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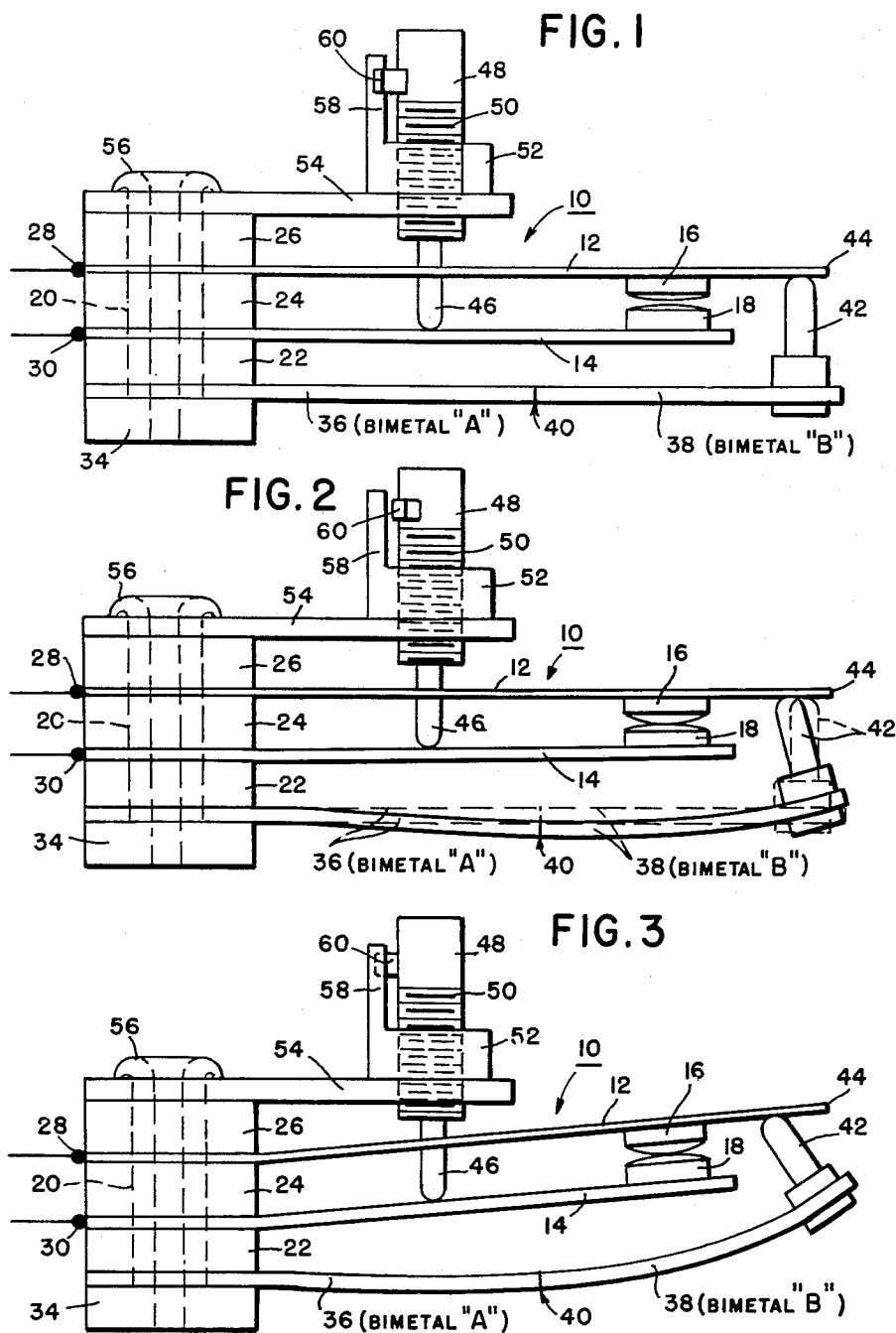
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THERMAL SWITCH AND IMPROVED THERMAL ACTUATOR

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THERMAL SWITCH AND IMPROVED THERMAL ACTUATOR 5

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The present invention relates to thermal switches and more particularly to thermal switches in which an improved thermal actuating arrangement provides a broader effective adjustment range for the switch.

Thermal switches are known in the prior art in which the circuit is controlled by two contacts. One of these contacts is customarily positioned by a bimetallic or other thermally responsive member, the position of which varies with temperature, while the position of the other contact is determined by some sort of adjusting member. Since the desired operating range for such a switch is often at least several hundred degrees above room temperature, it is necessary for the movable thermally responsive member and the contact controlled by it to move through a substantial range of displacement as the parts are heated from room temperature to the lower end of the desired operating range. In such cases, a corresponding range of movement of the adjusting member and its contact is ordinarily necessary in order to move the contact from a position in which the switch will be "off" at normal room temperatures, to a position in which the contacts will engage and disengage to maintain desired temperatures at the lower end of the operating range. Thus, there is a considerable range of movement of the adjusting member between this "off" position and the lower end of the operating range which represents motion which is wasted insofar as actual adjustment of the member within its operating range is concerned.

In many applications, for example, the adjusting member is in the form of a rotary control knob in which the complete range of movement must be limited to a single revolution to avoid confusion in setting the knob. If a substantial angular range of this single revolution is required merely for movement of the control knob from "off" position to the lower end of its operating range, it is apparent that the desired range of adjustment of the device between low and high operating temperatures must be compressed into the remaining fraction of a complete revolution. While this result can be achieved by the use of steeper cams or threads of higher pitch, the resulting adjustment at any point in the effective range is obviously less precise, when the available angular adjustment knob movement is more limited.

Various attempts have been made in the past to solve this problem. Some of these attempts, for example, have involved the prestressing of one of the switch elements, such as the bimetal, away from its room temperature position to the position it would occupy at the lower end of the desired operating range. Such prestressing, however, may be undesirable because of its possible adverse effects on the bimetallic member over a long period of time.

With the above problems of the prior art in view, it is accordingly one object of the present invention to provide an improved thermal switch in which there is a minimum of waste movement of the adjusting member between its "off" position and the lower end of its desired operating range of adjustment.

A further object is a thermal switch in which an adjust-

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ing member may be moved from an "off" position to an immediately adjacent low temperature operating position without prestressing of the thermally responsive actuating portion of the switch.

Still another object is a thermal switch in which an improved thermally responsive actuating member is provided.

Another object is the provision of such a switch in which the thermally responsive actuating member has a contact controlling portion which remains substantially stationary without prestressing, during temperature variations from room temperature to the lower end of the desired operating range.

Another object of the invention is an improved thermally responsive actuating device for applications in which no movement is desired during a predetermined range of temperature variation and in which relative movement of the actuator is desired during temperature variations through another range.

A still further object is an improved thermally responsive actuator composed of two bimetallic sections of different displacement versus temperature characteristics, joined to each other to produce desired non-linear displacement changes in response to temperature variations.

Other objects and advantages of the invention will be apparent from the following description in which certain preferred embodiments are set forth.

In the drawings which accompany this application and in which like reference characters indicate like parts,

Figure 1 is a side view of a thermal switch according to the present invention with the parts in "off" position.

Fig. 2 is a view similar to Fig. 1 showing the parts adjusted to the lower end of the operating range of the device, just prior to opening of the contacts by the thermally responsive actuator.

Fig. 3 is a view similar to Figs. 1 and 2 showing adjustment of the parts at the high temperature end of the operating range, just prior to opening of the contact by the thermally responsive actuating member.

Fig. 4 is a graph showing characteristic displacements plotted against temperature for the individual materials from which the thermally responsive actuator of the preceding figures is constructed and showing also the corresponding displacements of the composite actuating member.

Fig. 5 is a top view of a control knob applicable to the device of Figs. 1 to 3.

Fig. 6 is a view similar to Fig. 5 showing the effective range of control knob movement in a prior art device similar to that of Figs. 1 to 3 but incorporating an ordinary single strip of bimetal in lieu of the composite thermally responsive actuator of the present invention, and

Fig. 7 is a partial side view of a modified construction of the improved thermally responsive actuator.

As shown in Figs. 1 to 3, the improved thermal switch according to the present invention is indicated generally at 10. The switch includes first and second contact arms 12 and 14, respectively. Cooperating contacts 16 and 18 are carried by the respective arms and are designed to open and close the desired circuit by means of terminal connections 28 and 30 at the respective contact arms.

The ends of the contact arms opposite the contacts themselves are supported in spaced relation on a bolt or tubular shaft 20 by means of spacing insulators 22, 24, and 26. An improved thermally responsive actuating member according to the present invention is indicated at 32 and is also supported on the member 20 between insulating spacer 22 and the head or shoulder 34 at one end of member 20.

The improved thermally responsive actuator 32 includes a first portion 36 at the end secured to member 20, and a second portion 38 secured to the outer end of portion 36

at 40. The particular characteristics of the thermally responsive portions 36 and 38 and the manner in which they differ from each other are discussed below.

At the outer end of the thermally responsive portion 38 of actuator 32 is mounted an insulating member 42 which projects toward the first contact arm 12 and engages the outer end 44 of such arm. Contact arm 12 is resiliently biased toward the actuator 32 so that portion 44 will normally be held in engagement with the insulating button 42 when the parts are in the "off" position of Fig. 1.

The second contact arm 14 is resiliently biased upwardly toward the first contact arm 12 and against an adjustable stop 46 of insulating material. This stop 46 extends through an opening in the upper contact arm 12 and is connected to the lower end of an adjusting shaft 48 which is threaded at 50 for engagement within an internally threaded nut or body portion 52. This threaded body portion 52 is secured at the outer end of a rigid arm 54 which is fixed to the switch-supporting member 20 adjacent the insulating spacer 26. As shown in Fig. 1, the body portion 20 may extend upwardly through the rigid strip 54 and be riveted over on the upper side of said strip at 56. Thus the various parts of the switch are firmly secured in the desired stacked relationship between the shouldered or head portion 34 of member 20 and the riveted opposite end portion 56.

Because of the threads 50 on adjusting shaft 48, rotation of the shaft will result in axial movement of the insulating stop 46 for adjustment of the limiting position of second contact arm 14 and its associated contact 18. It is customary in such switches to limit the rotation of shaft 48 to substantially one complete revolution to avoid confusion in the indicia carried by or associated with the control knob attached to the shaft. For this purpose the body portion 52 is provided with a vertical stop 58, while the shaft 48 carries a radially extending projection 60 for engagement with opposite edges of stop 58 to limit the rotation of shaft 48 to slightly less than one complete revolution.

In the position of Fig. 1, projection 60 is shown in contact with the near edge of stop 58 to determine the "off" position of the switch. In this position the insulating portion 46 moves the lower contact arm 14 down so that its contact 18 is spaced below the contact 16. The resilient bias of the first contact arm 12 carrying contact 16 holds this contact arm down so that its outer end 44 is in engagement with the insulating button 42 on the actuator. The actuator is sufficiently stiff to limit this downward movement of the upper contact arm 12 and thus maintain the spacing between contacts 16 and 18 so that the contacts remain open and the switch is effectively in its "off" position. The parts are shown in Fig. 1 at normal or room temperature.

In Fig. 2 the control shaft 48 has been rotated slightly to move the projection 60 away from the stop 58 just far enough to move the insulating portion 46 upwardly and permit the resilient bias of second contact arm 14 to urge its contact 18 into engagement with contact 16. This engagement may shift the upper contact arm 12 slightly upwardly and thus space its outer end 44 a few thousandths of an inch above the insulating portion 42 of the actuating member. In Fig. 2, the actuating member is shown in dotted lines in its room temperature position corresponding to the position of Fig. 1.

The heavy line position of Fig. 2 illustrates the position assumed by this improved actuating member as the temperature increases to the point where it has just reached the lower end of the operating range, i. e., the temperature at which the adjusting member 48 is set to make and break the contact. Here the insulating button is just about to engage the portion 44 of upper contact arm 12. Slight additional heating of the parts will now cause upward movement of the insulating button 42 to raise the upper contact arm and space the contact, thus breaking

the controlled circuit. Subject to slight variations in temperature from the position shown in Fig. 2 at the lower end of the operating range, the bimetallic actuator will move up and down a few thousandths of an inch to cause engagement and disengagement of the contacts in response to slight variations above and below the desired operating temperature.

It will be noted that in the position shown in Fig. 2, just prior to opening of the contacts at the lower end of the operating range, the effective position of the insulating button 42 is essentially the same as far as engagement with contact arm 12 is concerned as was the case when the parts were in the room temperature position of Fig. 1, shown in dotted lines in Fig. 2. The actuating member 32 has been deflected in such a way that the portion 36 has deflected downwardly, while the portion 38 has deflected upwardly just enough to offset the downward deflection of portion 36 and thus maintain insulating button 42 at the same relative level. The reason for this behavior of the actuating member will be understood from Fig. 4 where the characteristics of the individual components of the actuator are shown together with the characteristics of the composite actuator. As shown here, the two thermally responsive portions of the actuator are made of bimetallic material of different displacement versus temperature characteristics. In this particular example, the portion 36, indicated as bimetal A, is constructed of material having a reversible displacement versus temperature characteristic. Such a material exhibits a negative displacement, i. e., a displacement in one direction, throughout certain temperature ranges, and then exhibits a positive displacement characteristic, i. e., a displacement in the opposite direction, in response to temperature changes through another range.

Materials are known which have such reversible displacement versus temperature characteristics. Some of these materials are based on the use of so-called "super-invars" or alloys of iron and nickel in which advantage is taken of the effect of adding cobalt to obtain a negative coefficient of thermal expansion at ordinary or low temperatures. By a proper combination of such materials, the desired effects can be achieved. One material which is commercially available at the present time and which has a reversible displacement versus temperature characteristic is the bimetal sold by the H. A. Wilson Company of Newark, New Jersey, under the trade name "Saflex." It is understood that this bimetal includes two "invar" or nickel-iron alloy layers of different thermal expansion characteristics which combine to produce a reversible displacement versus temperature characteristic as shown for bimetal A in Fig. 4.

The material illustrated as bimetal A in Fig. 4 thus has a negative displacement or deflection characteristic from room temperature to substantially the range of 250 degrees which is the lower end of the desired operating range for the particular switch in question. Up to this point, the bimetal portion 36 of Figs. 1 to 3 will tend to deflect downwardly thus moving the junction 40 downwardly and tending to move the entire actuator assembly including insulating portion 42 downwardly. At substantially 250 degrees, however, the material begins to deflect in the opposite direction so that its negative deflection is gradually reduced until at some higher temperature, between 250 degrees and 500 degrees, the deflection will be restored to that which occurred at room temperature. For temperatures above this point, a positive deflection will occur which tends to move the insulating portion 42 even higher.

The portion 38 of the actuator, which is indicated as bimetal B in Fig. 4 is formed, on the other hand, of a standard bimetallic material which exhibits a substantially linear and positive displacement versus temperature characteristic from ambient or room temperature all the way to the high end of the desired operating temperature range.

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Since these portions are coupled end to end, as shown in Figs. 1 to 3, it will be apparent that during the change from normal room or ambient temperature to the temperature at which bimetal A reverses its displacement versus temperature characteristics, the positive deflection of bimetal B will tend to move insulating portion 42 in the opposite direction from the downward movement that would be caused solely by use of bimetal A. By careful analysis of the relative displacement rates of the two

bimetals, it is possible to select relative lengths for portions 36 and 38 such that the positive displacement of bimetal B will almost exactly equal and offset the negative displacement of bimetal A. Thus for temperature changes in the range from zero to 250 degrees, the graph indicates that the net or resultant movement of the composite bimetal 32 remains substantially zero until the lower end of the operating range is reached. At this point, which coincides substantially with the point of reversal of the displacement versus temperature characteristics of bimetal A, both bimetal A and bimetal B assume substantially linear and positive deflection characteristics so that their movements will reinforce each other rather than oppose each other. Hence, from the lower end of the operating temperature range at 250 degrees to the upper end of the range of 500 degrees or above, the net displacement versus temperature characteristic of the composite bimetal 32 will be positive and will be more rapid or more steeply inclined than either of the individual characteristics.

It is believed to be possible in theory to provide a single bimetal strip, by suitable selection of the thermal characteristics of its individual layer portions, such that a similar net or resultant displacement characteristic would be achieved, i. e., zero displacement during temperature changes within a first range, and positive displacement versus temperature response within a second temperature range. Preferably, however, two complete bimetallic portions of different characteristics are used, particularly in view of the greater freedom in design in balancing and combining existing commercial bimetals, as against the difficulty of obtaining a single bimetal of specific characteristics where the expected volume of use might be small. Also it is believed to be easier to obtain a relatively sharp change in the resultant displacement characteristic at the boundary between two such temperature ranges with two bimetals of suitable characteristics than with a single bimetal.

With further reference to Fig. 2, the heavy line position of the composite bimetallic actuator shows the parts at substantially the lower end of the operating temperature range (i. e., at approximately 250 degrees F. in this example), just at the point of reversal of the displacement versus temperature characteristics of the portion 36. Thus a slight additional increase of temperature will cause upward deflection of both bimetallic portions 36 and 38 from the heavy line position of Fig. 2, these displacements being additive and therefore causing engagement of the insulator 42 against portion 44 to raise the upper contact arm 12 and open the contacts 16 and 18. The subsequent decrease of temperature would then restore the parts to the heavy line position of Fig. 2 for reengagement of the contacts. Thus the switch will continue to cycle in substantially the position of Fig. 2 in response to predetermined slight variations from the 250 degree temperature at this lower end of the operating range.

Fig. 3 illustrates the position of the switch parts when the device is set for operation at the high end of the operating range. Here the adjusting shaft 48 has been rotated all the way around until the projection 60 engages the far side of stop 58 to prevent rotary movement. This rotation of adjusting shaft 48 has raised insulating portion 46 and has thus permitted the resiliently biased contact arm 14 to follow the upper contact arm and maintain the contacts in engagement until the lower arm reengages insulating portion 46. In the position of Fig. 3, the further displacements of bimetal portions 36

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and 38 are both in an upward direction and the parts are shown in the position in which the upward displacement of insulating button 42 has carried the upper contact arm upwardly to a point where the lower contact arm has just begun to engage the insulating portion 46. Further upward deflection in response to a slight additional increase of temperature will move the upper contact away from the lower contact and open the circuit. Thus the parts are in essentially the position at which they will continue to cycle between open and closed position at the upper end of the operating range in response to slight variations in temperature from the predetermined high operating temperature.

Obviously, the operation of the switch at intermediate temperatures between the low operating temperature of Fig. 2 and the high operating temperature of Fig. 3 will depend on the actual position and adjustment of the shaft 48 and its insulating section 46. When it is desired to open the circuit by movement of the switch parts to "off" position, it is only necessary to rotate the control shaft 48 so that projection 60 reengages the near side of stop 58. Such rotation will cause downward movement of the insulating portion 46 and will force the lower contact arm and its associated contact downwardly away from the upper contact to open the circuit. This open circuit condition will be maintained even after the thermally responsive actuator cools below the operating temperature. At the ambient room temperature, insulating portion 42 on the actuator will remain in essentially the same displaced position and will thus hold the portion 44 and its associated upper contact in a position spaced slightly above the lower contact as clearly shown in Fig. 1.

Figs. 5 and 6 clearly show the advantages of the present invention in providing a larger useable range of angular adjustment in the operating knob connected to shaft 48. A control knob 61 is shown supported on the top of the adjusting shaft 48. The knob is provided with an "off" position indicated at 62, and the parts are shown with this "off" position in alignment with a suitable index mark 64. Thus the knob position of Fig. 5 corresponds to the switch position of Fig. 1, with the projection of 60 of shaft 48 engaging one edge of stop 58. The projection and stop have been extended beyond the control knob in Fig. 5 for convenience in understanding how the useable range of the control knob is increased.

With the construction of the present invention, the knob indicia for the low end of the operating temperature range can be located relatively close to the "off" position as shown by the 250 degree notation at point 66. The only angular spacing which is required between points 62 and 66 on knob 61 is that which is just sufficient to insure that the contacts will be open at the "off" position and closed at the 250 degree position.

The upper end of the useable temperature range is indicated in this case by the notation 575 degrees F. at point 68 on the control knob. This point is located at a position on the knob which will be opposite index 64 when knob 61 is rotated all the way around so that projection 60 engages the opposite side of stop 58. Thus a major portion of the angular movement of knob 61 through one complete revolution is available for effective adjustment of the switch between the low and high ends of the desired operating temperature range. This angular area is indicated by the arrow 70 in Fig. 5.

By the way of contrast, attention is directed to the prior art arrangement of Fig. 6 which shows a similar type knob as it would have to be arranged in the event that the bimetallic actuator of the present invention were eliminated and an ordinary single piece of bimetal including a positive linear displacement versus temperature characteristic were substituted. Here the adjusting shaft is shown at 72 and the knob controlling its position at 74. The "off" position of the knob is indicated at 76 in alignment with an index 78. A projection 80 on shaft 72 engages one

edge of a stop 82 to establish this "off" position just as in the previous case.

With an ordinary single piece of bimetal, there is, of course, a substantial displacement from ambient or room temperature up to the lower end of the operating temperature range which in this case has been chosen for example as 250 degrees. Thus the 250 degree position can not be located at point 84 on the knob corresponding to its location in Fig. 5, since rotation of the knob from the "off" position to alignment of point 84 with index 78 would merely suffice to close the contact at room or ambient temperature. The moment the bimetal started to heat slightly above room temperature, the contacts would be open and the switch would cycle at this temperature rather than at the desired 250 degrees. Therefore the 250 degree mark in this case must be located substantially around the circumference of the knob as indicated at point 86. The high position or 575 degree indicia is then located at a point 88 which will be in alignment with index 78 when the knob is completely turned so that projection 80 engages the opposite side of stop 82.

In this case, the useable range of control knob movement between the low and high operating temperatures is indicated by the arrow 90 and is only about half the circumference of the knob. In other words, in movement from "off" to high position, it was necessary for the knob first to move from "off" position to a point which would close the contacts at room or ambient temperature (i.e., the point 84) and then to turn the knob through a further angular displacement sufficient to keep the contacts closed as the thermally responsive actuator is heated up to the lower end of the operating range. This angular displacement between positions 84 and 86 on the knob of Fig. 6 serves no useful purpose of adjustment within the operating range of such a switch and therefore requires that all adjustments between the low and high end of the operating range be compressed into a smaller portion of the circumference as shown by arrow 90.

The present invention, by eliminating the necessity for angular displacement of the knob between ambient temperature and the low end of the operating temperature range, makes it possible to provide a much wider useable range of adjustment of the control knob as shown by arrow 70 of Fig. 5. Thus greater precision of adjustment is possible for any given setting between the lower and upper limits of the desired operating range. The only unused portions of the full 360 degree angular circumference of the control knob of Fig. 5 are represented by the narrow angular portion between the "off" position 62 and the high position 68 which is required by virtue of the finite width of the projection 60 and stop 58. This portion of the possible angular movement of the knob is effectively lost in either case. The same is true of the portion of the circumference between the "off" position and either position 66 of Fig. 5 or point 84 of Fig. 6, since some finite movement of the control knob is necessary to change the position of the contact from open to closed circuit condition in movement from "off" position to an energized position. But since the wasted angular displacement between positions 84 and 86 of Fig. 6 is eliminated in the arrangement of Figs. 1 to 5, it is clear that the present invention permits maximum utilization of the rotation of a control knob through substantially one revolution, for effective adjustment of the switch condition within the limits of the desired operating temperature range.

In Fig. 7 a modification in the construction of the thermally responsive actuator according to the invention is disclosed. Here the actuator is indicated generally at 92 and includes a first thermally responsive portion 94 and a second thermally responsive portion 96 connected together at 98. These thermally responsive portions are of different displacement versus temperature characteristics just as in the previous case, portion 94 preferably having a reversible displacement versus temperature characteristic while portion 96 has a linear and non-reversible

shown in Fig. 7, is in the form of a lap joint with the two layers of bimetallic material welded together at their overlapping faces. An insulating button 100 is carried at the outer end of portion 96, while the inner end of portion 94 is supported at 102 in a suitable stack arrangement between insulators 104 just as in the previous embodiment. Thus Fig. 7 illustrates a lap type of joint between the two thermally responsive portions of different displacement versus temperature characteristics, while the device of Figs. 1 to 3 includes a butt joint or butt weld between these two portions.

Example 1

By way of illustration, a switch was constructed as shown in Figs. 1 to 3, but with an actuator welded as in Fig. 7. The following dimensions and materials were used for the bimetallic actuator. The portion 94 was constructed of material having a displacement versus temperature characteristic which was reversible at substantially 250 degrees F. The above-described material sold commercially under the trade name "Saflex" by the H. A. Wilson Co. was used, with a thickness of 0.020 inch and an effective length of $\frac{5}{8}$ inch from the center of the overlapped welded area at 98 to the nearest edge of the clamping insulator 104.

For the outer portion 96, a material having a positive linear displacement versus temperature characteristic and sold commercially by the Wilson Co. under the trade name "Highheat" was used. The thickness of this portion was 0.020 inch and its effective length from the center of the overlapping welded area at 98 to the center of the insulated actuating button 100 was $1\frac{1}{32}$ inch.

The resulting actuator showed substantially no deflection of actuating button 100 in the temperature range from room temperature to substantially 250 degrees F. From 250 degrees F. to 600 degrees F., the button 100 moved substantially linearly through a total deflection or displacement of 0.070 inch.

While the examples shown and described herein have been limited to bimetallic actuating portions which deflect laterally in response to temperature variations, it will be understood that the principles of the present invention can also be applied to other types of thermally responsive members as long as such members have the desired displacement versus temperature characteristics, whether the displacement is in the form of a lateral deflection as in the case of bimetal or whether it is in the form of a longitudinal expansion as in the case of various expanding materials.

A construction has accordingly been provided which accomplishes the objects set forth at the beginning of this specification and which makes possible the construction of thermal switches with a minimum of lost motion in the adjusting mechanism for the switch. Since minor variations and changes in the exact details of construction will be apparent to persons skilled in this field, it is intended that this invention shall cover all such changes and modifications as fall within the spirit and scope of the attached claims.

Now, therefore, I claim:

1. A thermally responsive actuating member comprising first and second portions of thermally responsive materials having respectively different displacement versus temperature characteristics, and an operating point associated with at least one of said portions, the operating point and said portions being operatively interconnected for thermally responsive movement of said operating point according to the resultant of said different characteristics, and one of said portions comprising material having a reversible displacement versus temperature characteristic.

2. An actuating member according to claim 1 in which said one portion of reversible characteristic has a substantially negative displacement versus temperature characteristic throughout a first temperature range at one side

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of its reversal point and a substantially positive displacement versus temperature characteristic throughout a second temperature range at the other side of its reversal point and in which the other portion of thermally responsive material has a substantially positive displacement versus temperature characteristic throughout both of said first and second temperature ranges.

3. An actuating member according to claim 1 in which said one portion of reversible characteristic has a substantially linear and negative displacement versus temperature characteristic throughout a first temperature range at one side of its reversal point and a substantially linear and positive displacement versus temperature characteristic throughout a second temperature range at the other side of its reversal point and in which the other portion of thermally responsive material has a substantially linear and positive displacement versus temperature characteristic throughout both of said first and second temperature ranges.

4. An actuating member according to claim 3 in which the relative lengths and points of connection of said first and second portions are proportioned according to the steepness of the respective characteristics in said first temperature range, thereby maintaining the operating point of said member substantially stationary during changes in temperature throughout said first temperature range.

5. A thermally responsive actuating member comprising first and second portions of thermally responsive material having different displacement versus temperature characteristics, the first portion having means for rigidly securing one end thereof and the second portion having one end secured to the other end of the first portion, one of said portions comprising material having a reversible displacement versus temperature characteristic.

6. An actuating member according to claim 5 in which the other of said portions has a substantially non-reversible displacement versus temperature characteristic and in which the relative lengths of said portions are proportioned to retain the free end of the second portion substantially stationary with respect to the secured end of the first portion during changes in temperature through a temperature range located entirely at one side of the reversal temperature of said material with the reversible characteristic.

7. A thermal switch for selective operation at any of a plurality of temperatures within a predetermined operating temperature range the lower end of which is substantially above normal ambient temperature, said switch comprising first and second contacts, a manually adjustable member operatively controlling the operating position of at least one contact and thereby establishing the selected operating temperature of the switch, and a thermally responsive actuator operatively controlling the relative positions of the two contacts and thereby engaging and disengaging the contacts in response to predetermined variations from the selected operating temperature, said actuator including at least first and second portions of thermally responsive materials having different displacement versus temperature characteristics, said portions being operatively connected with each other and with one of said contacts for thermally responsive movement of said last-mentioned contact according to the resultant of said different characteristics, said first thermally responsive portion having one displacement versus temperature characteristic within said predetermined operating temperature range and a substantially different displacement versus temperature characteristic between ambient temperature and said operating temperature range, and said second thermally responsive portion having a displacement versus temperature characteristic in said operating temperature range which, in combination with said characteristic of said first thermally responsive portion in said operating temperature range, provides the desired engagement and disengagement of the contacts within said operating temperature range, and said second thermally responsive por-

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tion having a displacement versus temperature characteristic between ambient temperature and said operating temperature range which, in combination with said characteristic of said first thermally responsive portion between ambient temperature and said operating temperature range, substantially prevents relative movement of the contacts during temperature variations from ambient temperature to the operating temperature range.

8. A thermal switch for selective operation at any of a plurality of temperatures within a first predetermined operating temperature range, said switch being exposed to temperatures in a second predetermined temperature range adjacent to said first range during transition from ambient temperature to said operating range, said switch comprising first and second contacts, a manually adjustable member operatively controlling the position of at least one contact to establish an "off" position in which the contacts remain open at temperatures throughout both of said ranges and also to establish an adjusted operating position for any selected operating temperature in said first range, and a thermally responsive actuator operatively controlling the relative positions of the two contacts and thereby engaging and disengaging the contacts in response to predetermined variations from the selected operating temperature, said actuator including first and second portions of thermally responsive materials having respectively different displacement versus temperature characteristics, said portions being operatively connected with each other and with one of said contacts for thermally responsive movement of said last-mentioned contact according to the resultant of said different characteristics within said operating temperature range, the relative dimensions and point of connection of said first and second portions being proportioned according to their respective characteristics at temperatures between the normal ambient temperature and the operating temperature range and thereby maintaining the relative position of said last-mentioned contact substantially unchanged during temperature variations from ambient temperature to the operating range.

9. A thermal switch according to claim 8 in which one of said portions has a positive displacement versus temperature characteristic throughout said first temperature range and a negative displacement versus temperature characteristic throughout said second temperature range, and the other of said portions has a positive displacement versus temperature characteristic throughout both of said ranges.

10. A thermal switch according to claim 9 in which the first contact is resiliently biased toward the second contact and toward said actuator, positive displacement of the actuator as a whole tending to move the first contact against said bias and away from the second contact, and the second contact being resiliently biased toward the first contact and toward the manually adjustable member, said adjustable member thereby limiting the resiliently biased movement of the second contact and thereby selectively establishing said "off" position corresponding to a first position of the adjustable member and an operating position for the boundary temperature between said ranges corresponding to a second position of the adjustable member immediately adjacent its first or "off" position.

11. A thermal switch comprising first and second contacts and a thermally responsive actuator operatively controlling the position of one of said contacts to engage and disengage the contacts in response to predetermined variations from a selected operating temperature, said actuator including at least first and second portions of thermally responsive materials having different displacement versus temperature characteristics, said portions being operatively connected with each other and with said one contact and providing a displacement versus temperature characteristic for the contact which differs from the displacement versus temperature characteristics of the individual portions and is a resultant thereof, one of said

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portions having substantially different displacement versus temperature characteristics in two different temperature ranges thereby effecting different displacement characteristics of said one contact in the two ranges, said one of said portions having a reversible displacement versus temperature characteristic.

12. A thermal switch comprising first and second contacts and a thermally responsive actuator operatively controlling the position of one of said contacts to engage and disengage the contacts in responsive to predetermined variations from a selected operating temperature, said actuator including at least first and second portions of thermally responsive materials having different displacement versus temperature characteristics, said portions being operatively connected with each other and with said one contact and providing a displacement versus temperature characteristic for the contact which differs from the displacement versus temperature characteristics of the individual portions and is a resultant thereof, one of said portions having substantially different displacement versus temperature characteristics in two different temperature ranges thereby effecting different displacement characteristics of said one contact in the two ranges, said one of said portions having a reversible displacement versus temperature characteristic and the other portion having a substantially linear and non-reversible displacement versus temperature characteristic.

13. A thermal switch for selective operation at any of a plurality of temperatures within a predetermined operating temperature range the lower end of which is substantially above normal ambient temperature, said switch comprising first and second contacts, a manually adjustable member operatively controlling the operating position of at least one contact and thereby establishing the selected operating temperature of the switch, and a thermally responsive actuator operatively controlling the relative positions of the two contacts and thereby engaging and disengaging the contacts in response to predetermined variations from the selected operating temperature, said actuator including at least first and second portions of thermally responsive materials having different displacement versus temperature characteristics, said portions being operatively connected with each other and with one of said contacts for thermally responsive movement of said last-mentioned contact according to the resultant of said different characteristics within said operating temperature range, the relative dimensions and point of connection of said first and second portions being proportioned according to their respective characteristics at temperatures between the normal ambient temperature and the operating temperature range and thereby maintaining the relative position of said last-mentioned contact substantially unchanged during temperature variations from ambient temperature to the operating range, one of said portions having a reversible displacement versus temperature characteristic, the point of reversal being at substantially the lower end of said predetermined operating temperature range.

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14. A thermal switch according to claim 13 in which the other of said portions has a substantially linear and non-reversible displacement versus temperature characteristic from normal ambient temperature to the upper end of the predetermined operating temperature range.

15. A thermal switch for operation within a predetermined first temperature range which differs substantially from normal ambient temperature to provide a predetermined second temperature range to which the switch must be subjected in changing its temperature from said ambient temperature to said first temperature range, said switch comprising first and second contacts and thermally responsive actuating means operatively controlling the relative movement of the contacts to engage and disengage the contacts in response to predetermined variations from a selected operating temperature in said first range, said actuating means comprising at least first and second thermally responsive portions having respectively different displacement versus temperature characteristics, means operatively connecting said first and second portions to one of said contacts for causing relative movement of said one contact according to the resultant of said different characteristics, said first thermally responsive portion having one displacement versus temperature characteristic within said first temperature range and a substantially different displacement versus temperature characteristic within said second temperature range, and said second thermally responsive portion having a displacement versus temperature characteristic in said first temperature range which, in combination with said connecting means and said characteristic of said first thermally responsive portion in said first range, provides the desired relative movement of said one contact in response to temperature variations within said first temperature range, and said second thermally responsive portion having a displacement versus temperature characteristic in said second temperature range which, in combination with said connecting means and said characteristic of said first thermally responsive portion in said second range, substantially prevents relative movement of said one contact in response to temperature variations within said second temperature range.

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