A double acting switch construction geared to fail-safe operation, whereby the application of an actuating force to the switch serves to move the switch contacts from their normally biased position, either open or closed, to the other of said positions but the prolonged and/or increased application of the force, indicative of malfunction, causes a reversal of the switch's normal function and a return of the contacts to their original position. This double action is achieved by applying the force to resilient means which effect the movement of the contacts, the resilient means engaging an abutment under undesirable force conditions, being deformed thereby and thus causing the return of the contacts to their original position. In conjunction with the switch construction, temperature-sensitive elements may be utilized as the actuating means, the force exerted by the elements as well as their effective length varying with temperature.
The present invention relates to an improved, fail-safe switch construction wherein the normal opening-closing sequence of the contacts thereof is reversed in response to a malfunction as reflected in the actuating force applied thereto.

Snap action switches generally operate by the application of force to a spring means which effects the movement of the spring contacts from their normally biased portion, e.g., from open to closed. Removal of the force enables the contacts to return to their original position. Such switches are usually insensitive to malfunctions in the actuating mechanism, particularly those resulting in the exertion of excessive force on the switch. In such an instance, the contacts will remain in their engaged position, thereby permitting the continuous functioning of the circuit attached thereto. Such a situation is undesirable at best, and often dangerous, particularly when the exertion of excessive force arises from some improper condition, such as overheating.

To take another example, often such switches are activated by means of temperature-sensitive elements which normally retain a first configuration over a significant range of temperature, but when a particular temperature has been reached they will tend to change their configuration quite radically and exert an appreciable amount of force in thus tending to change their configuration. The exerted force is then used to apply pressure to the spring means in order to alter the positioning of the contacts and, typically, open a circuit to a heating element. That circuit will close, and the heating element will be energized, when the element is in its first configuration. However, in the event that the element breaks, loses its properties above the transition temperature or is incorrectly installed, it is essential that the switch be inactivated and the contacts returned to their circuit-opening position, since the element is no longer able in normal fashion to turn off the heating element when the temperature becomes excessive.

It is the prime object of this invention to provide a switch construction which exhibits fail-safe operation in response to a malfunction in the actuating mechanism.

It is another object to provide such a construction wherein the contacts are in a given position upon the application thereof of an actuating force below a given value as well as upon the application thereof of an actuating force above that value.

It is still another object to provide a lever and abutment construction for the switch such that the movement of the lever over a first distance serves to move the contacts from their normally biased position, either engaged or disengaged, to the other of said positions, while the movement of the lever over a second distance causes it to engage and be deformed by the abutment so as to return the contacts to their normal position.

It is a further object to utilize a lever construction which can function equally well whether positioned internally or externally of the switch housing.

It is still a further object to utilize temperature-sensitive elements as the force exerting means in the novel fail-safe switch construction of this invention.

These objects are achieved in accordance with the present invention by providing a switch construction which is generally characterized by a switch housing, contacts mounted therein and relatively movable between engaged and disengaged positions, an actuating or force exerting element, lever means which serve to convert the movement of the actuating element into movement of the contacts, and an abutment which is positioned in the path of the lever means. Thus, when the application of force to the lever results in a movement thereof within a predetermined normal range of distances, a movement of the contacts from their normally biased position, either engaged or disengaged, to the other of said positions results. The application of force which effects a movement of the lever means beyond the normal range of distances causes the lever to engage and be acted upon by the abutment, resulting in a reversal of the normal function of the switches and the return of the contacts to their normally biased position. In this manner fail-safe operation is achieved, it being seen that the contacts are in their normally biased position during any malfunction which would tend to locate the lever means either beyond its normal range of travel or in advance of that normal range of travel.

As a further embodiment, a temperature-sensitive element is utilized in the switch construction as the force exerting means which normally retains its shape without any appreciable change over a significant range of temperatures but when a transition temperature is reached, the element will tend to change its shape quite radically and exert an appreciable amount of force in thus tending to change its shape. It is this force when applied to the lever means that results in the movement of the lever which is subsequently converted to movement of the contacts. Fail-safe operation is also provided in this instance inasmuch as the contacts will also be in their normally biased position in response to a malfunction in the temperature-sensitive element.

To the accomplishment of the above and to such other objects as may hereinafter appear, the present invention relates to a switch construction as defined in the appended claims and as described in this specification, taken together with the accompanying drawings, in which:

FIG. 1 is a side view of a typical switch embodiment of the present invention showing the lever means in a first position;

FIG. 2 is a side view of the switch of FIG. 1 showing the lever means in a second position, the position of appropriate actuation;

FIG. 3 is a side view of the switch of FIG. 1 showing the lever means in a third position and the resultant deformation of the lever means;

FIG. 4 is a top view of the lever means utilized in the switch of FIGS. 1-3;

FIG. 5 is a side view of the lever means of FIG. 4;

FIG. 6 is a side view of a second embodiment of the present invention showing an internally positioned lever means in the position it assumes in the absence of any force exerted thereon;

FIG. 7 is a side view of the switch of FIG. 6 showing the movement of the lever means to a second position and the corresponding movement of the contacts upon the exertion thereon of a predetermined force;

FIG. 8 is a side view of the switch of FIG. 6 showing the deformation of the lever means by engagement with an abutment and the resulting reverse move-
ment of the contacts upon the exertion thereon of a greater force than in FIG. 7;

FIG. 9 is a view, in perspective, of the support member utilized in the switch of FIGS. 6–8; and

FIG. 10 is a fragmentary view, in perspective, of the support member showing the abutment positioned thereon.

In the embodiment depicted in FIG. 1–5, switch assembly 10 comprises a housing 12 with a pair of contacts (not shown) mounted therein. Biasing means (not shown) are operatively connected to at least one of the contacts within housing 12. The contacts may, accordingly, be normally biased in either engaged or disengaged position and are moveable therewith.

For purposes of convenience in this disclosure, the contacts will be described as being normally biased in a disengaged position and requiring an external force applied thereto to be placed in an engaged position. Direct action against the biasing means is accomplished by means of a push button 4 or other similar operating element, which when depressed acts upon the biasing means to effect the alternate engagement and disengagement of the contacts. The switch construction per se is conventional, and need not be further shown or described here.

Lever 16, as depicted in FIGS. 4 and 5, is seen to comprise a structural strip with bend 18 separating sections 20 and 22. Section 20 is pivotally secured to bars 23 of housing 12 by means of tabs 24, 26 so as to permit pivotal movement of lever 16. As seen in FIG. 1, the normal, unstressed positioning of lever 16 places section 20 in contact with push button 14 without exerting any pressure thereon. It is required, when the lever 16 is mounted as shown with tabs 24 and 26 only permitted pivotal motion relative to the housing 12, that lever 16 be prepared from a material which can be permanently bent into the desired configuration while still exhibiting sufficient resiliency to provide the desired spring-like action and configuration deformability. The dimensions of the lever may be selected by the practitioner in accordance with his particular switch assembly, merely being required that the selected length of section 20 ensure that the path of movement of bend 18 is intercepted by the upper surface 28 of housing 12, the upper surface 28 thereby acting as an abutment for lever 16.

The force exerting means, indicated at 30, which functions as the actuating element for the switch, is operatively connected to section 22 of lever 16. Force exerting means 30 may comprise any element capable of exerting variable amounts of force. It may, for example, comprise a temperature-sensitive element and, in particular, one which will normally retain a first configuration without any appreciable change over a significant range of temperatures, but when a particular temperature has been reached, that element will tend to change its configuration quite radically and exert an appreciable amount of force in thus tending to change its shape. One substance having that characteristic is a nickel-titanium intermetallic compound known as “Nitinol.” It is disclosed in U.S. Pat. No. 3,174,851 of Mar. 23, 1965, entitled “Nickel-Base Alloys,” U.S. Pat. No. 3,515,643 of Nov. 7, 1970 entitled “High Strength Nickel-Base Alloys,” and U.S. Pat. No. 3,403,238 of Sept. 24, 1965 entitled “Conversion of Heat Energy to Mechanical Energy,” all patents being assigned to the United States of America as represented by the Secretary of the Navy. This material has a “memory.” If it is given a first shape or configuration and subjected to appropriate treatment, and thereafter its shape or configuration is changed, it will retain that changed shape or configuration until such time as it is subjected to a predetermined elevated temperature. When it is subjected to that temperature, it tends quite strongly to return to its original shape or configuration.

The actual operation of switch 10 is depicted in FIGS. 1–3. Thus, in FIG. 1, with no force being exerted on resilient lever 16, or with insufficient force to cause a downward movement thereof against the resilient upward bias of the switch button 14, force exerting means 30 is seen to occupy a first position and lever 16 is seen to occupy a comparable first position being in contact with push button 14 but exerting no effective downward pressure thereon. Accordingly, the switch contacts will be retained in their normally biased position, e.g., open-circuit. FIG. 2 depicts the situation where a moderate amount of force is applied at 30, the exact amount of force being determined on the basis of the individual switch assembly. With the application of that force, actuating lever 30 is moved to a second position which, in turn, results in a corresponding downward movement of lever 16 such that section 20 thereof depresses button 14. The depressed button 14 acts upon the biasing means in order to move the contacts from a disengaged to an engaged position, thereby closing the appropriate circuit.

Where, however, as in FIG. 3, a still greater force is exerted on the lever 16 by the actuating means 30, the lever 16 moves to a third position in which bend 18 of lever 16 engages the upper surface 28 of housing 12 at A. As lever 16 continues to its third position, the stress against lever 16 as a result of its contact with surface 28 causes a deformation of section 20, specifically a ballooning or upwardly-curving effect. This deformation thus relieves the downward pressure of section 20 on push button 14 allowing push button 14 to return to its normal position. Correspondingly, this movement will be reflected in a movement of the contacts to their normally biased disengaged position. Switch 10 has thus assumed a fail-safe position thereby opening the circuit connected thereto.

To arrange the snap action switch described above for operation in accordance with the temperature of the thermally-sensitive element, an appropriate element such as Nitinol is secured to section 22 of lever 16, either directly or by means of part 30. The element is formed of a material having the characteristic previously described, to wit, that when given a particular shape or configuration, it will tend to maintain that configuration until it is subjected to a predetermined temperature, and when that transition temperature is attained, the material will tend to assume a “memory” configuration different from its given configuration. Thus, when the element is cool or slightly heated, it will exert the minimum force required to move lever 16 from its first to its second (FIG. 2) position, resulting in the depression of push button 14 and, the consequent closing of the switch contacts. Upon an increase in the temperature in excess of the transition temperature of the element, the element will change its shape to the memory configuration and thus exert an appreciable amount of force in tending to change its shape. This appreciable force thus results in a movement of lever 16 to engage abutment A, a corresponding defor-
mation of section 20 and release of push button 14 to return the contacts to their original disengaged position (FIG. 3).

The fail-safe operation of this switch construction is as follows: If the thermal-sensitive element breaks or becomes physically disconnected from the system in some manner, there will be insufficient force exerted on the lever 16 to move it from its first (FIG. 1) to its second (FIG. 2) position, the contacts thereby assuming their normally biased open-circuit position. The heat, no longer thermostatically controlled by the temperature sensitive element, will nevertheless be turned off.

FIGS. 6–10 depict another embodiment of the present invention, this time having a single, internally positioned element functioning as both the biasing means for the contacts and the resilient lever 16. In this instance, switch assembly 40 comprises a housing 42 with a pair of fixed contacts 44, 46 mounted therein, between which a movable contact 60 is located. The contacts 44, 46 and 60 are electrically connected to terminals 45, 47, and 61 respectively. Terminal 61 and either or both of terminals 45 and 47 may be connected to external circuitry in order to control the latter, all as is well known in the art. For example, when an external heater is to be controlled, it would be connected between terminals 61 and 47, with terminal 45 being unused, the switch thus being in a normally open-circuit condition (FIG. 6).

Also mounted in housing 42 is conductive support member 48 which comprises upstanding members 50, 52 and abutment 54 positioned therebetween, terminal 61 extending from member 52. The configuration of support member 48 is depicted in FIGS. 9 and 10.

Conductive resilient lever means 56 is internally positioned in housing 42 and is suspended on support member 48 by means of the upstanding members 50, 52. Thus, one end 58 of lever 56 is supported on member 52 and is integrally connected thereto. Lever 56 then is suspended to extend across to member 50, being spaced from abutment 54, and carrying movable contact 60. A finger 64 integral with the lever means 56 is deformed against the side of upstanding member 50, i.e., in recess 66, thereby normally to bias contact 60 against contact 44. As in the previous embodiment, lever 56 should be prepared from a material which exhibits sufficient resiliency to provide the desired spring-like action and configuration deformability.

The force exerting means may consist of a plunger or push button 62, which may be actuated either manually or by external connection to any desired means, such as a temperature-sensitive element. Push button 62 is directed against the suspended section of lever 56 with abutment 54 being positioned between said member 50 and the point of contact B of said push button 62 on said lever 56, this relative positioning of the abutment being specifically determined to maximize the subsequent deformation of lever 56 in response to the force exerted thereon, this phenomenon being described in detail hereinafter.

The operation of switch 40 is depicted in FIGS. 6–8. Thus, using push button 62 as the force exerting means and with engagement of contact 60 with contact pin 44 representing an open circuit, single engagement of contact 60 with contact 46 representing a closed circuit, FIG. 6 depicts the situation where no effective operative force is being exerted against lever 56, lever 56 thus occupying a normally biased first position. Accordingly, the engagement of contacts 60 and 44 is indicative of an open circuit. FIG. 7 depicts the situation where a moderate amount of force is exerted via push button 62 against lever 56, the exact amount of force being determined on the basis of the individual switch system. With the application of that force, lever 56 is moved to a second position which results in a corresponding downward movement of contact 60 to engage pin 46, thereby closing the circuit. Where, however, as in FIG. 8, a still greater force is exerted, lever 56 occupies a third position. In its downward movement to its third position, lever 56 engages abutment 54. The stress against lever 56 at point B causes a deformation in lever 56 causing an upward, reversed movement of the section of the lever 56 between abutment 54 and contact 60. Correspondingly, this movement is reflected in the upward movement of contact 60 to once again engage contact 44.

If a Nitinol or other thermosclatic element is operatively connected to push button 62, the operation of the switch of FIGS. 6–10 will be essentially the same as that of FIGS. 1–5, with FIGS. 7 and 8 representing the normal low and high temperature conditions respectively and FIG. 6 representing the fail-safe position. This represents but one way that the switches of the present invention could be used, however. For example, FIG. 6 could represent a low force condition, FIG. 7 could represent a normal high force condition and FIG. 8 could represent a fail-safe too-high force condition, with the external element connected to terminal 47 energized only during the existence of the normal high force and being deenergized when the force is low or too high, or with an external element connected to terminal 45 energized when the force is low or too high but not when it is normally high, or both. Other variations will suggest themselves, and all variations are applicable to both of the illustrated embodiments.

The configuration and transition temperature of the temperature sensitive element may be selected by the practitioner in accordance with his particular needs. Thus, within a range of temperatures, the predetermined temperature at which the element will tend to revert to its memory configuration can be varied by altering the proportions of the constituents of the intermetallic compound, as is known in the art. The element may be made available in elongated strip form. The strip can be given a bent configuration and heat treated, and can thereafter be straightened out to substantially linear configuration. It will retain that linear configuration until subjected to the predetermined transition temperature, at which time it will revert to its bent configuration. Likewise, an opposite sequence may be adopted. A typical Nitinol material utilized in the instant invention was prepared with a flat memory configuration and having an upper transition temperature of 190°F.

Summarizing, it is thus seen that the present invention provides switch assemblies geared to fail-safe operation. Thus, the application of force to a lever means sufficient to move it a first distance results in a corresponding movement of the contacts from their normally biased engagement, either engaged or disengaged, to the other of said positions. An increased force causes the lever to move an additional distance, thereby to engage and be acted upon by an abutment and to result
in the return of the contacts to their normally biased position.

While the invention has been described in terms of the specific embodiments herein, it should be apparent that variations may be developed without departing from the spirit or scope of the invention.

I claim:

1. A double acting switch comprising a support having a surface, a pair of contacts mounted on said support and relatively movable with respect to each other between engaged and disengaged positions, actuating means movable relative to said support and operably connected to one of said contacts to move same between said engaged and disengaged positions, a resilient lever one end of which is pivotally mounted to said support for movement between first, second and third positions, said lever being divided into first and second sections by a bend in said lever, said first section being defined by said one end and said bend, said first section engaging said actuating means to move same in accordance with the movement of said lever, said lever moving said actuating means such that said contact is in one of said contact positions when said lever is in the first position, in the other of said contact positions when the lever is in said second position and moved back to said one of said contact positions when said lever is in the third position, said bend abutting said support surface when said lever is in said second position such that as said lever moves from said second to said third position said first section is deformed by said surface.

2. The switch of claim 1 further comprising a temperature sensitive element operably connected to said second section of said resilient lever to move said resilient lever between said first, second and third positions.

3. A double acting switch comprising a support, a pair of contacts mounted on said support and relatively movable with respect to each other between engaged and disengaged positions, actuating means movable relative to said support between first, second and third positions, a resilient lever one end of which is fixedly mounted to said support, one of said contacts being mounted on the other end of said lever, biasing means operably connected to said lever and said support to normally bias said contacts together said resilient lever having a first and a second surface, one of said surfaces being contacted by said actuating means to move said lever between first, second and third positions, said one contact being moved between one of said positions, the other of said positions, and back to said one of said positions as said actuating means moves between said first, second and third positions respectively and an abutment integral with said support and extending above the surface thereof in a direction substantially parallel to the movement of said actuating means, said abutment being spaced from said actuating means along said resilient lever, said abutment acting on said other surface of said resilient lever at a point along said resilient lever between said one contact and the portion of said resilient lever upon which said actuating means acts, said resilient lever being deformed as it moves from said second to said third position by action of said abutment exerting a force in one direction on said resilient lever and said actuating means exerting a force on said resilient lever in the opposite direction.

4. In combination with the switch of claim 3, means operably connected to said actuating means normally exerting force on said actuating means to position said resilient lever in its second position against the normal biasing action of said biasing means and effective when appropriately externally acted upon to exert additional force on said actuating means to position said resilient lever in its third position, said normal biasing means being effected to position said resilient lever in its said first position when said force exerting means becomes inoperative.

5. The switch of claim 4 in which said force exerting means comprises a temperature sensitive element, the force exerted by which varies with temperature.

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