ABSTRACT: This specification discloses an electric switch characterized by a main electrode having the general form of an elongate member for connecting with one side of a power supply; a plurality of contacts having leads for connecting through loads to another side of the power supply, with the contacts being disposed linearly along, spaced from and closely adjacent the main electrode. The main electrode and the plurality of contacts are disposed within a container having a supply of mercury therein. There is provided means for sequentially immersing the respective contacts and adjacent portions of the main electrode in the mercury such that load elements may be sequentially connected to a power source. Various embodiments are also described.
SEQUENTIAL SWITCH DEVICES

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to electric switches and more particularly, to electric switches adapted to sequentially connect one or more of a plurality of loads or load elements to a power source.

2. Description of the Prior Art
In the prior art of which I am aware, the switches and switch arrangements available for sequentially connecting a plurality of loads or load elements to a power source have not been entirely satisfactory in several respects. The conventional approach has been to use a plurality of switches, each separately controlled, either manually or automatically. Such arrangement leaves much to be desired from the standpoint of low initial cost, simplicity, compactness, and low maintenance.

It has been known to employ switch devices utilizing mercury to sequentially connect a plurality of load elements to a power source in cases where the load currents were light, as for example in regulator applications. However, mercury has a relatively low current carrying capacity per unit volume and consequently has not been considered practical for use in applications involving relatively high load currents, that is, load current in excess of a few amperes. It is my object to provide a switch device for sequentially connecting a plurality of loads or load elements to a power source, which device shall obviate disadvantages of the prior art above mentioned.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional view, partly schematic, of one embodiment of the invention.
FIG. 2 is a cross-sectional view of another embodiment of the invention employing different forms of main electrode and of contacts.

DESCRIPTION OF PREFERRED EMBODIMENTS

It is a particular feature of this invention to employ a main electrode comprising an elongate member sized suitably to carry a desired total load current; a plurality of contacts disposed linearly along, spaced from but closely adjacent the main electrode; and means for sequentially immersing the contacts and the adjacent portions of the main electrode in mercury. By contacts being "disposed linearly along," I mean disposed at points along the longitudinal axis of the elongate member serving as the main electrode. I have discovered that with this arrangement relatively large total load currents can be effectively handled while employing mercury as a conductive element. By relatively large total load currents, I mean the order of 10 amperes per contact, with 10 or more contacts. Details of construction of the elements enumerated above and the container housing them can be seen in the FIGS.

In FIG. 1, electric switch 11 has main electrode 13 in the general form of a rod capable of carrying the total load current for a desired load. Disposed along the longitudinal axis of main electrode 13 are a plurality of contacts 15. Contacts 15 are spaced from but closely adjacent main electrode 13. The minimum spacing of the contacts 15 from the electrode 13 will depend upon the magnitude of the power source voltage, with the spacing being sufficient to prevent the occurrence of arcing in the absence of mercury immersion. There are as many contacts 15 and respective leads 17, 19, 21, etc. as there are loads or load elements to be interconnected with main electrode 13. Each contact 15 and its lead is electrically insulated from the others, as described in more detail hereinafter.

As illustrated schematically in FIG. 1, main electrode 13 is connected via conductor 23 with one side of a power source. Leads 17, 19, 21, etc. are few connected through their respective loads or load elements 25, 27, 29, etc. via their respective conductors 31, 33, 35, etc. and common conductor 37 with the other side of the power source.

Switch 11 has container 39 maintaining main electrode 13 and contacts 15 in their spaced relationship. Container 39 has a supply of mercury 41 therein and constrains the mercury 41 to a passageway along main electrode 13. Thus, when mercury 41 is caused to flow in the container, it sequentially immerses the contacts and portions of main electrode 13.

Means 43 effects flow of mercury 41 into container 39 for sequentially immersing contacts 15 and portions of main electrode 13 in the mercury. Means 43 consists of a relatively large diameter bellows 45 with at least semiflexible sidewalls and a relatively rigid bottom 47. Bellows 45 has a diameter which is large with respect to the diameter of container 39 such that small movements of bottom 47 effect relatively large corresponding movements of mercury 41 along the longitudinal axis of main electrode 13. To effect the small movements of bottom 47, threaded shaft 49 is moved reciprocally through supporting frame 52. As illustrated, frame 52 has a common mounting with the base of container 39 and the top of bellows 45. Shaft 49 may be moved reciprocally by any suitable means.

As illustrated, reciprocal movement of threaded shaft 49 is effected by internally threaded gear 51 being rotated by worm gear 53. Worm gear 53 is rotated by motor 55 responsive connected by conductors 57 with suitable control means (not shown). The arrangement illustrated wherein small diameter worm gear 53 turns relatively large threaded gear 51 and slowly moves threaded shaft 49 in either reciprocal direction, enables very small corrections to be made and enables the use of a low power, inexpensive motor 55. Shaft 49 is prevented from rotating. For example, it may be fixed to bottom 47 to prevent its rotation. Ordinarily, it is preferable that shaft 49 have a keyway slot (not shown) engaging a key (not shown) in frame 52 to prevent rotation of shaft 49.

A brief consideration of operation of the embodiment shown in FIG. 1 in conjunction with a practical use will afford insight and facilitate understanding. Suppose a high temperature furnace is being heated by electrical-heating elements. When the furnace is first turned on and is cold, its controller will send a signal via conductors 57 to motor 55 requiring the maximum power. Motor 55 will ultimately turn worm gear 53 to rotate internally threaded gear 51 and drive shaft 49 to its uppermost position. Mercury 41 within bellows 45 and container 39 will in turn be raised to immerse all of the contacts 15 as well as the major portion of the length of main electrode 13. Thus, mercury will interconnect contacts 15 with main electrode 13. To stop rotation of motor 55, a limit switch means is provided to break contact with conductors 57. Pin 61 operating a microswitch in the circuit with conductors 57 is depressed and the switch is opened by the shaft's physical protrusion; such as, nut 63 threaded onto shaft 39 and immobilised by lock nut 65. If desired, a similar arrangement for limit switch means can be employed to stop motor 55 when the upper extremity of the threaded portion, or part thereof to which it is desired to restrict movement, has been attained.

Ordinarily, controllers for such high temperature furnaces must control the temperature within a relatively narrow range and have a preact function. Such preact function operates to anticipate trends and to compensate for lag in response to the control signal. Specifically, when the temperature comes within a certain range of the desired temperature; for example, within 100 °C; the controller will signal motor 55 to disconnect a first electrical-heating element which may be, for example, connected via leads 59 with main electrode 13. Accordingly, motor 55 imparts a reverse direction of rotation to worm gear 53, consequently, imparting reverse rotation to internally threaded gear 51 and lowering shaft 49 a small amount. The controller, operating through its preact, will send out only a short signal, effecting a small amount of the lowering of mercury 41 such that only the top contacts 15 is disconnected by lowering of mercury 41 between main electrode 13. A time period is provided to evaluate the effects of this action on the slope of the approach of the temperature profile to the desired controlled temperature. If the approach
is still too steep, the controller, again acting through its preact function, signals an additional lowering of mercury 41, disconnecting the second heating element. The controller successively lowers the level of the mercury and disconnects successive contacts and, hence, successive electric-heating elements until the proper temperature approach is effected. For example, it may be that only element 25 remains connected to main electrode 13 via lead 17, bottommost contact 15, and mercury 41. This heating element alone may be sufficient to maintain the furnace at equilibrium conditions until some condition is altered; for example, a batch of semiconductor chips is introduced into the furnace. Upon such an occurrence to upset the equilibrium, the controller will sense the departure from the desired controlled temperature and compensate by raising the level of the mercury to interconnect load 27 via lead 19 with main electrode 13. As described before, the preact is then deactivated for a given time to evaluate the effect of the second load, or heating element, in maintaining equilibrium. After the lapsed time interval, if the preact indicates a continued direction of the lowering of the temperature below the controlled temperature, lead 21 will be interconnected by a preact signal raising the level of mercury 41 through the above-described operation of motor 55 raising shaft 49.

Ideally, there should be a simple approach to the equilibrium number of elements. In fact, there is frequently overcontrolling. Too many a time via such an incorporation into the electric circuit with the power source, such that the preact will sense an overcontrol and have to drop out one of the elements. In this mode of operation, the switch of the invention is particularly advantageous and enables use of the greatest flexibility that can be built into a controller, including the most refined aspects of preact and lag anticipation.

On the other hand, the switch of the invention is useful in applications requiring a straight sequential interconnection of load elements to a power source. For example, where a plurality of individual lighting loads are to be sequentially connected to a power source, the switch is advantageously employed. The lighting loads may individually require up to 10 amps or so of current and may have a large number of such lighting loads, typically 10 to 20. To interconnect a single load as high as 200 amps at one time would require an expensive contactor, and still would permit no flexibility as to varied lighting conditions that might be desirable.

Many other applications, such as, sequentially engaging blowers for movement of fluids like air; afford opportunities for advantageous employment of the switch of the invention.

Main electrode 13 should be constructed of materials that have electrical resistivity and that resist amalgamation with mercury. Ordinarily, copper or copper alloys are preferred.

The advantages of employing a main electrode 13 of the low resistivity material in accordance with the invention can be appreciated by referring to the following table showing the resistivity of some common materials compared with mercury at 100°C.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Resistivity at 100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>108.0</td>
</tr>
<tr>
<td>Gold</td>
<td>2.9</td>
</tr>
<tr>
<td>Copper</td>
<td>5.8</td>
</tr>
<tr>
<td>Aluminum</td>
<td>5.8</td>
</tr>
<tr>
<td>Iron</td>
<td>18.0</td>
</tr>
</tbody>
</table>

It can be seen that a sequential switch device capable of handling relatively large load currents and using mercury alone would require such a large volume and cross-sectional area of mercury as to render such a device impracticable. Even iron is six times as conductive as mercury, whereas, copper is about 55 times as conductive as mercury.

Container 39 can be constructed of almost any material. Ordinarily, insulation of leads and contacts are facilitated if the container is constructed of an insulating material. For example, glass, or insulating plastic; such as, polypropylene or polymerized methyl methacrylate resin like Lucite; can be employed. As illustrated in the FIG., a layer 67 of insulating material; such as, Neoprene; can be employed to facilitate embedding contacts 15 and their respective leads therein. If container 39 is constructed of an electrically conductive material, layer 67 can form bushings about the leads and extend through the sidewall of container 39. To avoid difficulties with an electrical potential at the outer surface of container 39, it is preferred to employ insulating materials in constructing container 39.

Bellows 45 can be constructed of any material that will withstand the pressure of the column of mercury and will allow the desired flexibility for raising and lowering the column of mercury in container 39. Suitable bellows can be formed from the dense flexible plastic; such as, polystyrene and polypropylene; having a rigid base 47 formed of the solid plastic; such as, polystyrene. Dense flexible synthetic rubber; such as, Neoprene, can be employed with a stiffening element in bottom 47. Even flexible metallic bellows can be employed although as mentioned hereinbefore, there is a problem with having the electrical potential on the skin of the bellows by way of the conductive mercury therein.

Frame 52 can be constructed of any material having the desired rigidity. For example, frame 52 can be constructed of thermostetting plastic or the phenolic resins such as, Bakelite or polyesters. On the other hand, the frame of glass, for example, an electrically nonconductive support at the base of container 39 and contiguous with the top of bellows 45 may be employed in conjunction with a stronger and lighter metal frame; such as, steel, aluminum or magnesium.

Threaded shaft 49 may be constructed of any rigid material; such as, metals, thermosetting plastics or plastics like nylon; as long as the material is capable of imparting the requisite force to raise bottom 47 and column of mercury 41 or to oppose any vacuum that may be employed in container 39. Similarly, internally threaded gear 51 may be constructed of any material having the requisite strength. For example, gear 51 may be constructed of metal, nylon, or thermosetting plastic. Worm gear 53 can also be constructed of any material having the requisite strength. It may be advantageous to employ a metallic worm gear 53.

Motor 55 is a reversible motor and may be any of the well-known motors available on the market, and capable of delivering the requisite small amount of torque to worm gear 53. On the other hand, the limit switch means may be unnecessary in some commercial embodiments. For example, in some straight sequential power applications it is desirable to have the loads disconnected upon power failure. Therefore, a shaded pole motor is employed, in conjunction with a manual rewind spring, as motor 55. Upon power application the motor will wind the spring to its stop position, simultaneously advancing mercury 41 to its uppermost level. Thereafter, the motor acts as a solenoid until its power is shut off, automatically or through power failure. The spring unwinds upon removal of power from the motor, lowering mercury 41 to its lowermost level and providing a fail-safe function.

Only one form of the container and the means for sequentially immersing the contacts in the mercury have been shown. Various modifications of different forms of containers may be employed although it is vital that the container enable oxygen to be excluded from the mercury. Otherwise, mercuric oxide is formed during the arcing attending the electrical connection of the contacts effected by the mercury. For example, container 39 may be sealed about the elements penetrating
and contiguous with its walls and evacuated to remove oxygen and moisture, and to prevent any problem with compression of any gaseous fluid other than mercury vapor above the mercury when the column of mercury is raised into contact with the plurality of contacts.

On the other hand, oxygen can be excluded by flushing with an inert gas such as nitrogen or argon a U-shaped or J-shaped container having the tops of the legs of the U or J-vented to each other. The inert gas eliminates the necessity for an evacuated container. This type of container will be generically referred to as "U-shaped" hereinafter since this nomenclature is more widely employed than J-shaped.

When such a U-shaped container is employed, the main electrode and the contacts may be in one leg whereas in another leg a pig can be employed to force the column of mercury around the shape of the U and up the leg in which the contacts and main electrode are housed. The term "pig" is a term commonly employed to signify a free piston sealingly engaging the walls of a conduit and moving any fluid in the conduit before it as it is advanced in the conduit. Accordingly, the pig in one leg of the U will advance the mercury in the other leg. If desired, the leg containing the pig can be of larger diameter such that small movements of the pig in one leg of the container will effect relatively large movements of the mercury in the leg of the container housing the contacts and main electrode. The pig can be of a material which is responsive to an electromagnetic field and an electromagnetic field-inducing coil positioned about the leg containing the pig. Thus, the pig may be moved in response to a field induced by the electromagnetic coil in response to signals from a controller. The coil may be movable if larger movement of the pig is desired. Alternatively, the pig can be a magnet which would be repelled by a like pole of an external magnet mounted about the leg and movable along the longitudinal axis of the leg. The externally mounted magnet and if desired the electromagnetic coil can be moved by a device similar to that disclosed in connection with the figure and in response to signals from the controller.

In another arrangement, the means for sequentially immersing the contacts in the mercury may comprise a diaphragm separating a mercury portion of a lower chamber from a pneumatic portion. The pneumatic portion is then connected by a suitable conduit with a pneumatic instrument which supplies pressure in response to control signals.

Other means for sequentially immersing the contacts may be employed and still be within the purview of this invention.

Main electrode 13 may enter container 39 from the top as shown in FIG. 1. On the other hand, with a U-shaped configuration, it may be advantageous for main electrode 13 to enter from the bottom of the U-shaped container. In another arrangement, main electrode 13 may advantageously be positioned such that it enters from the side and has a 90° bend upward or downward in order that contacts 15 can be disposed linearly therealong.

FIG. 2 illustrates another form of the invention. Therein main electrode 13 for connecting with one side of a power source is an elongated tubular member instead of a rod. Contacts 15 are arranged annularly between container 39 and main electrode 13 and along the longitudinal axis of and spaced from the elongated tubular member serving as main electrode 13. Contacts 15 are connected with their respective leads 17, etc. for connecting, via their respective leads, with another side of the power source. Mercury 41 can be raised into container 39 by any suitable means such as described hereinbefore to sequentially immerse contacts 15 and the associated portions of main electrode 13. Container 39 is shown as a glass container scaled about main electrode 13 and the leads 17, etc. associated with the respective contacts 15.

In either the embodiment illustrated in FIG. 1 or FIG. 2 a plurality of contacts 15 may be provided at any point along the longitudinal axis of main electrode 13, if desired. The plurality of contacts at a given point, or level, allow electrical connection of a plurality of loads with a given level of mercury.

Thus, it can be seen that the invention provides a simple, compact, dependable, economically feasible switch capable of connecting a power source sequentially to a plurality of loads or load elements in applications involving relatively high total load currents, obviating the difficulties of the prior art. Moreover, as described hereinbefore, the switch of the invention, not only enables straight sequential interconnection of load elements to a power source, but also enables use of the greatest flexibility and most advanced principles that can be built into controllers.

Although the invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim:

1. A sequential switch comprising:

a. a main electrode of low resistivity conductive material having the general form of an elongate member for connecting to one side of a power source;

b. a plurality of contacts having leads for connecting through loads to another side of said power source, said contacts being disposed linearly along, spaced from, and closely adjacent said main electrode; each said contact being adapted for normally conducting a current of at least 10 amperes;

c. a container having a supply of mercury therein and housing said main electrode and said plurality of contacts and said adjacent portions of said main electrode in said mercury.

2. The switch of claim 1 wherein said main electrode is a rod.

3. The switch of claim 1 wherein said main electrode is an elongated tubular member.

4. The switch of claim 1 wherein said container comprises a sealed, evacuated chamber.

5. The switch of claim 1 wherein said main electrode enters the top of said container and comprises within said container a substantially straight rod.

6. The switch of claim 1 wherein means for sequentially immersing said contacts and portions of said main electrode in said mercury comprises a second chamber contiguous with said container and having means displacing mercury therefrom into said container to increase the height of the column of mercury in said container.

7. The switch of claim 6 wherein said second chamber comprises a bellows having a bottom that can be elevated to displace said mercury into said container.