May 10, 1932.

E. FOUCAULT

1,858,082

TIME DELAY DEVICE

Filed March 14, 1930

Fig. 1.

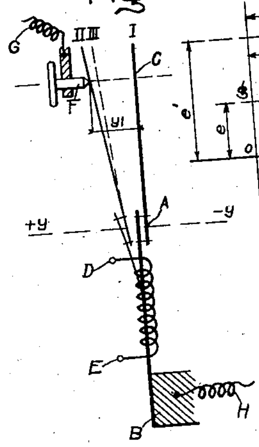


Fig. 2.

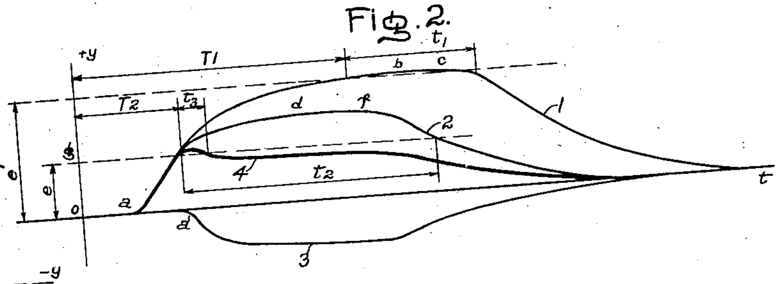


Fig. 3.

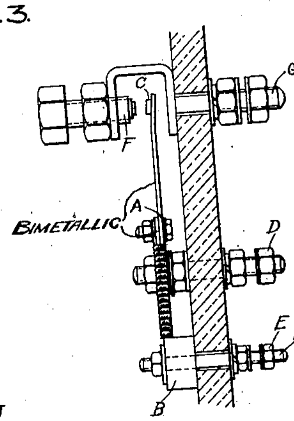


Fig. 4.

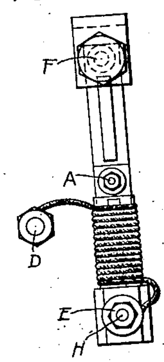
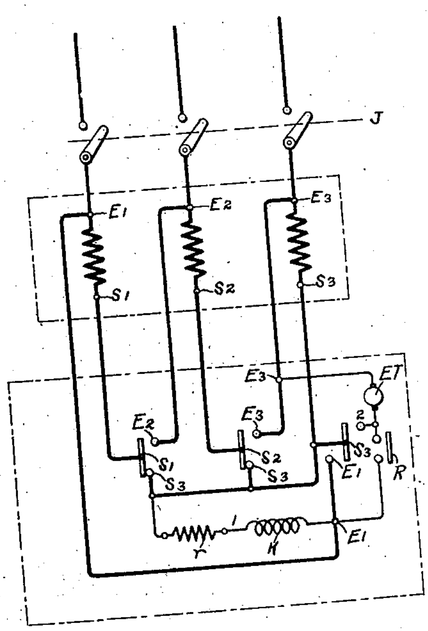


Fig. 5.



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1,858,082

UNITED STATES PATENT OFFICE

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TIME DELAY DEVICE

Application filed March 14, 1930, Serial No. 435,890, and in France August 26, 1929.

The invention relates to time delay devices, particularly those involving an electrically heated thermal operating element and has for its object to render such devices more quickly capable of repeating their timing operations.

For actuating time delay devices it has been customary to use an element, ordinarily of the bi-metallic type, the deformation of which under the effect of variations in its temperature brought about by a suitable heat source accomplishes the closing or opening of an electric contact or performs other operations such as the turning of a valve. In order to simplify the description of the present invention, reference will be made particularly to electric relays which are intended to insure the closing of an electric contact with a time delay. However, the invention can be applied also to relays that are intended for other purposes and which are deferred by the action of an element which is deformable by dilation but which may not be a bi-metallic contact.

The time delay relays of the kind considered have the advantage of being simple and of moderate price for the reason that they do not comprise any special mechanism, particularly no electromagnets. Moreover, the variations in the control potential have little influence on the time setting. However, these relays in certain applications have a considerable shortcoming. When the bi-metallic operating element, after having been suitably heated, has attained such a deformation that the desired electric contact is established, this contact lasts for a rather long time even if the heating should be stopped shortly after it is established. This is because of the natural slowness of cooling of the bi-metallic element. The result is that if one wishes to repeat the operation before the element cools, one will not get the retarded functioning which is wanted but instead instantaneous operation.

Particularly when such apparatus is used as an accelerating relay in an automatic starter for the contactors of an electric motor, there is the possibility that in the case of two consecutive operations the second starting will proceed under abnormal conditions. Because of this severe disadvantage, this thermal time delay system is not ordinarily used for accelerating purposes.

The present invention provides an improved deferred-action relay with a thermostatic element which avoids the short-comings just mentioned. It is characterized principally by the fact that its deformable element consists of two parts, one main part which is affected by the heat source and which becomes deformed in a proper direction for the operation which the relay must perform, and a second part which is an extension of the main part which is heated only through conductivity by that main part and which is deformed in the opposite direction.

The construction and operation of a preferred form of thermal time delay relay embodying the invention can be best understood by referring to the accompanying drawings in which Fig. 1 is a schematic diagram of a thermal time delay relay conforming to the invention, Fig. 2 is a chart showing typical time displacement characteristics of such a device, Figs. 3 and 4 are respectively side and front views of a preferred construction of a relay embodying the invention, and Fig. 5 is a circuit diagram illustrating the manner of applying the thermal time delay relay to an automatic star-delta starter for electric motors.

In accordance with the present invention, the thermostatic element consists of two bi-metallic elements AB and AC which are so assembled and joined together at A that, under the effect of the heat, the lower bi-metallic contact AB is curved toward the left while the bi-metallic contact AC is curved toward the right.

The heating element which is represented by an electric resistance is associated with the lower bi-metallic contact AB and its terminals are D and E. The upper end of the element AC can engage with a micrometric screw F which closes the circuit GH, this closing representing here the desired operation. The thermostatic element is mounted upon support B.

The operation can be briefly explained as follows:

When the relay is energized by sending current into the heating system DE, the lower strip AB is immediately heated and bends to the left. The upper strip AC which can only be heated by conductivity is not subjected to any deformation at the beginning, for it takes a certain amount of time before it is reached by the heat conducted thereto from the strip AB.

Thus contact FC becomes closed in position II of the thermostatic element which is shown as a thin line in the drawings while the starting position is shown as a heavy line.

At this moment (or in general when one wishes to bring the relay to the rest position), the circuit of the heating apparatus is interrupted by an auxiliary contact of the apparatus which is controlled by the relay and the lower strip AB begins to cool.

If the cooling took place only by conductivity through the surrounding air, it would be very slow and the end C of the thermostatic element would remain for a long time in contact with screw F just as it happens in the relays that are known at present. But, because of conductivity, a certain quantity of heat goes from the lower strip AB to the upper strip AC. Under this influence this strip is curved to the right according to the dot-and-dash line of position III, and interrupts in this manner the contact FC. As soon as the time required for this displacement has lapsed, the operation can be repeated and, if the thermostatic element is, for instance, in position III, one will not have such a long delay as if one were starting from the cold element, but there will always be a delay, whereas without this arrangement, no time delay would be possible if the operation were repeated after the same period of time.

It is possible to judiciously combine the heating conditions of each one of the two bi-metallic contacts so that the position II lasts only a very short time which can be adjusted at will.

To this end one must examine the ratio which exists between the displacements of point C and the heating conditions of the thermostatic element.

The displacement of point C, which is intended to come in contact with screw F, is the result of the displacements of A with respect to B and of C with respect to A. These two displacements are of the same nature and are both due to the deformation of the bi-metallic contact under the effect of the heat.

The law according to which point A moves with respect to B is given by the curve (1) of Fig. 2, in which the times are plotted as abscissas and the displacements—measured at right angles to BC when the latter is in the rest position—are plotted as ordinates. The heating period lasts from o to b. During the interval o to a the heat which is produced serves simply to heat the heating element itself and no heat goes over to the bi-metallic contact which indicates a time of rest. At b a balance or steady state position has been attained for a given power in the heating element and any continued heating at the same regime would not modify this deformation.

Let us assume that the heating is stopped at this point. During the time bc the heating element which is hotter than the strip AB yields still a sufficient amount of heat to the latter to balance the losses by conductivity through the air and the point A, at which the two strips meet, indicates the time of rest. Then at c the cooling begins, according to a law, which is much slower than the law which controls the heating.

Assuming that the part AC of the thermostatic element be indeformable and that the starting distance y_1 (see Fig. 1) has been adjusted to the value e', the operation, according to curve (1), gives a time delay T_1, and a minimum waiting t_1, during which the contact FC remains closed.

If, without modifying the heating system, one regulate y_1 to a valve e which is much lower than the balance deformation, and one ceases to apply heat at point g, one obtains the curve (2) which gives the time delay T_2 shorter than T_1 and the minimum waiting time t_2 which is much longer than t_1.

Curve (3) refers to the displacement of point C with respect to A, under the influence of the heat from the heating element, which also passes, through conductivity, from strip AB to strip AC. It is a curve similar to (1) but of less amplitude (since the heating is not direct) and with a longer initial time of rest oa' since the heat goes over into strip AC only after a certain time following the heating of strip AB.

The resultant of the two displacements (2 and 3) is the curve (4) which represents the absolute motion of point C. One will realize that with the regulation of y_1 to the value e one obtains the same delay T_2 as above but a reduction of the minimum waiting time to t_3 which is much smaller than t_2. This brings out clearly the advantage of the new relay.

In order to reduce the time t_3 to its minimum value, curve (2) being given, one must modify the amplitude and time displacement of curve (3). This is obtained by varying the heating conditions of strip AC: Variation of the distance between the heating element and that strip, variation of the conductivity at the contact A (which may be either soldered or simply created by pressure through rivets, bolts, etc.).

Figs. 3 and 4 represent schematically a physical embodiment of a relay which conforms to the invention, where the heating is assured by a heating element involving the Joulian effect. Fig. 3 is a side view and Fig. 4 is a front view, the notation having the same meaning as in Fig. 1. It goes without saying that any arrangement which is equivalent to those of Figs. 3 and 4 may be used without going beyond the scope of the invention.

The latter is of general application, no matter what operation is to be performed by the relay, and how the latter is heated. Fig. 5 shows a schematic view of an application to the automatic control of a star-delta switch for the stator winding of an induction motor, the change-over having to take place after a given time following the application of voltage to the motor so as to reduce the starting current.

The particular motor control arrangements that are described with respect to this example must be considered as constituting part of the invention and it goes without saying that all other equivalents may be used without leaving the scope of the invention.

The stator element of the motor is represented schematically by the three phase E_1 S_1—E_2 S_2—E_3 S_3 (the rotor is not shown for the sake of simplicity) which may be supplied through a three-pole breaker J.

The star-delta switch is operated by an electro-magnet ET which, when it is energized, controls at the terminals of two phases E_1 and E_3, through the closing of contact R, the opening of the contacts S_1 S_3 and S_2 S_3 as well as the closing of contacts S_1 E_2—S_2 E_3 and E_1 S_3 2. This device can be built, for instance, according to Fig. 1 in the French patent application that was filed May 18, 1928, by the "Compagnie Francaise pour l'Exploitation des Procedes Thomson-Houston" for an "automatic starter for alternating-current motors" or according to any other arrangement.

Contact R consists, in conformity with the invention, of terminals G and H of a thermostatic relay (see Fig. 1), the heating element K of which, in series with the resistance r, is connected between phase and neutral toward the load end of breaker J.

In the rest position contacts S_1 S_3 and S_2 S_3 are normally closed and the contacts S_1 E_2—S_2 E_3—E_1 S_3 2 and R are open.

By closing breaker J, the stator winding of the motor being star-connected, the motor will start, and voltage is applied to a heating element K.

When the time interval, for which the bi-metallic contact relay is set, has elapsed, this relay operates by closing its contact R. The latter energizes electro-magnet ET and the three contact fingers of the commutator tilt over. The phases of the motor are then delta-connected and the starting continues. Contact E_1 S_3 2 accomplishes the energization of electromagnet ET and the contact E_1 S_3 short-circuits the heating element of the relay which begins to cool, as has been explained in the preceding. The contact R opens which permits of proceeding anew with a repeated starting under favorable conditions.

With the bi-metallic contact relays that are known at present there is a possibility that, if one wishes to have a second starting shortly after the first, contact R may still be closed and this would occasion a direct delta starting. This danger is avoided by applying the invention.

The delay which is obtained by this relay system varies slightly with the potential of the network. One may widely reduce its variations by providing the resistance r with a sufficiently high temperature coefficient.

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

1. A thermal responsive device having oppositely acting portions in heat conducting relation and means for heating only one of said portions to effect operation of the device whereby the heat conducted to the other portion effects the reverse operation of the device when the heating of said one portion ceases.

2. A quick return thermal time delay device comprising a pair of oppositely acting heat responsive elements in heat conducting relation, and means for heating only one of said elements to effect time delayed operation of the device and insure quick return operation of the device by the heat conducted to the other element.

3. In combination, oppositely acting bi-metallic elements in heat conducting relation, means jointly controlled thereby, and electrical means for heating only one of said elements to effect operation of the means jointly controlled thereby a desired interval after the heating means is energized and insure a reverse operation of said controlled means before said one element is cooled when the heating means is deenergized.

4. In combination, a heat responsive element having one portion fixed and another portion movable, an oppositely acting heat responsive element mounted on said movable portion of the first element in heat conducting relation therewith, a member movable between two positions under the joint control of said elements, and heating means associated with only one of the elements to insure a quick reverse movement of the mem-

ber by the other element when the heating is stopped.

5. In combination, a bi-metallic element having one end fixed, an oppositely acting bi-metallic element having one end secured in heat conducting relation with the free end of the first element, and heating means associated with only one of the elements to insure a quick reverse movement of the free end of the said oppositely acting element when the heating is stopped.

In witness whereof I have hereto set my hand this 13th day of February, 1930.

EDOUARD FOUCAULT.