This invention relates to power relays of the delayed action type, and particularly to relays adapted for sequential operations, such as may be connected in cascade to provide for the operation of groups of street-lighting circuits.

At the present time street lighting is largely provided by lamps of the incandescent type. The difference between the cold resistance and the hot resistance in such lamps is very large, the hot resistance being many times that which the lamps exhibit when cold. Ordinarily all of the lamps in a single city are lighted at dusk, and if all are lighted at the same time the initial surge of current, lasting until the lamps have come up to approximately their final temperature, may be such as greatly to overload the circuits, throwing undue strain upon the generating equipment and the protective devices appurtenant thereto. Accordingly, it is much better if the distribution system for such lighting be divided into groups or sections which are excited successively, so that the transient currents or surges consequent upon the excitation of one group may have an opportunity to die away before the next section is excited. If the entire system is divided into a sufficient number of groups an initial current of up to ten times the steady value in one section is not sufficient to seriously disturb the system as a whole, whereas if the entire system were forced to carry a current bearing this ratio to the steady value it would amount to a very serious overload indeed.

Sequential operation of a large number of sections from a central station, particularly in a large city, would require an extremely expensive distribution system, all the circuits being terminated at the station, or, in the alternative, a large number of separate control lines being required. If, on the other hand, the excitation of one section can be made to accomplish the delayed excitation of a succeeding section, and this, in turn, cause the delayed excitation of the next section in the series, an extensive subdivision of the system can be accomplished at a reasonable cost and with a very simple type of control network.

Such operations as just mentioned presuppose that the control relays be mounted in exposed positions; on the poles supporting the light, in manholes, or the like. This implies that in many cases the operating relay be exposed to extreme variations in temperature, and it is well known that equipment which will operate perfectly at "average" temperatures—60 degrees Fahrenheit...
nearly the entire periphery of the disk leaving a projecting tooth in which case a delay as long as 59 seconds (assuming a one-minute period of rotation for the shaft) will be the result. The faces at the edges of the slot engage a tiltable support which holds the mercury tube, rotation of the disk in one direction tilting the support and tube in such sense as to close the contact, while rotation in the other tilts it back to open the contacts. To operate the relay current is supplied to the motor field which rotates the shaft in the proper direction to tilt the mercury switch to the closed position. Rotation in this sense continues until the cam disk engages the tiltable structure and closes the switch, energizing the line to be controlled and the other motor field structure which is bridged across this line. This tends to rotate the armature structure in the opposite direction, balances the torque produced by the control field and brings the device to rest. The fields remain in this balanced condition until the voltage is removed from the control winding, whereupon the second winding assumes control, tilts the switch into the open position, and deenergizes the motor.

It will be apparent that the controlled line for one relay may become the controlling line for another, which may have either the same one or a different delay constant depending upon the formation of the cam disk. As many relays as may be desired can therefore be connected in cascade, closing successive circuits at successive predetermined intervals.

Mercury switches of the type here considered have relatively long lives and will stand a large number of cycles of operation when carrying the loads for which they are designed. We have found, however, that when failure does occur as a result of continued use, the failure is caused by the flaking off of minute chips of glass from the interior of the tube. This flaking or sloughing action takes place very gradually and is apparently caused by intense local heating of the glass envelope due to the arcing or sparking which occurs, usually at the time of the break, but which may also occur at the time that the circuit is closed. It is usually in such cases that the sparking which occurs upon the make action is more destructive than that occurring at the break, even though it occurs less frequently and is apparently less severe.

It has been found, moreover, that the action referred to is much more serious at low temperatures than it is at high.

The reason for the phenomena just mentioned appears to lie in the nature of glass. Glass is frequently referred to as a “supercooled liquid” the reason being that when a true glass is cooled from a liquid state too slowly it can be definitely said that solidification occurs.

The cooling curve of the material is practically continuous, no discontinuities occurring as in the case of a crystalline substance wherein energy is liberated upon the transition from a liquid to a solid phase. Moreover, the viscosity or curve of glass indicates it to be one of the most rigid and elastic substances known, but its rigidity increases with decrease in temperature. Local heating, causing expansion of the glass, is therefore very much more destructive when the glass is at greatly reduced temperatures than it is when it is relatively warm, not only because of the marked difference in temperature but also because the glass has more “give” when it is warmer.

A very important part of this invention, therefore, is the fact that there is provided, adjacent to and preferably surrounding the mercury tube, a heating winding of relatively high resistance which is bridged across the operating contacts and which carries current when the switch is open, thereby maintaining the glass at a temperature which is slightly above the ambient temperature. To accentuate this, the relay is preferably surrounded by a complete enclosure.

When the mercury switch is open the temperature is therefore maintained by the heating coil. When the switch is closed the heating coil is shorted out by the mercury itself, but since the latter is carrying a relatively heavy load, the heat generated would be of the same order of magnitude, or even higher, so that it will maintain the glass in its more malleable condition. Furthermore, when the relay is closed, additional heat is generated in both of the actuating coils and this is retained by the enclosure. The total temperature rise under both conditions will be generally of the same order of magnitude, although somewhat higher, usually, during the closed condition of the switch. This is not disadvantageous, however, as it keeps the glass in its least malleable condition at the time of severest sparking, occurring at the break.

The invention will be more clearly understood from the following description of a preferred embodiment, taken in connection with the accompanying drawings, wherein:

Figure 1 is a plan view of a relay embodying this invention, with the cover removed;

Figure 2 is a front elevational view of the relay, the cover and base being shown in section;

Figure 3 is an end elevation of the relay mechanism, the base and cover and the connection between the motor and switch rocker being shown in section;

Figure 4 is a wiring diagram showing a plurality of sections of a lighting distribution system actuated by relays in cascade and showing the wiring of the relay and heating coils.

Figure 5 is a front elevation of a modified form of relay of this invention which may be used where time delays of from one to two seconds are desired.

The embodiment of the relay of this invention illustrated in the first three figures comprises a baseplate 1 wherein there is mounted the frame 3 of the relay motor mechanism. In this case the frame comprises an L-shaped strip, the vertical arm of the L being of a length which extends from the baseplate 1 to the full height of the structure so that a surrounding enclosure or cover 5, when in place, rests upon the top of the frame. The horizontal branch of the L is secured to the baseplate, and is provided, at its end, with a motor being shown in a motor mechanism, generally indicated by a reference character 9, is mounted upon studs 11 and 13 respectively, the lower of these studs being supported between the riser portion 7 and the vertical arm of the L-shaped frame 3, while the upper one is secured to the vertical arm alone.

The two field structures of the motor, comprising the cores 15 and 15' and the windings 17 and 17' are mounted on the studs just described.

The armature structure of the motor is enclosed in a cylindrical housing 19. This structure is not illustrated in detail as it comprises essentially simply because of the important difference in temperature in bucking relationship, and various types of such motors are well known and are commercially
5 available. The usual step-down gear case 21, of the same type as is used in most clock motors, is mounted on the end of the housing 18. The gear within this housing reduces the speed of the projecting shaft 23 by any desired ratio; in this case to a speed of one revolution per minute when one of the motor fields is supplied with 60-cycle current.

The lower of the two studs, supporting the motor, i.e., stud 11, projects forward of the support frame 3 to form a stationary shaft 25 on which is mounted a bearing bushing 27. The lower end of a vertical arm 29 of a T-shaped rocker is secured to this bushing. The horizontal arm 31 of the rocker is provided with spring clips 33 for holding a mercury switch-tube or capsule 35 of known type.

The vertical arm 29 of the rocker is slotted, as shown at the reference character 37, to permit the passage of the motor shaft. The arm 29 is also provided with pin 39 (which may be formed by bending a tab out of the material of the rocker itself) projecting outwardly at its median line between the shaft 23 and rocker bearing 27.

An operating disk or cam 39 is secured on the end of the shaft 23. The periphery of this disk is cut away or slotted as shown at the reference character 40, and the time delay of the relay is determined by the width of this slot, which may be varied as desired, as has already been stated. In the present instance the slot is shown of such proportions as would give a delay of approximately six seconds with a shaft speed of one revolution per minute. It should be clear that any portion of the periphery may be cut away in this manner, or to almost the entire periphery of the disk, in which case the cutaway portion loses its slot-like character and the disk becomes more comparable to a single-tooth gear. The relative position of the parts as shown in Figure 2 is one which would never be assumed in actual operation but which is shown in the drawing for purpose of clarity. As shown in the drawing the rocker 27 would be in unstable equilibrium and this position would be assumed only when one or the other of the two edges of the slot 49 were in contact with the pin 39 on the rocker arm.

Clockwise motion of the cam disk 39 causes the right hand edge of the slot to engage the pin and tilt the rocker to the left, causing the mercury in the tube 35 to bridge the two contacts connecting two leads 43 and 45 (which are shown only in part) and thus making the circuit. Counterclockwise rotation of the cam disk will move the rocker in the opposite direction, breaking the circuit. The instability of the rocker arm when it is nearly in the position shown is increased by the fluidity of the mercury, which, as the device is otherwise nearly in balance, starts to flow in the direction of motion and speeds up the make or break operation.

A terminal block 49 is provided on the forward portion of the base plate and the power and control leads 51 and 53 are connected to this block. The switch leads 43 and 45 connect with the power lead 51, but this is not shown in the first three figures in order to prevent confusion in the drawings, the actual connections being indicated in the circuit diagram of Figure 4.

Station 35 in this diagram is the tiching coil 55. This coil is wound with fine resistance wire insulated by heat-resisting material such as asbestos or Fiberglas. The coil terminates at the same contacts as the leads 43 and 45, also as indicated in the circuit diagram. In the particular relays shown in the drawings the coil 55 is designed to dissipate about six watts, having 2440 ohms resistance when built for operation on a 120 volt circuit or nearly a thousand ohms if designed for operation on 240 volts. When the switch is closed the dissipation by the heating element is of the order of one one-hundredth of a watt, while a 30 amp. current through the mercury generates about 3.6 watts. To this, however, must be added the heat generated in the coils of the motor so that actually the heat liberated within the casing is very nearly the same under both conditions.

The operation of the device can best be appreciated by considering the circuit diagram of Figure 4. The control leads 53 connect to the coil 17 and nothing else. Excitation of this coil causes clockwise operation of the motor of relay A, tilting the switch tube 35 into the position shown, and closing the circuit between the input leads 51 to the switch. These leads are in series with the lighting circuit 57 which is a branch of a distribution network 59, thus lighting the lamps 61, exciting coil 17, 71 and thus bringing the motor of relay A to rest. At the same time the control circuit 53B of relay B is energized, starting the timer in turn in the clockwise direction so that eventually the switchtube 35B will close and the operation repeat. Relay A will remain closed until the control voltage is removed from the leads 53, at which time coil 17, no longer balanced by an opposing torque, will take control and open the relay, thus, in turn, removing the control voltage from coil 53B and again the operation will repeat, as many circuits as desired being opened or closed in succession after the required delays.

The relays just described are exceptionally reliable in operation even under extreme changes of operating voltage and unbalance between control and operating circuits. Tests have shown that the device will work satisfactorily with full voltage on the coil 17, i.e., 120 volts, even though the control voltage across coil 17 be dropped to less than 90 volts. Similarly, operation was still satisfactory with a control voltage on coil 17 of 120 volts and a controlled circuit voltage of 90 or less. When the voltages of both coils were reduced together, satisfactory operation could still be obtained through about the same range of voltages.

Because of the use of the heating coil operation under extreme conditions is still satisfactory; the device has been cycled repeatedly at temperatures of minus one hundred degrees Fahrenheit, the freezing temperature of mercury being minus forty. Furthermore, the life of the device, using the heating coil is indefinitely long. The heating coil was operated at normal ambient temperatures the life of the device even without the use of the coil and considering a cycling operation of once per day as normal for this type of use, indicates a life expectancy of approximately forty years. The etching or flaking off of the inner surface of the tube when used at greatly reduced temperatures without the coil indicated a greatly decreased life under these circumstances, but using the heating coil an approximately equal life may be expected even under these conditions. The durability of the relay indicates that it may be expected to last longer than the circuits in which it is operated.

Where time delays of short duration only are required, i.e., delays of from one to two seconds, the cam and rocker mechanism may be omitted. This modification of the device is illustrated in
Figure 5, wherein the motor mechanism itself is identical with that described above and the parts therefore are identified by the same reference characters. In this instance, however, a crank arm 60 is mounted directly upon the motor shaft. This arm carries a clip 61 for holding the mercury switch tube. The switch tube in this case is supplied with the heating coil 55 as before.

A stop 63 may be provided for limiting the motion of the crank arm in the counterclockwise or "off" position. The reason for the stop is that there is one specific set of conditions wherein the current through the heating coil may become a "sneak current" which tends to cause rotation of the relay. This condition occurs only when through some accident the load is removed from the work circuit, as, for example, by the burning out of all the lights in the circuit. Under these circumstances the potential across the work circuit divides between the "off" coil 17' and the heating element, in which case enough current may flow through the coil to produce sufficient torque to actuate the motor in the "off" direction when the coil 17 is not excited. The stop blocks any such motion. When normal load is connected to the work circuit this effect does not occur, since, in a 120-volt, 30-amp. circuit, the resistance of the load, bridging the coil 17', is of the order of from one-half to four ohms, so that practically the entire voltage drop takes place across the heating coil 55. In the form of the device shown in Figures 1 to 3, no additional stop is necessary since the slot 40 serves the same purpose in locking rotation of the motor.

Street-lighting circuit require complete reliability. Ordinarily the relays here described have shown such extreme durability that no special precautionary measures appear necessary to take care of the situation where some relay early in the cascade system may fail causing those later in the sequence to turn to the "off" position. If, however, some such difficulty is feared, the relays described are sufficiently inexpensive to permit two of them being operated in parallel with respect to both their control and work circuits, so that should one fail to operate through switch-tube failure or otherwise the other will carry the current. A slightly less, but often adequate degree of protection may be obtained merely by the use of two mercury switch tubes in parallel, both operated by the same actuating mechanism.

We claim:

1. A time-delay power relay comprising a mercury switch tube, a mounting for said switch tube tiltable in two directions to open or close a circuit through said switch tube depending on the direction of tilt, connections for completing a work circuit through said switch tube, means for tilting said switch tube to control said work circuit comprising a motor having a rotor structure and means for establishing two electromagnetic fields tending to rotate said structure respectively in opposite directions, connections for exciting one of said electromagnetic fields from a control circuit, and connections for exciting the other of said electromagnetic fields from said work circuit when completed through said switch tube.

2. A relay in accordance with claim 1 including step-down gearing between said rotor structure and said switch tube mounting.

3. A relay in accordance with claim 1 wherein said motor comprises a clock-type self-starting synchronous motor having two opposed field structures.

4. A time-delay relay comprising a self-starting motor having a rotor structure and a pair of opposed field coils excitation whereof tends to turn said rotor in opposite directions, step-down gearing driven by said rotor, a work shaft driven by said gearing, and a cam element on said work shaft; a switch mechanism and a cam follower element thereof, one of said cam and follower elements having spaced faces for engaging a portion of the other, means for connecting a control circuit to the one of said field coils tending to so rotate said cam as to close said switch mechanism, means for connecting said work circuit in series with said switch mechanism, and means for connecting the other of said field coils across said work circuit.

5. A relay in accordance with claim 4 wherein said switch mechanism comprises a mercury switch-tube and a tiltable mounting therefor, said cam follower element being so positioned on said mounting as to tilt the same through a position of unstable equilibrium when engaged by said cam element.

6. A relay in accordance with claim 4 wherein said switch mechanism comprises a mercury switch tube having a pair of contacts therein for connection to said work circuit and including a heating coil connected across said contacts so as to be shorted out when said contacts are closed.

7. A relay in accordance with claim 4 wherein said switch mechanism comprises a mercury switch-tube a rocker on which said switch tube is mounted and a pivot mounting for said rocker positioned at the bottom thereof, said cam follower comprises a pin projecting from said rocker and said cam comprises a disk having a portion of its periphery interrupted to leave substantially radial faces engaging said pin.

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REFERENCES CITED

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

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,941,920</td>
<td>Wilhelm</td>
<td>Jan. 2, 1934</td>
</tr>
</tbody>
</table>