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(54) IMPROVEMENTS RELATING TO SNAP-ACTING THERMALLY RESPONSIVE BIMETALLIC ACTUATORS

(71) I, JOHN CRAWSHAW TAYLOR, a British subject of 9 Homefield Park, Ballasalla, Castletown, Isle of Man, formerly of Edge Lee, Bishops Lane, Buxton, Derbyshire, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to snap acting thermally responsive bimetallic actuators for use in actuating the switch contacts of thermally responsive electric switches such as cut-outs, circuit breakers and thermostats.

A well known form of bimetallic actuator is a bimetallic disc of domed configuration which moves to an oppositely domed configuration with a snap action with changes in temperature. The simplicity of discs and their ease of manufacture, the basic operation being pressing a flat disc between steel dies to a desired domed configuration, has resulted in their widespread use, despite serious disadvantages.

One disadvantage particularly is that with wide differential discs very high peripheral stress concentrations result during inversion and in consequence the operating temperature at which the disc snaps tends to drift with age and its life is limited by stress-cracking: thus after about 10,000 operations the disc may stress-crack, whilst the operating temperature may have drifted by as much as 20°C. The net result is that in use such discs do not have accurately determined operating temperatures throughout their life.

Another disadvantage of discs is that of

their very small range of useful movement with snap-action which is often of the order of the uncertainties in the dimensions of other related components of a switch in which the disc may be incorporated.

In view of the widespread use of discs, extensive research has been made into their characteristics. There have been various proposals over the past 40 or so years to increase the movement and to decrease the accuracy of the operating temperature of discs. For example, radial corrugations have been impressed in a disc, stress-relief apertures have been inserted at the centre of a disc and mechanical arrangements for transmitting and increasing the effective movement of a disc have been proposed (see for example British Patent Specification 1031827). Despite the large amount of research that has gone into improving the characteristics of discs, none of the various proposals has done anything more than mitigate to a certain extent the disadvantages inherent in bimetal discs.

Another type of snap-acting bimetallic actuator which is well known and which avoids most of the disadvantages of discs is that described in British Patent Specification 657434. In the preferred form, such an actuator comprises a rectangular sheet or blade of bimetal having a central tongue released from between two outer legs whose ends adjacent the free end of the tongue are joined by a bridge portion. The bridge portion is mechanically crimped to impart a dish configuration to the bimetal blade so that it moves with changes in temperature between oppositely dished configurations with a snap action. Such an actuator has a much larger amount of movement with snap

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action than a disc. It is also possible accurately to set the operating temperature, which is in any case more stable under repeated use than that of a disc.

5 A disadvantage of such an actuator is that as a result of the method of deforming the blade by crimping, it cannot be mass produced to a closely predetermined operating temperature. The main disadvantage is that
10 the life of this actuator, although greater than that of a disc, tends to be shortened by cracks developing in maximum stress concentration areas at the junction of the central tongue with the outer legs.

15 Thus despite extensive research into and extensive use of various snap-acting bimetallic actuators the need still exists for a thermally responsive snap-acting bimetallic actuator which is suitable for mass production, provides an adequate range of useful
20 movement with snap action, has a reasonably stable operating temperature over its working life, and, very importantly has a long working life which is not prematurely ended by stress-cracking.

25 The invention provides a snap-acting thermally responsive bimetallic actuator comprising a member of sheet bimetal having an aperture with an outer perimeter and an inner perimeter defining a tongue free at
30 one end intermediate two lobe portions of said aperture, said inner perimeter and arcuate portions of said outer perimeter smoothly merging at rounded ends of the aperture adjacent the tongue root, an area
35 of said member surrounding said tongue and in relation to which said tongue, at least in part, is generally centrally disposed having been deformed in a die pressing operation to conform in shape to a die of domed
40 configuration, said domed area being such as to reverse its curvature with a snap action with change in temperature, the width of the domed area surrounding said tongue measured
45 radially from the centre of the domed area being greatest in the region of the tongue root, and the length of the tongue being greater than the width of the tongue as measured at the mid-point of the length of the tongue.

50 The actuator according to the invention can have a long working life without a significant danger of stress cracking, particularly at the tongue root which is an area
55 where high stress concentrations are developed.

60 The design of the region of the tongue root is important as regards the lifetime of the actuator, since it is here that the major part of the force for moving the tongue in the snap action is developed and hence high stress concentrations are developed in this region. Sharp corners in this region would
65 tend to provide localised areas of very high stress concentrations which would tend to

stress crack early in the working life of the actuator.

The smooth merging of the arcuate outer and inner perimeters in rounded ends, the radius of the rounded ends being necessarily
70 relatively large in order to avoid any discontinuities at the ends, helps to avoid high local stress concentrations in these regions.

75 The radial width of the domed area of the actuator surrounding the tongue is greatest in the region of the tongue root and in particular is preferably substantially greater than the width of the area generally opposite the free end of the tongue in order to ensure
80 that the major part of the force developed in the snap action of the actuator occurs at the root of the tongue and not in other parts of the remainder of the domed area which do not contribute greatly to the movement of the tongue. It is thereby ensured that the
85 remaining parts of the domed area have sufficient flexibility not to oppose the movement of the area at the tongue root, which might give rise to stress-cracking.

90 The remaining parts of the domed area are preferably narrow relatively to the tongue root region since it is unnecessary in these regions to develop a large force. It is however necessary not to reduce the width of the domed area so as to impair the overall
95 mechanical strength of the actuator to the point where it is incapable of delivering the necessary developed force on inversion.

1 Thus portions of said domed area bordering said lobe portions of said aperture and extending from said aperture rounded ends
10 towards the free end of said tongue preferably progressively reduce in width from said rounded ends towards the free end of said tongue. As preferred the width of said
15 domed area portions each reduce to a minimum value of the width of the domed area in the region opposite the free end of said tongue and the greatest radial width is at least twice as great as said minimum
20 width. Such progressive reduction in width has been found to provide a better compromise of the various design factors involved than for example a constant width from the tongue root to opposite the tongue
25 free end.

The arcuate portions of said outer perimeter of said aperture are preferably
30 circular for ease of manufacture and for providing an aperture with a smoothly flowing contour. The centre of the arcuate portions is preferably displaced from the centre of said domed area in the direction of the free end and the diameter of said arcuate
35 portions is greater than half the diameter of said domed area.

The tongue must itself have sufficient mechanical strength to deliver the desired
40 developed force. A long tongue is preferable in order to increase the movement of the

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actuator in the snap action movement whilst the tongue should be wide at its root in order to provide sufficient force in the snap action movement. The tongue should be such as to minimise any tendency for the tongue itself to invert breadthwise with snap-action of the actuator which would tend to reduce the useful movement of the free end of the tongue. In accordance with the invention the length of the tongue is greater than the width of the tongue as measured at the mid-point of the length of the tongue, preferably at least 1.5 times as great. Said greatest radial width as the domed area may be greater than the width of the tongue as measured at the mid-point of the length of the tongue. The tongue may be tapered with an angle of taper desirably between 15° to 30°. The shape of the free end of the tongue is not critical. If desired, the free end may be bent to change the reference plane of movement of the actuator. The inner perimeter of the aperture defining said tongue is preferably symmetrically disposed about a diameter of the domed area which diameter is also preferably a mirror axis of symmetry of the actuator, the longitudinal axis of the tongue then coinciding with the said axis of symmetry.

Preferably for convenience in manufacture of the bimetal member, the actuator according to the invention is domed over its whole surface, although if desired, some or all of the tongue may not be deformed during the die pressing operation. However other areas of the bimetal member may be provided which are left flat and undeformed; for example flat ears for mounting purposes may be provided extending from the domed area. The actuator is preferably circular in shape.

In a specific aspect, the invention provides a snap-acting thermally responsive bimetallic actuator comprising a circular member of sheet bimetal having an aperture therein with an outer perimeter having arcuate portions with a diameter greater than half that of said member and the aperture having an inner perimeter defining a tongue free at one end intermediate two lobe portions of said aperture, said inner perimeter and said arcuate portions of said outer perimeter smoothly merging at rounded ends of the aperture adjacent the tongue root, an area of said member surrounding said tongue and in relation to which said tongue at least in part, is generally centrally disposed having been deformed in a die-pressing operation to conform in shape to a die of domed configuration and being such as to reverse its curvature with a snap-action with change in temperature, the width of the domed area surrounding the tongue measured radially

from the centre of the domed area being greatest in the region of the tongue root, portions of the domed area bordering said lobe portions and extending from said aperture rounded ends towards the free end of the tongue each progressively reducing in width from said aperture rounded ends to a minimum value of the width of the domed area in the region opposite the free end of the tongue, and the length of the tongue being at least 1.5 times greater than the width of the tongue as measured at the mid-point of the length of the tongue.

By forming an actuator in accordance with the invention by a die-pressing operation, it is possible to mass produce actuators in a particularly simple and effective way. It has been found that actuators according to the invention can be formed in mass-production with more accurately determined operating temperatures, and with better stability, such stability in operating temperature being better not only than that of discs but also than that of bimetallic actuators as described in British Patent Specification 657434. This stability arises in large measure from the stress relief in said domed area provided by said aperture, and from the method of formation by die-pressing such an actuator which creates few undesired and unintentional local stress concentrations. The lack of such stress concentrations also contributes to an accurately determined operating temperature.

A further advantage of an actuator according to the invention is that for many applications its range of useful movement with snap-action can be substantially greater than that of an "equivalent disc," by which is meant an actuator identical to an actuator according to the invention apart from having no said aperture and hence no tongue.

A practical measure for many purposes of the useful movement of an actuator is the movement at the free end of said tongue with snap action measured from the periphery of the actuator to one side of the actuator against a nominal force of 50g wt. This useful movement is that which can ordinarily be employed in many typical electrical switches. It has been found that, using the above measure, an actuator according to the invention can provide between two and three times the useful movement of an equivalent disc. It is however the case that the greater the useful movement, the greater the differential, i.e. the difference in operating temperatures for increasing and decreasing ambient temperature, but this is not important for many applications.

This increase in useful movement is explicable in that whilst a disc has only a small useful movement, it develops a comparatively large force (~ 200 g wt), far greater than that required to open typical switch

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contacts, so that although relieving the stresses in the centre of an actuator by providing said aperture substantially reduces the force developed, this is unimportant for most purposes, and the resultant freedom of movement of the free end of the tongue results in a magnified, still useful movement of the actuator.

In view of this increased useful movement, it is possible to use cheaper types of bimetal sheeting (e.g. Ni-Cr/Ni-Fe laminates) rather than the more expensive types having a high manganese content such as are commonly used in discs.

Thus an actuator according to the invention can have various advantageous features in addition to a long working life, in particular a large range of useful movement and an accurately predetermined and stable operating temperature. Depending on the particular application envisaged, the actuator will be designed to emphasize one or other of such features. Thus for an inexpensive cut-out for high currents, a large range of useful movement will be required to ensure satisfactory operation. However a large range of movement involves a high differential between the operating temperatures of the actuator for increasing and decreasing temperature and this may be undesirable for example in some forms of thermostat where a low differential is required, but an accurately predetermined and stable operating temperature is necessary. Again, for example, for circuit breakers sensitive to an excess current in a circuit, neither a large range of useful movement nor an accurately predetermined operating temperature is required, merely an adequate range of movement together with a reasonable consistency and stability in the operating temperature so that excess current may reliably be detected.

In some applications, the actuator may be loosely mounted; in other applications the actuator may be welded or rivetted to a mounting boss and may in addition carry an electrical contact. The actuator may suitably be mounted at the free end of its tongue, where the effects on stresses in the actuator will be at a minimum, or on the periphery of the actuator opposite the free end of the tongue.

For actuators arranged to be incorporated in current sensitive switches, an electrical contact is mounted on the actuator so that current can pass through the actuator, the actuator being heated above its operating temperature as a result of excess current. A major problem with known current sensitive actuators is to increase their electrical resistance to current flow so that they respond to relatively low currents while ensuring that the actuator is not unduly mechanically weakened. Thus reducing the bimetal thick-

ness and the overall dimensions of an actuator will increase electrical resistance, but it may unduly weaken the actuator. This problem is particularly acute since it is common nowadays to require sensitivity to currents of about 2 amps.

It has been found that the actuator according to the invention is intrinsically suitable for use in a current sensitive switch since the stress concentrations necessary for snap action are disposed in the margin and tongue root which are inherently strong and stable regions, and the actuator may thus be formed of thin bimetal and be of small dimensions.

In order to increase the electrical resistance and hence sensitivity of the actuator according to the invention, one or more parts of the domed area surrounding the tongue may be narrowed, particularly in the region opposite the free end of the tongue to provide the main resistance of the actuator to current flow therethrough. Alternatively perforations may be formed in such regions. The tongue may also be narrowed or alternatively and as preferred for maintaining the strength of the tongue, may have an aperture or apertures, preferably formed as a longitudinal slot.

As stated above, actuators for current sensitive switches mount an electrical contact. It is usually the case that the mounting of an electrical contact, by welding or rivetting, substantially alters the operating parameters of the actuator, in particular the operating temperature. Whilst it is possible to make allowance for such alterations, it is possible (as is disclosed in the provisional specification accompanying copending application 45023/75) Pending in accordance with a preferred method of manufacturing the actuator according to the invention, to mount a contact on the actuator without altering its anticipated parameters, by applying the contact to the actuator before the doming operation. Copending application 45023/75 discloses a method of forming an actuator comprising pressing a bimetallic sheet member between a die shaped to a domed configuration desired for the actuator and means acting as an incompressible fluid. This carries the advantage that an electrical contact may be applied to the sheet member prior to the doming operation and by laying the sheet member on said incompressible fluid means with the contact face down, the incompressible fluid means moves during the pressing operation to accommodate the contact without affecting the resultant desired configuration and operating characteristics of the actuator. Thus an actuator according to the invention may carry an electrical contact and if the contact is applied as described above, the operating characteristics may still accurately

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Preferred embodiments of the invention will now be described with reference to the accompanying drawings wherein:
5 Figures 1 to 6 are plan views to scale of actuators according to the invention;
Figure 7 is a table of parameters for the actuators of Figures 1 to 4; and
10 Figure 8 is a schematic sectional view of apparatus for forming by a preferred method an actuator according to the inven- tion.
All the actuators shown except that in Figure 4 have a circular perimoter.
15 Referring to Figures 1 to 3, each actuator has a circular periphery 10 and has a semi-circular locating recess 11 in its periphery. Each actuator has a tongue 12 at least in part centrally disposed of the actuator defined by the inner perimoter 14 of an aperture 16, aperture 16 having an outer perimoter 18 in the form of an arc of a circle which smoothly merges with inner perimoter 14 at rounded ends 20 of the aperture adja- cent the root 22 of the tongue.
25 The actuators are formed in a die pressing operation in which a spherical curvature is imparted over the entire actuator surface. Whilst conventional die pressing operations may be employed, it is preferred to use the die pressing operation described and claimed in our copending application 45023/75.
30 The differences between the various actuators shown reside in the shape and position of tongue 12 and aperture 16 and these differences give rise to differing operating characteristics, some of which (range of useful movement and differential) are indicated in Figure 7.
35 The figures listed in Fig. 7 are for selected actuators all formed by the same method with an equal spherical radius of curvature, a diameter of 12 mm and formed from 0.2 mm thick bimetal. The actuators have been selected as having a break temperature of 100°C so that their differential and useful movement are comparable. Whilst the values given are representative of the various shapes, they should not necessarily be taken as median values for actuators produced in those particular shapes.
40 Considering the values given it will be noted that the range of useful movement is considerably greater than that of an equivalent disc, the smallest range being 0.34 mm for the element of Figure 2, i.e. about 1.9-2.4 times that of an "equivalent disc" whereas the largest range, for the elements of Figures 3 and 4 is 0.45 mm, about 2.5-3 times that of an "equivalent disc".
45 The differential for the actuators is between 30° and 40°C. The differential for any particular shape is dependent on the movement of the actuator and hence in order to

reduce significantly the differential, it will usually be necessary to reduce the move- ment.
The actuator shown in Fig. 1 has a tongue 12 of constant width, 2.5 mm, with a semi-circular end. The length of the tongue meas- 70 ures 4.5 mm from tip to root and terminates 1 mm away, i.e. close to, outer perimeter 18. Aperture 16 has relatively large side lobes formed with 1 mm radius rounded ends 20 adjacent the tongue root 22 and a circular 3.5 mm radius outer perimeter 18 whose centre coincides with the centre of the actuator. The margin 24 is thus of roughly constant radial width, 2.5 mm, widening to about 3.5 mm adjacent the tongue root. The diameter of perimeter 18 is 7 mm, i.e. greater than half that of the actuator. The width of the side lobes of the aperture are of the same order as the width of the tongue. 75
As shown in Figure 7 a representative value for the useful movement of the actuator of Figure 1 is 0.36 mm for a differential of 37°C.
Thus it follows for the actuator of Figure 1 90 that the inner perimeter of the aperture 14 smoothly merges in rounded ends (formed as 1 mm radius rounded ends) with arcuate portions of the circular outer perimeter of the aperture 14 adjacent the tongue root 22. The margin 24 widens adjacent tongue root 22 and the greatest width of the margin surrounding the tongue, measured radially from the centre of the actuator, is in the region of the tongue root. The length of the tongue, 4.5 mm is 1.8 times greater than the tongue width 2.5 mm (the tongue is of constant width and thus the width of the tongue as measured at the mid-point of the length of the tongue is also 2.5 mm), and the great- 105 est width of the margin of the tongue, being greater than the width of the remainder of the margin 24 (2.5 mm) is also greater than the tongue width (2.5 mm).
The actuator of Figure 1 has a constant width tongue and a constant width margin apart from the domed area in the region of the tongue root. It has been found that constant width tongues are not wholly desirable since whilst the tongue should be wide at its root for mechanical strength, substantial width in its central regions is undesirable as the tongue tends to invert across its width with snap action of the actuator. A constant width margin is not preferred, rather it has been found that a better comprise of the various design factors involved is achieved by a maximum margin width in the region of the tongue root which width, progressively reduces to a minimum opposite the free end of the tongue. 110
Accordingly the actuators of Figures 2 and 3 have been proposed, with tongues tapering from their roots and their margins continuously decreasing from a maximum in 115
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the region of the tongue root to a minimum opposite the free end of the tongue.

The actuator of Figure 2 has a wide tongue root 22, namely 4 mm. The tongue 12 tapers with a 30° taper to a semicircular 1 mm radius free end. The tongue is 4 mm long and terminates 1 mm away, i.e. close to outer perimeter 18. The aperture 16 has rounded ends 20 of 0.75 mm radius at the tongue root and its outer perimeter 18 is defined by a circular arc of 3.50 mm radius whose centre is displaced 1 mm from the centre of the actuator. This results in a margin 24 having its maximum width in the region of the tongue root 22 and decreasing continuously to a minimum of 1.5 mm opposite the free end of the tongue, and it follows that the width of the domed area in the region of the tongue root is more than twice the width of the area opposite the tongue free end. The side lobes of aperture 16 have a width of the same order as the average width of the tongue. As shown in Figure 7 a representative value of the useful movement of this actuator is 0.34 mm with a differential of 34°C.

Thus it follows for the actuator of Figure 2 that the inner perimeter of aperture 16 smoothly merges in rounded ends having 0.75 mm radius with part-circular portions of the outer perimeter of aperture 16 adjacent tongue root 22. The greatest width of margin 24, measured radially from the centre of the actuator lies in the region of the tongue root. The portions of the margin 24 bordering the side lobes of the aperture 16 each progressively reduce in width from the rounded ends of the aperture towards the free end of the tongue and merge to a minimum width of 1.5 mm opposite the free end of the tongue. The width of tongue 12 as measured at the mid-point of the length of the tongue, given the length and breadth and angle of taper of the tongue, is 2.61 mm; thus the length of the tongue 12 (4 mm) is 1.54 times as great as this dimension. Further the greatest radial width of the margin in the region of the tongue root is greater than the width as measured at the mid-point of the length of the tongue (2.61 mm). This is because the radius of the outer perimeter of aperture 16 is 3.5 mm and is spaced 1 mm from the centre of the actuator in the direction of the free end of the tongue; thus it follows that such greatest radial width is greater than the width as measured at the mid-point of the length of the tongue.

In Figure 3, the actuator tongue 12 tapers at 15° from a tongue root 22 3.5 mm wide to a rounded free end with a 1 mm radius. The tongue is 4.5 mm long and terminates 1 mm away, i.e. close to, outer perimeter 18. The aperture 16 has rounded ends 20 of 0.75 mm radius adjacent the tongue root 22

and the outer perimeter 18 of the aperture is defined by an arc of 3.50 mm radius whose centre is spaced 1 mm from the centre of the actuator. The margin 24 has a maximum width in the region of the tongue root decreasing to a minimum of 1.5 mm opposite the free end of the tongue and it follows that such maximum width is more than twice the width of the area opposite the tongue free end. The side lobes of aperture 16 have a width of the same order as the average width of the tongue. From Figure 7, a representative value of the useful movement of the actuator is 0.45 mm with 38°C differential.

Thus it follows for the actuator of Figure 3 that the inner perimeter of aperture 16 smoothly merges in rounded ends having 0.75 mm radius with part-circular portions of the outer perimeter of aperture 16 adjacent tongue root 22. The greatest width of margin 24, measured radially from the centre of the actuator lies in the region of the tongue root. The portions of the margin 24 bordering the side lobes of the aperture 16 each progressively reduce in width from the rounded ends of the aperture towards the free end of the tongue and merge to a minimum width of 1.5 mm opposite the free end of the tongue. The width of tongue 12 as measured at the mid-point of the length of the tongue, given the length and breadth and angle of taper of the tongue, is 2.35 mm; thus the length of the tongue 12 (4.5 mm) is 1.91 times as great as this dimension. Further the greatest detail width of the margin in the region of the tongue root is greater than the width as measured at the mid-point of the length of the tongue (2.35 mm). This is because the radius of the outer perimeter of aperture 16 is 3.5 mm and is spaced 1 mm from the centre of the actuator in the direction of the free end of the tongue; thus it follows that such greatest radial width is greater than the width as measured at the mid-point of the length of the tongue.

It has been found that the actuator of Figure 3 offers overall minimum stress concentrations as a result of its flowing contours provided by the shape of the aperture 16. The wide margin at the tongue root provides ample strength in the snap action movement and the actuator has proved to have a very stable break temperature (2°-3°C after 10,000 operations) and it has no abnormally high local stress concentrations where cracking is likely to occur.

The actuator of Figure 4 has an internal shape of tongue and aperture exactly the same as that of Figure 3. It has been found that the differential and useful range of movement characteristics of this actuator are similar to that of Figure 3 despite the square periphery.

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The actuators of Figures 5 and 6 are intended for use with current sensitive switches (contact-breakers) and have a contact 26 welded to the margin 24 of the actuator opposite the free end of tongue 12. The contacts are applied to the bimetal prior to the doming operation as is more fully described in copending application 45023/75. In use current flows from the free end of the tongue, through the tongue root 22 and both parts of margin 24 to contact 26.

Both actuators of Figures 5 and 6 have the same general configuration as that shown in Figure 3, but in order to increase their electrical resistance to current flow, they are smaller, being 10 mm in diameter, and are formed from 0.1 mm thick bimetal. Both actuators have a longitudinal slot 28 in tongue 12 to increase electrical resistance. The actuator of Figure 6 has three circular apertures 30 either side of contact 26 in the narrowest portion of margin 24 and this serves substantially to increase electrical resistance. The actuator of Figure 5, instead of apertures in its margin, has its margin in the region 32 either side of contact 26 substantially narrowed as compared with the margin in Figure 6 whilst still being thick enough to ensure sufficient force is produced in the snap action. This also serves substantially to increase electrical resistance.

Both actuators of Figures 5 and 6 are sensitive to currents as low as 2 amps to perform a snap action movement.

Various other arrangements may be envisaged for increasing electrical resistance. Thus the tongue may be split into two separate tongue portions each extending from the same tongue root.

The electrical contact need not necessarily be positioned on the margin adjacent the free end of the tongue but could for example be positioned on the tongue itself or any other convenient position. In addition more than one contact may be employed.

In a preferred method of forming the above actuators, (as is more fully described in copending application 45023/75) the actuator shape is punched from bimetal strip. One or more electrical contacts may be welded or rivetted to the actuator at any suitable point on the actuator. The actuator is then domed to the desired configuration.

As shown in Figure 8, the actuator is transported to a doming station where a predetermined domed configuration is imparted to provide the desired temperature responsive characteristics. The station comprises two hydraulic presses in which the actuator is successively pressed, the first press imparting a reverse domed configuration and the second press imparting the desired domed configuration. It has been found that the operation of reverse doming is highly desirable since it removes smaller

stresses and deformations that may be present in the actuator arising from the punching operation. In addition the reverse doming "stretches" the bimetal, i.e. produces irreversible movement and stress between the two layers of the bimetal, which to a considerable extent determines the differential between the operating temperatures of the actuator for increasing and decreasing temperatures.

In the doming station, the actuator A is located in a dolly 33 which is transportable between a hydraulic press 34 having a die 36 for reverse doming the actuator and a hydraulic press 38 having a die 40 for positively doming the actuator. The dolly comprises a container having a base 42, sidewalls 44 and a top 46. The top 46 has a circular aperture 48 therein in which the actuator A closely fits. The container houses a pad 50 of synthetic rubber, Avothane (RTM), which acts in a pressing operation as an incompressible fluid. The top 46 and sidewalls 44 are integral with each other and are slidable up and down relative to base 42.

Reverse doming die 36 has a tip 52 with a face 54 having a desired spherical curvature. In a pressing operation die 36 moves downward so that tip 52 closely fits within aperture 48 and face 54 contacts the actuator A.

On further downward movement, a shoulder 56 of die 36 contacts container top 46 so that when the full press pressure is exerted, the die 36, top 46 and sidewalls 44 move down as one relative to base 42 and pad 50. Pad 50 acts as an incompressible fluid and provides the necessary resistance to impart the desired configuration to the actuator A. Movement of the rubber during the pressing operation to accommodate the shape of the die and as a result of any slight compression that may occur in the rubber, is spread over the whole cross-section of the container and thus breakdown of the rubber due to excessive extrusion in the forming area does not occur. When a predetermined pressure has been exerted on actuator A, the tip 52 is retracted.

Actuator A is left in the dolly, and the dolly is transported to the positive doming press 38. Die 40 has a tip 60 with a face 62 having a desired positive spherical curvature for imparting the desired domed configuration to actuator A. The actuator A is positively domed by press 38, the pressing operation being carried out in the same way as described above and with a predetermined pressure being applied to the actuator.

By employing the rubber pad 50, it has been found more reliable results are had in obtaining accurately predetermined characteristics of the actuator as compared with the known method of forming between two steel dies. This may be explained by small dimensional inaccuracies in dies and bimetal

sheet which create high local stress concentrations affecting the operating characteristics of the actuator, whereas a rubber pad acting as an incompressible fluid adapts itself to any such dimensional inaccuracies and in consequence local stress concentrations are reduced. In addition pressure fluctuations during the pressing operation are effectively reduced by half as compared with pressing between steel dies.

WHAT WE CLAIM IS:-

1. A snap-acting thermally responsive bimetallic actuator comprising a member of sheet bimetal having an aperture with an outer perimeter and an inner perimeter defining a tongue free at one end intermediate two lobe portions of said aperture, said inner perimeter and arcuate portions of said outer perimeter smoothly merging at rounded ends of the aperture adjacent the tongue root, an area of said member surrounding said tongue and in relation to which said tongue, at least in part, is generally centrally disposed having been deformed in a die pressing operation to conform in shape to a die of domed configuration, said domed area being such as to reverse its curvature with a snap action with change in temperature, the width of the domed area surrounding said tongue measured radially from the centre of the domed area being greatest in the region of the tongue root, and the length of the tongue being greater than the width of the tongue as measured at the mid-point of the length of the tongue.

2. An actuator as claimed in claim 1 wherein portions of said domed area bordering said lobe portions of said aperture and extending from said aperture rounded ends towards the free end of said tongue progressively reduce in width from said rounded ends towards the free end of said tongue.

3. An actuator as claimed in claim 2 wherein the width of said domed area portions each reduce to a minimum value of the width of the domed area in the region opposite the free end of said tongue.

4. An actuator as claimed in claim 3 wherein said greatest radial width is at least twice as great as said minimum width.

5. An actuator as claimed in any preceding claim wherein said arcuate portions of said outer aperture perimeter are part-circular.

6. An actuator as claimed in claim 5 wherein said arcuate portions have a common centre displaced from the centre of the domed area in the direction of the free end of said tongue.

7. An actuator as claimed in claim 4, 5 or 6 wherein the diameter of said arcuate portions is greater than half the diameter of said domed area.

8. An actuator as claimed in any preceding claim wherein the tongue tapers from its root towards its free end.

9. An actuator as claimed in claim 8 wherein the angle of taper of the tongue is between 15° and 30°.

10. An actuator as claimed in any preceding claim wherein said aperture is symmetrically disposed about a diameter of said domed area.

11. An actuator as claimed in claim 10 wherein said diameter is a mirror axis of symmetry of the actuator.

12. An actuator as claimed in any preceding claim wherein the actuator is domed over its entire surface.

13. An actuator as claimed in any preceding claim wherein the actuator is circular.

14. An actuator as claimed in any preceding claim wherein an electrical contact is mounted at the free end of the tongue or on a part of the domed area of the actuator opposite the free end of the tongue.

15. An actuator as claimed in claim 14 wherein one or more parts of the domed area in the region opposite the free end of the tongue have sufficiently small dimensions to provide the main resistance to electrical current passing through the actuator.

16. An actuator as claimed in claim 14 wherein apertures are formed in the domed area in the region opposite the free end of the tongue and/or in the tongue such as to increase the resistance to current flow there-through.

17. An actuator as claimed in any preceding claim wherein the length of the tongue is at least 1.5 times greater than the width of the tongue as measured at the mid-point of the length of the tongue.

18. An actuator as claimed in any preceding claim wherein said greatest radial width of said domed area in the region of the tongue root is greater than the width of the tongue as measured at the mid-point of the length of the tongue.

19. Snap-acting thermally responsive bimetallic actuators substantially as described with reference to the accompanying drawings.

20. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 1 of the accompanying drawings.

21. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 2 of the accompanying drawings.

22. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 3 of the accompanying drawings.

23. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 4 of the

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sheet which create local stress concentrations affecting the operating characteristics of the actuator, whereas a rubber pad acting as an incompressible fluid adapts itself to any such dimensional inaccuracies and in consequence local stress concentrations are reduced. In addition pressure fluctuations during the pressing operation are effectively reduced by half as compared with pressing between steel dies.

WHAT WE CLAIM IS:-

1. A snap-acting thermally responsive bimetallic actuator comprising a member of sheet bimetals having an aperture with an outer perimeter and an inner perimeter defining a tongue free at one end intermediate two lobe portions of said aperture, said inner perimeter and arcuate portions of said outer perimeter smoothly merging at rounded ends of the aperture adjacent the tongue root, an area of said member surrounding said tongue and in relation to which said tongue, at least in part, is generally centrally disposed having been deformed in a die pressing operation to conform in shape to a die of domed configuration, said domed area being such as to reverse its curvature with a snap action with change in temperature, the width of the domed area surrounding said tongue measured radially from the centre of the domed area being greatest in the region of the tongue root, and the length of the tongue being greater than the width of the tongue as measured at the mid-point of the length of the tongue.

2. An actuator as claimed in claim 1 wherein portions of said domed area bordering said lobe portions of said aperture and extending from said aperture rounded ends towards the free end of said tongue progressively reduce in width from said rounded ends towards the free end of said tongue.

3. An actuator as claimed in claim 2 wherein the width of said domed area portions each reduce to a minimum value of the width of the domed area in the region opposite the free end of said tongue.

4. An actuator as claimed in claim 3 wherein said greatest radial width is at least twice as great as said minimum width.

5. An actuator as claimed in any preceding claim wherein said arcuate portions of said outer aperture perimeter are part-circular.

6. An actuator as claimed in claim 5 wherein said arcuate portions have a common centre displaced from the centre of the domed area in the direction of the free end of said tongue.

7. An actuator as claimed in claim 4, 5 or 6 wherein the diameter of said arcuate portions is greater than half the diameter of said domed area.

8. An actuator as claimed in any preceding claim wherein the tongue tapers from its root towards its free end.

9. An actuator as claimed in claim 8 wherein the angle of taper of the tongue is between 15° and 30°.

10. An actuator as claimed in any preceding claim wherein said aperture is symmetrically disposed about a diameter of said domed area.

11. An actuator as claimed in claim 10 wherein said diameter is a mirror axis of symmetry of the actuator.

12. An actuator as claimed in any preceding claim wherein the actuator is domed over its entire surface.

13. An actuator as claimed in any preceding claim wherein the actuator is circular.

14. An actuator as claimed in any preceding claim wherein an electrical contact is mounted at the free end of the tongue or on a part of the domed area of the actuator opposite the free end of the tongue.

15. An actuator as claimed in claim 14 wherein one or more parts of the domed area in the region opposite the free end of the tongue have sufficiently small dimensions to provide the main resistance to electrical current passing through the actuator.

16. An actuator as claimed in claim 14 wherein apertures are formed in the domed area in the region opposite the free end of the tongue and/or in the tongue such as to increase the resistance to current flow there-through.

17. An actuator as claimed in any preceding claim wherein the length of the tongue is at least 1.5 times greater than the width of the tongue as measured at the mid-point of the length of the tongue.

18. An actuator as claimed in any preceding claim wherein said greatest radial width of said domed area in the region of the tongue root is greater than the width of the tongue as measured at the mid-point of the length of the tongue.

19. Snap-acting thermally responsive bimetallic actuators substantially as described with reference to the accompanying drawings.

20. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 1 of the accompanying drawings.

21. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 2 of the accompanying drawings.

22. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 3 of the accompanying drawings.

23. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 4 of the



21

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accompanying drawings.

24. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 5 of the accompanying drawings.

25. A snap-acting thermally responsive bimetallic actuator substantially as described with reference to Figure 6 of the accompanying drawings.

26. A snap-acting thermally responsive bimetallic actuator comprising a circular member of sheet bimetal having an aperture therein with an outer perimeter having arcuate portions with a diameter greater than half that of said member and the aperture having an inner perimeter defining a tongue free at one end intermediate two lobe portions of said aperture, said inner perimeter and said arcuate portions of said outer perimeter smoothly merging at rounded ends of the aperture adjacent the tongue root, an area of said member surrounding said tongue and in relation to which said tongue, at least in part, is generally centrally disposed having been deformed in a die-pressing operation to conform in shape to a die of domed configura-

tion and being such as to reverse its curvature with a snap-action with change in temperature, the width of the domed area surrounding the tongue measured radially from the centre of the domed area being greatest in the region of the tongue root. portions of the domed area bordering said lobe portions and extending from said aperture rounded ends toward the free end of the tongue each progressively reducing in width from said aperture rounded ends to a minimum value of the width of the domed area in the region opposite the free end of the tongue, and the length of the tongue being at least 1.5 times greater than the width of the tongue as measured at the mid-point of the length of the tongue.

27. An actuator as claimed in claim 1 or 26 wherein said tongue at least in part has not been deformed in a die pressing operation.

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