is based upon modifications of the structure disclosed in United States Patent 2,516,790 granted July 25, 1950 to E. R. Morton and H. M. Stoller.

The series-make contact 42 (Figs. 4 and 5) is a magnetically operable switch which is more fully disclosed in Patent 2,289,890 granted July 14, 1942 to Walter B. Ellwood. It comprises essentially a pair of mating contacts sealed in a chamber and operable at a given flux density.

The thermistor 47 (Figs. 1, 2, 3 and 5) may be of any suitable type such as a bead of the semiconductor with two metallic conductors inserted therein, a disc between two metallic plates, or a film on a metallic plate with a second metallic point contact. In the depicted embodiment, a bead formed of the heat-treated mixed oxides of manganese, nickel and cobalt has been used and is enclosed in a sealed glass envelope and further protected by an outer sleeve. The large negative temperature coefficient of the bead used in this embodiment causes the resistance to decrease as the temperature rises due to the power dissipated in the structure. Since the heating effect implies a time interval, a time lag is introduced in the reduction of the thermistor to a low resistance, and an additional time lag is introduced in the return of the thermistor to a high value of resistance upon cooling. Both of these delay periods may be utilized in the present invention.

Referring now to Figs. 1 through 5 of the accompanying drawings in which the reference characters refer to the same parts in all figures, the core 1 is of flat E-shaped construction with the center leg 2 longer than the two outer legs 3. Mounted in juxtaposition to the core 1 is a flat E-shaped frame mounting piece 4 having a center leg 5 and outer legs 6. An angle extension 7, integral with frame mounting piece 4, is provided with apertures 8 (Fig. 5) adapted to receive frame mounting bolts. Mounted upon the core center leg 2 near the front of the relay is a main coil 9 having spoolheads 10 and 11.

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Seated against the crosspieces of the core 1 and the frame mounting piece 4 and mounted upon the center legs 2 and 5 thereof is the secondary coil 12 having spoolheads 13 and 14.

The armature 15 is a flat member of magnetic material comprising two legs 16, a rear crosspiece 17, a center crosspiece 18, and a front U-shaped crosspiece 19. The armature rear crosspiece 17 is provided with pins adapted to engage apertures in the crosspiece of the core 1 with non-magnetic washers 20 maintaining the core and armature in spaced relationship at the hinging points, and thus providing a hinge air gap in the magnetic circuit. The armature center crosspiece 18 extends transversely of the relay in the area between the main coil 9 and the secondary coil 12, and is positioned relative to the core 1 so that upon energization of the magnetic circuit, a force is exerted which tends to cause the armature center crosspiece 18 to bridge the core outer legs 3 and the core center leg 2 which form the poles of the magnetic circuit induced by the secondary winding 12. The gap between the armature center crosspiece 18 and the core 1 will be called the hold gap. The front U-shaped armature crosspiece 19 is offset so that the armature at this point is on the opposite side of the core 1 from the armature center crosspiece 18. The air gap between the armature front crosspiece 19 and the front end of the core center leg 2 will be hereinafter referred to as the main gap and may be appreciably larger than the aforementioned hold gap. Energization of the main coil 9 will induce a flux that will cause a force to be exerted across the main gap which will tend to bring the armature front crosspiece 19 into engagement with the front of the core center leg 2. It will be noted that as a result of the conformation of the armature, the comparative sizes of the hold and main gaps, and the length of the force arm from the hinge to each of the operating air gaps, two opposing moments will act upon the armature when both coils are energized.

The relay structure as thus recited is substantially that of the relay disclosed in the aforementioned patent application to Morton and Stoller, and reference may be made thereto for a more complete discussion of these elements.

The spring member 21 (Figs. 1 and 2) is adapted to retain backstop screw 22 in adjusted position in armature center crosspiece 18. Engagement of the end of this screw 22 with core center leg 2 provides a positive adjustment of the main air gap between the armature 15 and the core 1.

Spring pile-up assemblies 23 are positioned along the top and along the bottom of the relay, and are attached to the core 1 by means of screws 24 which pass through apertures 25 (Fig. 5) in the frame mounting piece 4 and engage tapped holes in the core outer legs 3. Each spring pile-up assembly comprises a plurality of fixed contact springs 26, a plurality of movable contact springs 27, inner and outer balancing springs 28, and a plurality of terminal lugs 29. Insulator plates separate each of the abovementioned elements and insulator sleeves are provided for the screws 24. An armature-return spring 30 is also mounted in each spring pile-up assembly 23 and engages a tang 31 on each armature leg 16 so as to exert a force tending to restore the armature 15 to its unoperated position. The contact springs 26 and 27 extend forwardly substantially parallel with the axis of the core and the heavier fixed contact springs 26 rest in notches 32 in the

main coil front spoolhead 11. Each fixed contact spring 26 is suitably bent so that it is pretensioned against either of the upper or lower edge of its associated notch 32 depending upon whether it makes or breaks contact with its associated movable contact spring 27. This provides for a slight movement of the fixed spring upon contact with the movable spring and, coupled with the double contacts provided on each of the movable and fixed springs, insures good electrical contact. The lighter movable contact springs 27 rest in notches 33 in actuating card 34, and are also pretensioned so as to tend to contact their associated fixed contact springs 26. As shown in Fig. 1, the contacts which break contact upon operation of the relay are normally in contact, and the movable springs are not engaged by the actuating card until the relay operates; the movable springs of those sets that make contact upon operation of the relay are normally biased out of contact with their mating fixed springs and are allowed to move into contact by the actuating card 34. The balancing springs 28 are pretensioned so as to cooperate with the armature-return springs 30 in returning the armature 15 to its unoperated position. Except for one of the balancing springs 28, the springs have not, for reasons of clarity, been shown suitably bent or bowed so as to be pretensioned.

A pair of U-shaped tangs 35 integral with the armature front crosspiece 19 are arranged to engage notches 36 in the actuating cards 34. It will be noted that upon actuation, the armature is free to travel a short distance before picking up the spring load and thereby the time delay element is effectively independent of spring loading.

Referring now particularly to Figs. 4 and 5, a differential coil 37 is mounted adjacent the main coil 9 and may be taped or clamped thereto although such has not been shown. The differential coil comprises a shunt differential winding 38 and a series differential winding 39 wound on a thin walled tube 40 of brass or of other non-magnetic material. A support plate 41 is mounted upon the core center leg 2 and extends in juxtaposition to the main coil front spoolhead 11. The front end of tube 40 extends through registering apertures in front spoolhead 11 and support plate 41 and may be soldered or otherwise attached to the latter. A series-make contact or magnetically operable switch 42, previously described, is placed within the tube 40 with the terminals 43 and 44 thereof extending beyond each end of the tube. An iron screw 45 extends through the end of the core center leg 2 and is adjustable to provide a small air gap between the end thereof and the front terminal 44 of the switch 42 (Figs. 2 and 4). The switch 42 is operated primarily by the leakage flux from the main coil 9 and the flux path may be traced through core 1, screw 45, across the small air gap to the switch front terminal 44, through the switch, and across the air gap from the switch rear terminal 43 to the core 1. The differential coil 37 exerts an opposing flux on the switch as will be hereinafter explained. The switch rear terminal 43 is soldered to a strap 46 which, in turn, is affixed to one of the terminal lugs 29, thus establishing an electrical connection therebetween as well as providing a supporting means for the rear of the switch. The remaining requisite circuit elements, the thermistor 47 and the two resistances 48 and 49, are shown connected across certain of the terminal lugs 29.

The wires interconnecting the various elements have not been shown for reasons of clarity but the several elements have been given the same numbers in the circuit diagram of Fig. 5 and the wiring should be done in accordance therewith.

Referring now to Fig. 6, the operation of the circuit will first be described with only those elements that are of major importance in the functioning of the circuit, i. e., the line switch 50, the main coil 9 in series therewith, the series connected thermistor 47 and secondary coil 12 on one parallel path, and the magnetically operable switch 42 and resistance 49 in the other parallel path. The remaining circuit elements, i. e., the resistance 48, and the differential coil assembly 37 comprising a shunt differential winding 38 and a series differential winding 39, will then be described in relation to the specific functions which they perform.

First considering the invention without the effect introduced by coil assembly 37 and resistance 48, as the line switch 50 is closed, a voltage E_L is applied to the circuit, and since the switch 42 is not operated, current will flow only through the series path of main coil 9, thermistor 47 and secondary coil 12. The initial resistance of the thermistor 47 is relatively high and therefore but a small current flows in this circuit, but it sufficiently energizes secondary coil 12 to cause the armature 15 to be held in its unoperated position by the force exerted across the hold gap. The current is insufficient, however, to cause the main coil to induce sufficient leakage flux to establish the critical flux density at which the magnetically operable switch 42 will operate.

As the thermistor 47 heats as the result of the power dissipated therein, its resistance gradually decreases, and, accordingly, the current through the above-mentioned series path increases proportionally. Since the flux induced by the main and secondary coils is increased equally relative one to the other, the armature is maintained in its unoperated position. When the resistance of the thermistor decreases sufficiently so that the leakage flux from the main coil reaches the critical value, the switch 42 will operate and shunt a portion of the current from the thermistor and secondary coil circuit through the resistance 49. The value of resistance 49 is such that sufficient current continues to flow through the secondary coil to hold the relay unoperated, i. e., the moment exerted on the armature by the force across the hold gap continues to exceed the moment exerted by the force across the main gap. Since the current through thermistor 47 is reduced, the thermistor will begin to cool and its resistance will gradually increase thereby further reducing the current flow through itself and through the secondary coil 12. The flux induced by the secondary coil therefore continues to decrease until such time as the moment exerted on the armature 15 across the main gap by the flux induced by the main coil will sufficiently exceed the opposing moment exerted across the hold gap by the flux induced by the secondary coil. At this time the armature will operate. It will be noted that only the heating period of the thermistor 47 may be utilized, if such appears desirable, by reducing the value of resistance 49 to zero.

From the above description it may be seen that switch 42 operates at a critical flux density which is achieved when a certain current flows

through the main coil. This current, in turn, is controlled by the resistance in the circuit, and thus, when the whole circuit reaches a critical value of resistance, the switch 42 will operate. However, it is also evident that if the line voltage E_L varies, the current in the circuit will vary proportionately. If, for instance, the line voltage is increased, the critical current will be reached sooner with a higher value of thermistor resistance which means that the thermistor will not be heated to as high a degree as it would under a lower line voltage, and therefore the cooling time will also be less. Thus, the time element will vary appreciably with variations in line voltage. Similarly, it will be noted that the time element will vary with variations in ambient temperatures inasmuch as the initial resistance of the thermistor is determined by its initial temperature.

It is to rectify the above deficiencies that the shunt differential winding 38 has been provided. Since this shunt differential winding shunts the switch 42, upon the closure of the line switch 50 current will flow through this winding. The magnetically operable switch 42 will therefore be subject to the leakage flux from the main coil and also to the opposing flux induced by the shunt differential winding 38. Since the shunt differential winding 38 is in parallel with the thermistor 47, the current through the winding 38 (and thus the flux induced thereby) will be greater the higher the resistance of the thermistor 47. As above discussed, the value of the resistance of the thermistor at which the switch 42 will operate is proportional to the line voltage. Therefore, with, for instance, an increased value of line voltage, the resistance of the thermistor will be greater, a greater current will therefore flow through the shunt differential winding 38, a greater opposing flux will be induced, and a greater current will be required to flow through the main coil 9 in order for the switch 42 to operate. In other words, the operation of the shunt differential winding at the instant of closure of the line switch reduces the total flux through the switch 42 to a negligible value, and as the thermistor warms, the voltage across the shunt winding drops thereby reducing the differential effect. Thus, at higher line voltages (and conversely at lower voltages) the thermistor will be required to heat longer in order to sufficiently reduce its resistance, and a constant delay interval will thereby be obtained. The same considerations apply in respect to variations in ambient temperature.

The series differential winding 39 has been added to further improve the constancy of time delay despite variations in line voltage. Referring now to Fig. 8, the flux through the main core of the relay follows the usual saturation curve, and the main component of flux through the switch 42 therefore follows a similar saturation pattern. This is represented by the upper curve of Fig. 8. By adding the series differential winding 39, an additional flux component acts upon the switch 42, and this component is represented by the straight line curve at the bottom of Fig. 8. The flux induced by this coil is represented by a straight line since the magnetic circuit of the switch 42 is open and therefore not subject to saturation; the differential coil being sufficiently decoupled from the main relay winding to accomplish this result. The resultant of these fluxes, represented by the center curve of Fig. 8, is horizontal above the knee thus giving a

main flux component to the switch 42 which is substantially independent of variations in line voltage.

Definite control is established for the flux path from the main core through the switch 42 and return by air leakage from the rear end of switch 42 by means of the adjustability of iron screw 45.

The purpose of the relatively high resistance 48 which is placed in shunt of thermistor 47 is to establish a maximum threshold value for the thermistor. At very low ambient temperatures, the thermistor resistance becomes too high and passes insufficient current initially to cause the secondary coil 12 to hold the armature unoperated. The shunting resistance 48 obviates this difficulty.

The efficiency of the above-described elements in performing their functions is evidenced by the results obtained in tests made upon a relay constructed in accordance with this invention. The graph of Fig. 9 shows the total time delay response obtained as a function of line voltage, demonstrating a high degree of constancy of delay interval despite larger variations in line voltage than would be expected to be met in industrial use. The curve of Fig. 10 illustrates the small variation of delay interval obtained with relatively great variations in room temperature.

It will further be noted that the circuit of the preferred embodiment herein described employs the full cycle of heating and cooling of the thermistor, with the heating portion of the cycle being short relative to the cooling portion. The use of such a cycle practically eliminates the memory effect of the relay because the thermistor is cooled off by the time the relay operates, and if a subsequent operation occurs immediately after release, the thermistor is cooled down and the time element of the subsequent operation will be practically the same as the first. Even in the case of the application of current pulses which are too short to operate the relay (but which have nevertheless heated up the thermistor) there is also substantially no memory effect. The only effect of such non-operating pulses is to raise the initial temperature of the thermistor and thereby shorten the heating time from say .25 second to one-tenth of a second. Since, however, the cooling portion of the cycle is the main component of the time element the over-all effect and the total time of operation of the relay is negligible.

The time delay intervals may be purposely changed to meet a variety of requirements. Precise adjustment through a range sufficiently great for most purposes can be obtained by adjusting the value of resistance 49. The curve of Fig. 7 demonstrates the time delay intervals obtained through changing the value of this resistance on the above-mentioned test model. If still longer time elements are desired, a thermistor having a larger bead may be used.

The embodiment herein presented is illustrative and any values of resistance, time, or voltage are only exemplary. Many modifications in the structure or circuit may be made within the scope of the accompanying claims, and the above description and drawings are not to be interpreted in a limiting sense.

What is claimed is:

1. In a time delay apparatus, a pivoted armature, first means for producing a first moment on said armature proportional to the current in said first means, second means for producing a

second moment on said armature proportional to the current in said second means and opposing said first moment, and means for varying the current in said first and said second means relative to each other comprising a resistor having a negative temperature coefficient of resistance connected electrically intermediate said first and second means and in series therewith, and means for shunting said resistor and said second means comprising magnetically operable switch means controlled by said first means and a resistor connected in series with said magnetically operable means.

2. In a time delay apparatus, a pivoted armature, first means for producing a first moment on said armature proportional to the current in said first means, second means for producing a second moment on said armature proportional to the current in said second means and opposing said first moment, and means for varying the current in said first and said second means relative to each other comprising a resistor having a negative temperature coefficient of resistance connected electrically intermediate said first and said second means and in series therewith, and means for shunting said resistor and said second means comprising a resistor and a differential coil connected in series with each other and magnetically operable switch means connected in shunt of said differential coil only and controlled conjointly by said first means and said differential coil.

3. In a time delay apparatus, a pivoted armature, first means for producing a first moment on said armature proportional to the current in said first means, second means for producing a second moment on said armature proportional to the current in said second means and opposing said first moment, and means for varying the current in said first and said second means relative to each other comprising a resistor having a negative temperature coefficient of resistance connected electrically intermediate said first and said second means and in series therewith, a differential coil connected electrically intermediate said first and said second means and in series therewith, and means for shunting said resistor, said second means and said differential coil comprising magnetically operable switch means controlled conjointly by said first means and said differential coil.

4. In a time delay apparatus, an electromagnetic relay comprising a core, an armature hinged at one end to said core and having a first and a second position, first means at the end of said armature opposite the hinged end for establishing a first air-gap between said armature and one side of said core, means intermediate the hinged end of said armature and said first means for establishing a second air-gap between said armature and the other side of said core, first flux-producing means for exerting a force on said armature primarily across said first air-gap, second flux-producing means for exerting a force on said armature primarily across said second air-gap, said armature assuming the first of said positions in response to the resultant of said forces, and circuit means including said first and said second flux-producing means for varying said forces relative to each other for causing said armature to assume said second position.

5. In a time delay apparatus, an electromagnetic relay comprising a core, an armature hinged at one end to said core and having a first and a second position, first means at the end of said armature opposite the hinged end for establishing

a first air-gap between said armature and one side of said core, second means on said armature intermediate the hinged end of said armature and said first means and on the opposite side of said core from said first means for establishing a second air-gap between said armature and the other side of said core, first flux-producing means on said core and intermediate said first and said second means for exerting a force on said armature primarily across said first air-gap, second flux-producing means on said core and intermediate said second means and the hinged end of said armature for exerting a force on said armature primarily across said second air-gap, said armature assuming the first of said positions in response to the resultant of said forces, and circuit means including said first and said second flux-producing means for varying said forces relative to each other for causing said armature to assume said second position.

6. In a time delay apparatus, an electromagnetic relay comprising a core, an armature hinged at one end of said core and having a first and a second position, first means at the end of said armature opposite the hinged end for establishing a first air-gap between said armature and one side of said core, second means on said armature intermediate the hinged end of said armature and said first means and on the opposite side of said core from said first means for establishing a second air-gap between said armature and the other side of said core, first flux-producing means on said core and intermediate said first and said second means for exerting a force on said armature primarily across said first air-gap, second flux-producing means on said core and intermediate said second means and the hinged end of said armature for exerting a force on said armature primarily across said second air-gap, said armature assuming the first of said positions in response to the resultant of said forces, and circuit means including said first and said second flux-producing means for varying said forces relative to each other for causing said armature to assume said second position, said circuit means comprising a resistor having a negative temperature coefficient of resistance connected electrically intermediate said first and said second flux-producing means and in series therewith, and means for shunting said resistor and said second flux-producing means comprising magnetically operable switch means controlled by said first flux-producing means.

7. In a time delay apparatus, an electromagnetic relay comprising a core, an armature hinged at one end to said core and having a first and a second position, first means at the end of said armature opposite the hinged end for establishing a first air-gap between said armature and one side of said core, second means on said armature intermediate the hinged end of said armature and said first means and on the opposite side of said core from said first means for establishing a second air-gap between said armature and the other side of said core, first flux-producing means on said core and intermediate said first and said second means for exerting a force on said armature primarily across said first air-gap, second flux-producing means on said core and intermediate said second means and the hinged end of said armature for exerting a force on said armature primarily across said second air-gap, said armature assuming the first of said positions in response to the resultant of said forces, and circuit means

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including said first and said second flux-producing means for varying said forces relative to each other for causing said armature to assume said second position, said circuit means comprising a resistor having a negative temperature coefficient of resistance connected electrically intermediate said first and said second flux-producing means and in series therewith, and means for shunting said resistor and said second flux-producing means comprising a resistor and a differential coil connected in series with each other and magnetically operable switch means connected in shunt of said differential coil only and controlled conjointly by said first flux-producing means and said differential coil.

8. In a time delay apparatus, an electromagnetic relay comprising a core, an armature hinged at one end to said core and having a first and a second position, first means at the end of said armature opposite the hinged end for establishing a first air-gap between said armature and one side of said core, second means on said armature intermediate the hinged end of said armature and said first means and on the opposite side of said core from said first means for establishing a second air-gap between said armature and the other side of said core, first flux-producing means on said core and intermediate said first and said second means for exerting a force on said armature primarily across said first air-gap, second flux-producing means on said core and intermediate said second means and the hinged end of said armature for exerting a force on said armature primarily across said second air-gap, said armature as-

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suming the first of said positions in response to the resultant of said forces, and circuit means including said first and said second flux-producing means for varying said forces relative to each other for causing said armature to assume said second position, said circuit means comprising a resistor having a negative temperature coefficient of resistance connected electrically intermediate said first and said second flux-producing means and in series therewith, a differential coil connected electrically intermediate said first and said second flux-producing means and in series therewith, and means for shunting said resistor, said second flux-producing means and said differential coil comprising magnetically operable switch means controlled conjointly by said first coil and by said differential coil.

MARIAN M. STOLLER,

Executrix of the Estate of Hugh M. Stoller, Deceased.

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