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## (54) Energy regulator.

(57) An energy regulator 1 has a bimetal element 5 as primary limb with a compensator limb 13. The primary limb is responsive to the heater 11 and the compensator limb compensates for ambient temperature fluctuation. The primary and compensator limbs are formed by splitting a single bimetal strip part-way along its length. The bimetal structure may be mounted on a flexible pivot 17.

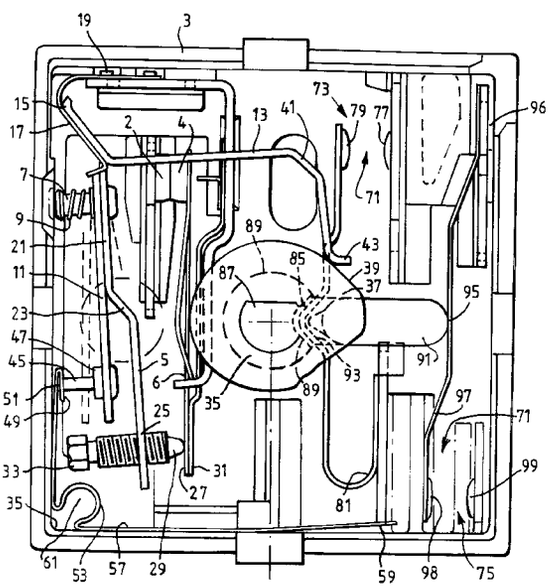


FIG. 1

EP 0 682 352 A2

The present invention relates to an energy regulator of the kind which incorporates a bimetal element.

It has long been common to utilise temperature-dependent deflection of a bimetal strip to fulfil a regulating function in a wide range of equipment, for example in domestic appliances such as cookers. The bimetal strip is heated by a heating element in intimate contact with the active leg of the bimetal element which is contained within the regulator, specifically for that purpose. Typically, the deflection is used to actuate a switch mechanism to open and close electrical contacts for the supply of power to the load. The setting at which the bimetal strip actuates the switch mechanism is determined by a rotary cam arrangement.

It is also known to incorporate a compensation element to compensate for variation in ambient temperature so that deflection of the bimetal strip is more accurately dependent on the temperature of the heating element which heats the bimetal strip. It is common practice to provide a primary switch for single pole operation and secondary switches for double pole and auxiliary functions operation within the same regulator, for example to isolate the regulator and load from the electrical supply when the regulator is set to the "off" position. Conveniently, this operates in response to a second rotary cam arrangement mounted on the same shaft as the cam which determines the switching effected by the bimetal element.

A new form of bimetal energy regulator has now been devised which in its various possible forms provides one or more advantages over previously known such regulators and/or overcomes technical problems associated with these conventional regulators.

A common form of heating element for such a regulator is a ceramic substrate thick film heater. Current methods of making electrical connection to ceramic substrate heaters have shortcomings in maintaining a reliable electrical connection at high ambient temperatures and heater power levels. Soldered connections are difficult to fuse (e.g. Ag to CuNi) and creep and melt points of HMP solder limit maximum safe operating temperatures. Mechanical rivet/tape compression types are prone to intermittent, i.e. high resistance, connection. Spring wiper connection types suffer from stress relaxation as well as friction and wear. The magnitude and degree of change of force experienced can adversely affect control performance.

A new low cost method of ensuring a reliable mechanical and electrical connection to such substrate heaters has now been developed.

Thus, a first aspect of the present invention provides a method of making an electrical connection to a ceramic substrate heater comprising a resistor track, a conductor pad for the resistor track, and an electrical lead making electrical connection to said conductor pad, the method comprising welding said lead to said conductor pad by ultrasonic welding.

According to a second aspect of the present invention, there is provided a ceramic substrate thick film heater comprising a resistor track in electrical contact with a conductor pad and an electrical lead making electrical connection to said conductor pad, whereby the lead is ultrasonically welded to the conductor pad.

Preferably, the conductor pad is made from a material comprising a noble metal, e.g. comprising silver and platinum. Preferably, the lead comprises copper or especially comprises cupronickel or nichrome. In any event, it is preferred for the electrical lead to comprise a tape or wire formed of an electrical conducting material. This can form part of an electrical connection to the clip securing the tape to the body of the regulator and/or its electrical supply terminal.

It is known from European Patent Specification No. EP 0 194 512 A to operate a double pole secondary switch by means of an auxilliary cam arrangement acting upon a switch contact arm ganged by means of a ganging bar to a second contact arm. However, this does not permit the second contact arm to switch independently of the contact arm which interacts directly with the auxilliary cam. However, another aspect of the present invention overcomes this disadvantage.

Thus, according to a third aspect of the present invention, there is provided an energy regulator comprising a bimetal element and a heating element for heating the bimetal element such that deflection of the bimetal element effects a switching action. The input power level of the heating element or heating effect of the heating element at which the bimetal element effects switching being determined by the position of a first cam surface upon which a first cam follower bears, the first cam follower being mechanically linked to said bimetal element, a second cam surface being mechanically integrally linked to said first cam surface and a second cam follower being arranged to bear upon said second cam surface to effect a first independent switching function at one or more predetermined regulator settings, wherein a third cam surface is also provided, mechanically integrally linked to said first and second cam surfaces and upon which a third cam follower bears for effecting a further independent switching function at one or more predetermined regulator settings.

Another advantage of the independent switching feature over other such devices is that a dual circuit control of elements can be obtained. Both line and neutral switched versions are possible. The independent operation of respective switch contact arms overcomes manufacturing problems, reduces the number of components and cost and complexity compared with devices employing simultaneous gang bar type switching arms.

The linked first, second and third cams can be in

any suitable arrangement, for example linked to a slider control. However, in a preferred embodiment they are in the form of rotary cam elements, most preferably mounted on a common shaft, e.g. integral with each other.

According to a preferred feature of the third aspect of the invention, the third cam follower is not directly attached to the contact arm which it actuates. Conveniently, such a "loose" cam follower is supported on the regulator case by support and guide means.

One piece energy regulator bimetal designs are normally associated with "face" profile type cam arrangements (see PCT Patent Application WO 93/26027) in which the bimetal is stamped from one piece and with adjustment to obtain the correct ratio of length of limbs, optimum compensation can be obtained, irrespective of bimetal constant variation.

Alternative designs such as disclosed in EP-A-0 194 512 use two strips of bimetal independently mounted onto a fixed pivot arrangement, acting against an edge cam. This method is problematical in controlling deflection constant variation between different strips and detecting non deflection/delamination manufacturing problems of the compensator limb, together with obtaining a reliable rigid fixing to the pivot. This arrangement gives less than optimum compensation but improved low profile control design options.

A fourth aspect of the present invention now provides an energy regulator comprising a bimetal element comprising a primary limb responsive to a heating element and a compensator limb for compensating for the effects of ambient temperature fluctuation, wherein the primary and compensator limbs are formed of the same piece of bimetal and the bimetal element is mounted on a flexible pivot member.

Using this form of construction, ambient compensation is automatically achieved whilst substantially eliminating deflection constant variations.

A preferred embodiment of the fourth aspect of the invention incorporates an edge cam arrangement, by forming/bending the bimetal it can be arranged that the high expansion side of the bimetal is such that full ambient compensation is achievable, the design also makes economical use of an expensive material and simplifies assembly to the frictionless pivot.

The design therefore has the advantages of giving optimum compensation, elimination of bimetal constant variation problems and also enabled a low profile design of control to be considered.

The feature of a one piece split bimetal welded to a frictionless pivot and incorporating an edge cam differs in design to both arrangements disclosed in WO93/26027 and EP-A-0 194 512 and has not previously been utilised in other controls.

Preferably, the primary and compensator limbs are integral, e.g. formed by splitting a bimetal strip lengthways from one end along a part of its length. This bimetal strip can be supported at its unsplit end. The unsplit end of such a split bimetal strip can be supported on the pivot.

Thus, a fifth aspect of the present invention provides an energy regulator comprising a bimetal element comprising a primary limb responsive to a heating element and a compensator limb for compensating for the effects of ambient temperature fluctuation, wherein the primary and compensator limbs are formed of a bimetal strip split lengthways from one end thereof along part of its length.

A preferred form of flexible pivot comprises a spring, preferably of the leaf spring type. Stainless steel is a preferred material for making this spring pivot. This form of pivot can eliminate the need for lubrication, and avoid backlash and friction problems associated with high ambient temperature and thermal ageing of the components.

Preferably, the primary and compensator limbs are approximately at right angles or otherwise in a mutual V configuration.

Preferably also, the compensator limb terminates in a cam follower arranged to bear upon a cam surface. To enhance the elimination of deflection constant variation, it is preferred for the cam follower to be integral with and formed of part of an end of the compensator limb. The cam surface is preferably a periphery of a cam element attached to a knob or other device for user control. Using the aforementioned spring type of pivot, the force generated by this pivot spring together with the force generated by the switch mechanism maintains and holds the compensator limb against the cam surface under all setting positions of the knob or device assisting user control, resulting in a positive location and setting of the cam. The primary limb presents a negative force at the point of operation, thus reducing bimetal stress loading. This enables high working temperatures to be obtained without permanent deformation of the bimetal element.

Preferably, a calibration feature is provided for determining the particular regulator setting, i.e. percentage output, (for a predetermined cam position) at which the energy regulator turns on or off. This may be constituted by an adjustment screw device protruding through a free end of the primary leg, terminating in an actuating member. However, such an adjustment feature could be provided elsewhere. For example, a screw adjustment with protrusion could be put through a free end of the compensator leg to bear upon the cam surface, i.e. to act as the cam follower.

The invention will now be explained in more detail by way of the following description of a preferred embodiment and with reference to the accompanying drawings, in which: -

Figure 1 shows an energy regulator according to the present invention;

Figure 2 shows an alternative manner of electrical connection to the ceramic substrate thick film heater of the regulator shown in Figure 1 and in accordance with the present invention;

Figure 3 shows a detail of the electrical connection shown in Figure 2 when implemented in the regulator depicted in Figure 1;

Figure 4 shows a detail of a cam follower as used in the regulator shown in Figure 1;

Figure 5 shows a perspective view of the cam follower shown in Figure 4;

Figure 6 shows a lateral cross-section of the cam follower shown in Figures 4 and 5;

Figure 7 shows a circuit diagram of a regulator according to the present invention with a basic single-circuit connection through a bimetallic strip switching element;

Figure 8 shows a circuit diagram analogous to that shown in Figure 7 but with an independent switching element connected to a signal lamp;

Figure 9 shows a typical scale for a regulator as shown in Figure 7 or Figure 8;

Figure 10 shows a circuit diagram of a regulator according to the present invention with an independent switching element in series with the load and bimetallic switching element;

Figure 11 shows a circuit diagram analogous to that shown in Figure 10 but with a second independent switching element operating a signal lamp; and

Figure 12 shows a typical scale for a regulator as shown in Figure 10 or Figure 11.

First, as shown in Figure 1, there is provided a regulator denoted generally by reference numeral 1. The regulator 1 comprises a base 3 in which the constituent parts of the regulator are housed.

The main part of the regulator comprises a primary bimetal leg 5 to which a ceramic substrate thick film heater assembly 11 is secured by means of an eyelet 7 and a surrounding coil spring 9. A compensator bimetal strip 13 extends at approximately right angles to the primary strip 5 and is contiguous therewith. In other words, the primary strip and compensator strip constitute separate limbs formed from a single piece of bimetal, joined by a base region 15.

The base region 15 is secured to a pivot spring 17 in the form of a leaf spring, so that the primary bimetal strip 5 and the compensator bimetal strips 13 together with the substrate heater 11 pivot together as a single rigid assembly. The pivot spring 17 is fixed to the base 3 by means of a support 19.

The primary bimetal strip 5 comprises a root portion 21 in contact with the substrate heater 11 and an oblique portion 23 extending away from the substrate heater and a distal portion 25 spaced apart from the substrate heater. The fact that only the root portion 21 is in direct contact with the substrate heater 11 maximises the differential deflection of the primary strip 5 for a unit temperature change. This is in accordance with the applicants' U.K. patent No. GB 1 201 537.

The bimetal leg 5 bears on a deflectable snap action, spring member 27 by means of the calibration screw 33 extending through an end thereof remote from the root portion 21, so that the deflection of the bimetal leg 5 results in the electrical contacts 2, 4 operating (make and break) as a function of the over centre action of the switch mechanism 6.

Calibration of the regulator to preset the precise power level (for a given user setting) at which electrical connection between the contacts 2, 4 is made or broken is effected by means of a calibration screw 33.

The regulator setting controlled by the user is set by means of a knob (not shown) mounted on a spindle 87 which a cam element 37 is rotatably mounted. The outer circumference of the cam element presents a cam surface 39.

Remote from the base region 15, the compensator strip has a bend 41 so that it is angled towards the cam element 37 and terminates in a cam follower 43 which bears against the cam surface 39. In accordance with the position of the knob, the position of the cam surface 39 contacted by the cam follower 43 alters the orientation of the compensator bimetal strip 13 relative to the pivot spring 17 and so also, the orientation of the primary bimetal strip 11 relative to the pivot spring. Thus, the position of the calibration screw 33 relative to the switch mechanism 6 is also varied.

Thus, in use, the calibration screw is used in initial set-up to calibrate the regulator as described above. Then, the user turns the knob to orientate the compensator and primary bimetal strips 13, 5 by means of the cam action. This determines the power level to the substrate heater and to the corresponding load connected across the electrical contacts 2, 4. For a given set cam/spindle position the output power would by cyclic at contacts 2, 4.

It will readily be appreciated that the temperature change as a result of electrically energising the substrate heater circuit will excite the root portion 21 of the bimetal leg 5. The advantages lever ratio will result in the calibration screw 33 operating switch 6 to make or break contacts 2, 4, thus maintaining preset power level. However, the compensator strip 13 will compensate for ambient temperature variation.

The two limbs (primary and compensator strips) are formed from a single strip split laterally with the unsplit remnant at one end forming the base region 15 which is mounted on the pivot spring. Thus, the metal on the top side (facing the cam element 37) of the primary strip 5 is on the reverse side (not facing the cam element) of the compensator strip 13 and vice versa.

The formation of the primary and compensator strips 5, 13 from a single element substantially ensures elimination of deflection constant variations which would result if the two strips were fabricated

separately. This is also aided by the fact that the cam follower 43 is integral with the compensator strip rather than a joined-on element.

Electrical connection is made to the substrate heater 11 by way of a cupronickel or nichrome tape 45, or a tape of similar material, via a rivet connector 47. In order to allow the substrate heater 11 and primary strip 5 to pivot freely without unduly stressing this electrical connection, the following features are provided, namely, a fold-back bend 49 at the end of a link clip 53 formed between the bend 49, in a corner 55 of the base 3 so that the remainder 57 of the link clip connecting to a supply terminal 59 is sprung onto a boss 61 in the base.

An alternative but preferred method of welding the tape 45 to the ceramic substrate thick film heater 11 is shown in Figure 2.

The resistor track 63 of the ceramic substrate thick film heater is electrically connected to a conductor pad 65. The tape 45 is welded to the conductor pad by ultrasonic welding. The conductor pad is made of a silver/platinum alloy. The ultrasonic energy is applied generally in the direction of the arrow defined by numeral 67. This weld is capable of operating at an ambient temperature in excess of 380°C without oxidation or deterioration with age.

As shown in more detail in Figure 3, the tape 45 is connected to the link clip 53 by means of a U-shaped portion 68 and a clip arrangement 69 which could be strengthened by means of spot welding or ultrasonic welding.

Referring again to Figure 1, there is also shown in the same regulator, auxiliary switch elements denoted generally by reference numeral 71. These switch elements 71 comprises pair of switches 73 and 75. The first of these switches 73 has a fixed contact 77 and a moving contact 79. The moving contact 79 is mounted on a spring mounting 81. Part of this moving contact 79 is shaped to act as a cam follower 83.

The cam follower 83 bears upon a second cam surface 85 behind the primary cam surface 39, relative to the plane of the paper. The second cam surface 85 rotates in accordance with rotation of the primary cam surface 39 in response to rotation of a common shaft 87. As will be explained in more detail hereinbelow, the second cam surface is configured to open and close the contacts 77, 79 of the first switch 73, at one or more positions of rotation of the shaft 87. As shown in Figure 1, the contacts 77 and 79 are in the open position.

Behind the second cam surface 85 is located a third cam surface 89 which also rotates in accordance with rotation of the common shaft 87. A third cam follower 91 bears upon the third cam surface 89. Further details of the cam follower can be seen from Figures 4, 5 and 6.

The third cam follower 91 is elongate in one dimension and has a first curved end surface 93 which rides over the third cam surface 89. It also has a second curved end surface 95, remote from said first end surface 93, which acts upon a movable arm 97 of the third switch 75. The third switch comprises a movable arm and is fixed to a terminal support 96. As shown in Figure 1, the contacts 98, 99 of the third switch 75 are shown in the open position.

Also as will be explained further hereinbelow, the third cam surface is configured to open and close the contacts 98, 99 of the third switch 75 through the agency of the third cam follower 91. It will be appreciated that the opening and closing of the second and third switches 73, 75 is independent of each other and also independent of the opening and closing of the contacts 2, 4 in response to the operation of the bimetal strip 5 and the action of the primary cam surface 39.

The third cam follower 91 is not attached to the movable signal arm 97 on which it acts but is "loose" within the assembly. It is however, constrained by side supports (not shown) in the top and bottom of the regulator casing. Thus, the cam follower is slidable in the left-right direction as shown in Figure 1. The third cam follower has an upper stepped profile 101 and a lower stepped profile 103 which is configured to locate within upper, lower and side supports.

Figures 7 - 9 shows typical circuit diagrams and a regulator scale for using an energy regulator according to the present invention in a domestic appliance such as an electric cooker, adapted for the UK market.

In Figures 7 and 8, and also in Figures 10 and 11 to be described in more detail hereinbelow, as in Figure 1 reference numeral 5 denotes the bimetal element and numeral 11 denotes the ceramic substrate thick film heater. Again also, numerals 2 and 4 respectively indicate the switch contacts which are opened or closed in accordance with deflection of this bimetal element. Moreover, in each of Figures 7, 8, 10 and 11, numeral 110 denotes a load, in this case an electrical heating ring of the cooker, and numeral 113 denotes the main electricity supply.

In the arrangement of Figure 7, the main supply 113, the load 110 and the regulator switch contacts are all in series. No other switching is effected. The arrangement shown in Figure 8 is the same as that of Figure 7, except that a further switch element 115 comprising a pair of contacts 117, 119 is provided. This further switch element 115 is connected in series between the main supply 113 and a signal lamp 121. The contacts 117, 119 open and close in response to a relevant secondary cam acting upon actuator arm 123 connected to the movable contact 4 of the pair. This can be arranged, for example to switch the signal lamp on as soon as the regulator knob (attached to the respective cams mounted on a common shaft) is moved from the off position.

As shown in Figure 9, a typical scale could com-

prise a (vertical) off position 125, low power being arranged to energise the load at (say) 75° movement clockwise, full power being achieved at 285° in the clockwise direction.

Figures 10 to 12 show circuit diagram and scale arrangements of a regulator according to the present invention, suitable for use in a domestic appliance intended for the continental European market.

As shown in Figure 10, as with the arrangement of Figure 8, there is a further switch 115 with contacts 117, 119 in addition to and switchable independently of the contacts 27, 31 of the switch actuated by the bimetal element 5. Here though, the further switch 115 is in series with the load 110 and the switch contacts 27, 31, across the main supply.

Figure 12 shows the scale of the regulator. Immediately rotating the spindle of the control from the vertical 'OFF' position 125, causes the contacts 117, 119 to close. Further rotation will close contacts 27 and 31 and energise the bimetal heater circuit in accordance with operation of an appropriate cam. Then, at 51.5° clockwise, the main cam pre-sets the bimetal assembly to power the load at the "low" level in accordance with opening and closing of the contacts 27, 31. Full power is achieved at the 308.5° clockwise position.

The arrangement of Figure 11 is the same as that of Figure 10 except that a further switch element is provided. Thus, the arrangement is that shown in Figure 1 and the same reference numerals are used for the switch contacts as in the latter drawing. The switch contacts 77, 79 are connected in the same way as contacts 117, 119 in the arrangement of Figure 10 and therefore operate in the same way. However, the other pair of contacts 75 are in series between the mains supply 113 and a signal lamp 121 which can be switched independently of the isolation contacts 77, 79 and the contacts 27, 31 operated by the bimetal element 5. In other words, the cam follower 91 operates movable contact arm 97 and operates third switch 75 in accordance with its own cam arranged on the common shaft.

In the light of this disclosure, modification of the described embodiment, as well as other embodiments, all within the scope of the present invention as defined by the appended claims, will now become apparent to persons skilled in this art.

## Claims

1. An energy regulator comprising a bimetal element comprising a primary limb responsive to a heating element and a compensator limb for compensating for the effects of ambient temperature fluctuation, wherein the primary and compensator limbs are formed from the same piece of bimetal and the bimetal element is mounted on a flexible pivot member.

2. An energy regulator according to claim 1, wherein said flexible pivot member is in the form of a spring.

3. An energy regulator according to claim 2, wherein the spring is in the form of a leaf spring.

4. An energy regulator according to claim any preceding claim, wherein the primary and compensator limbs are integral.

5. An energy regulator according to claim 4, wherein the primary and compensator limbs are formed by splitting a bimetal strip lengthways from one end along part of its length.

6. An energy regulator according to claim 5, wherein the bimetal strip is supported on the flexible pivot member at its unsplit end.

7. An energy regulator according to any preceding claim, wherein the primary and compensator limbs are approximately at right angles or otherwise in a mutual V configuration.

8. An energy regulator according to any preceding claim, wherein the compensator limb terminates in a cam follower arranged to bear upon a cam surface.

9. An energy regulator according to claim 8, wherein the cam follower is integral with and formed of part of an end of the compensator limb.

10. An energy regulator according to claim 8 or claim 9, wherein the cam surface is constituted by a periphery of a cam element attached to a user control knob or device.

11. An energy regulator according to any preceding claim, wherein deflection of the primary limb in response to the heating element is arranged to make or break an electrical connection.

12. An energy regulator comprising a bimetal element and a heating element for heating the bimetal element such that deflection of the bimetal element effects a switching action, the power level of the heating element at which the bimetal element effects switching being determined by the position of a first cam surface upon which a first cam follower bears, the first cam follower being mechanically linked to said bimetal element, a second cam surface being mechanically linked to said first cam surface and a second cam follower being arranged to bear upon said second cam

surface to effect a first independent switching function at one or more predetermined regulator settings, wherein a third cam surface is also provided, mechanically linked to said first and second cam surfaces and upon which a third cam follower bears for effecting a further independent switching function at one or more predetermined regulator settings.

**13.** An energy regulator according to claim 12, wherein said first, second and third cam surfaces are respectively formed on first, second and third rotary cam elements.

**14.** An energy regulator according to claim 13, wherein said first, second and third rotary cam elements are mounted on a common shaft.

**15.** An energy regulator according to claim 13 or claim 14, wherein said first, second and third rotary cam elements are formed integral with each other.

**16.** An energy regulator according to any of claims 12-15, comprising a switch element for being actuated by said third cam follower, wherein said switch element is not fixed to said third cam follower.

**17.** An energy regulator according to any of claims 12-16 wherein support means is provided in which said third cam follower rests.

**18.** An energy regulator according to claim 17, which regulator comprises a case and said support means is moulded as part of the case.

**19.** An energy regulator according to any preceding claim comprising a heating element in the form of a ceramic substrate thick film heater.

**20.** An energy regulator according to claim 19, wherein said ceramic substrate thick film heater is a ceramic substrate thick film heater comprising a resistor track in electrical contact with a conductor pad and an electrical lead making electrical connection to said conductor pad, whereby the lead is ultrasonically welded to the conductor pad.

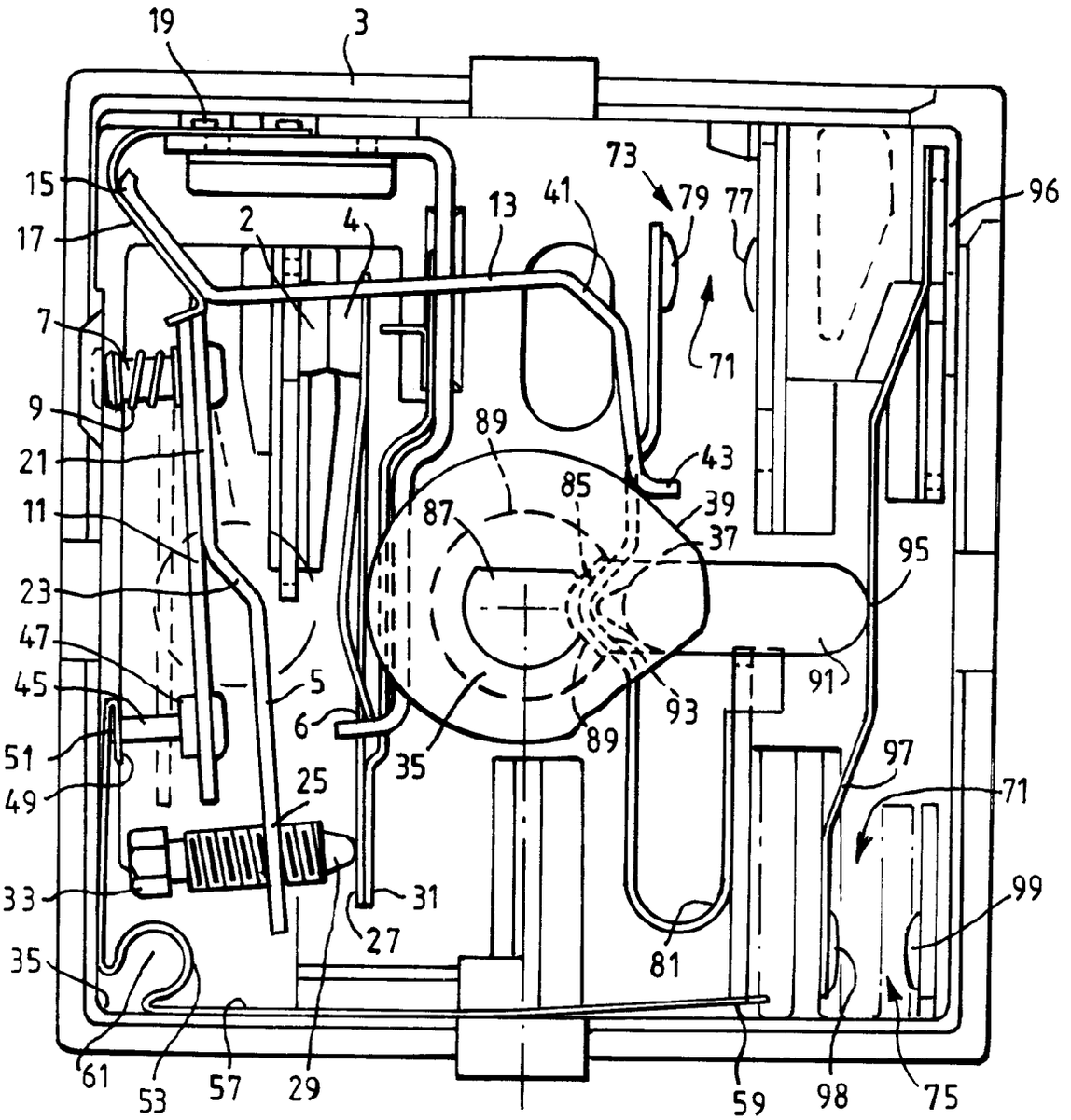
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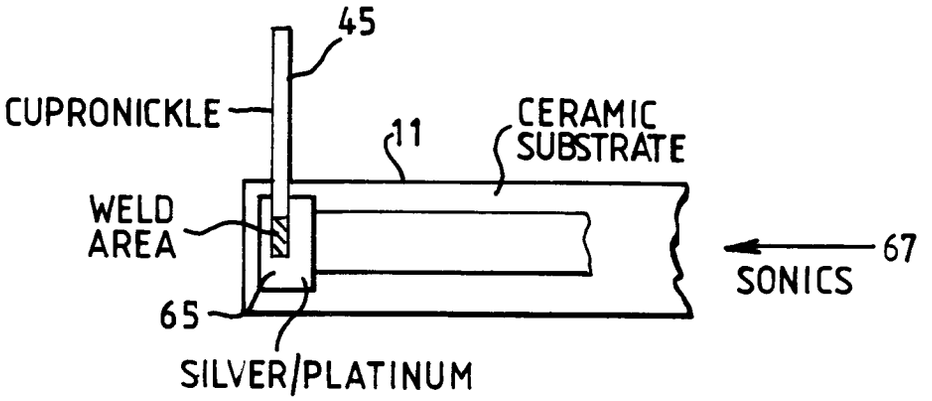
FIG. 1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CUPRONICKLE
11
CERAMIC SUBSTRATE
WELD AREA
67
SONICS
65
SILVER/PLATINUM

FIG. 2

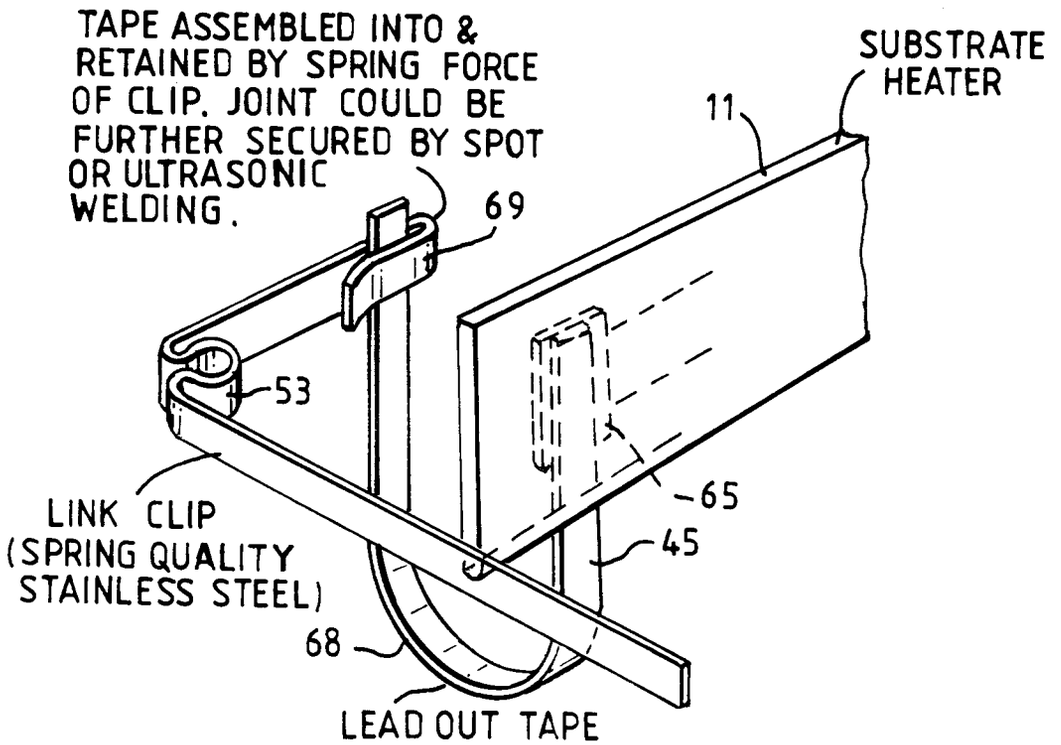
TAPE ASSEMBLED INTO & RETAINED BY SPRING FORCE OF CLIP. JOINT COULD BE FURTHER SECURED BY SPOT OR ULTRASONIC WELDING.
69
SUBSTRATE HEATER
11
53
65
45
LINK CLIP (SPRING QUALITY STAINLESS STEEL)
68
LEAD OUT TAPE

FIG. 3

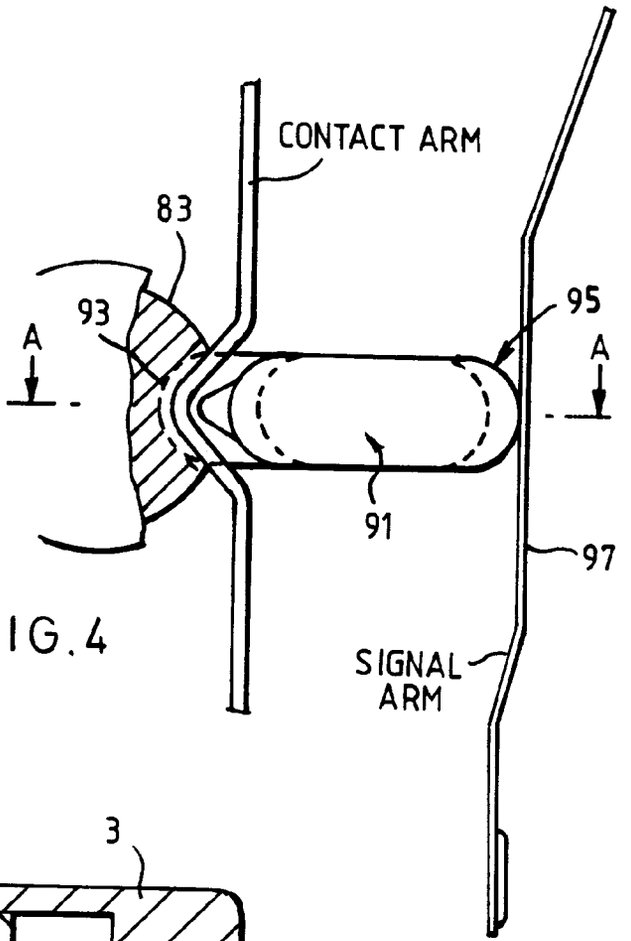


FIG.4

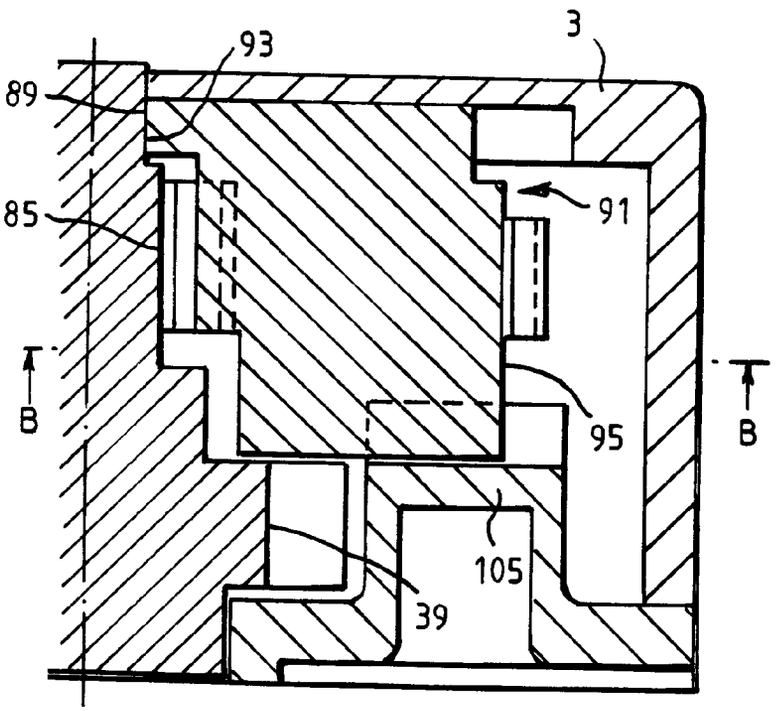


FIG.5

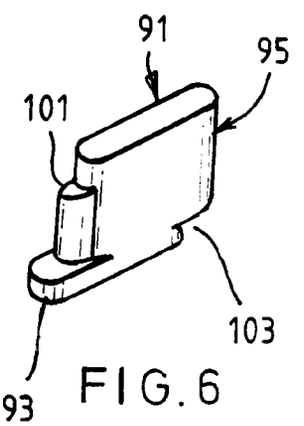


FIG.6

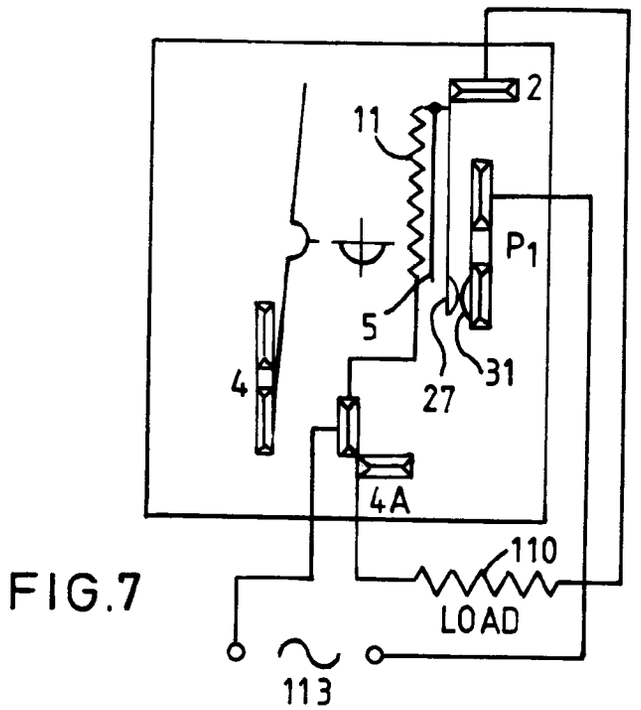


FIG.7

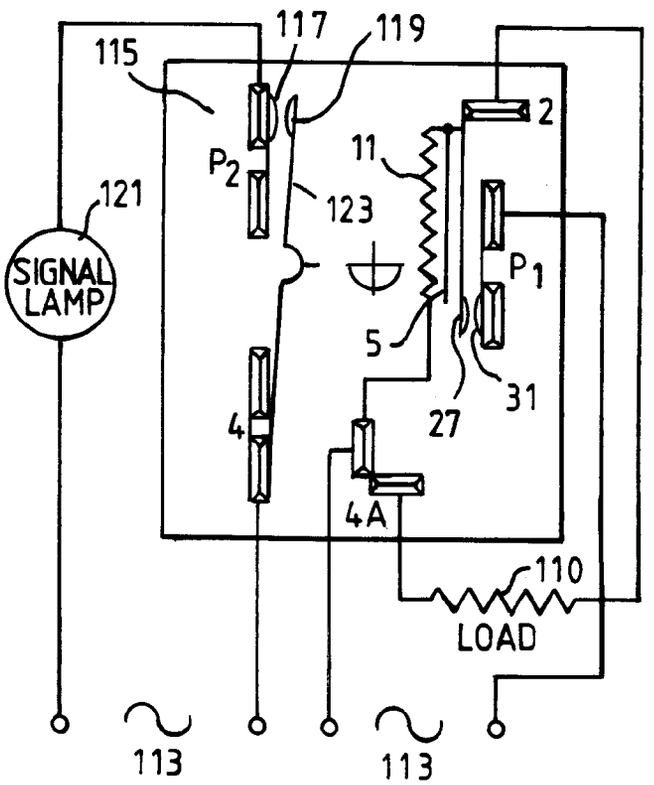


FIG.8

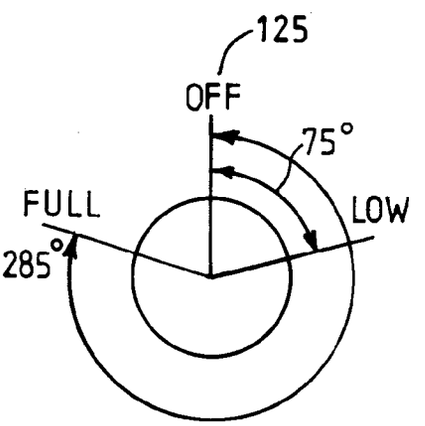


FIG.9

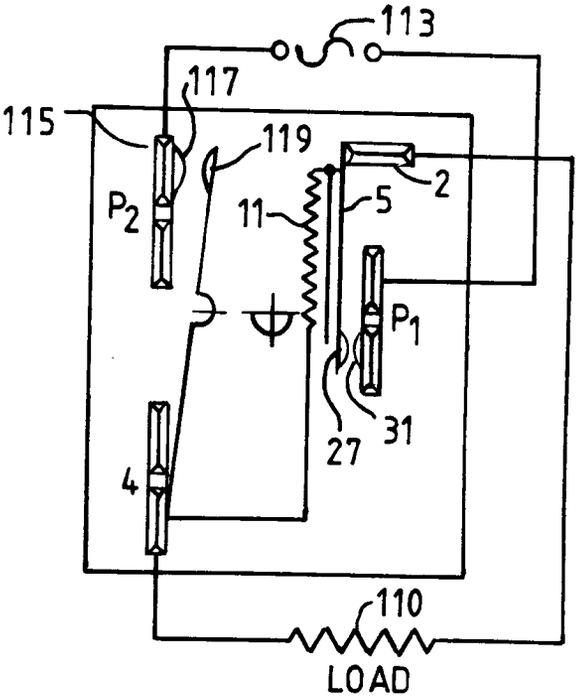


FIG.10

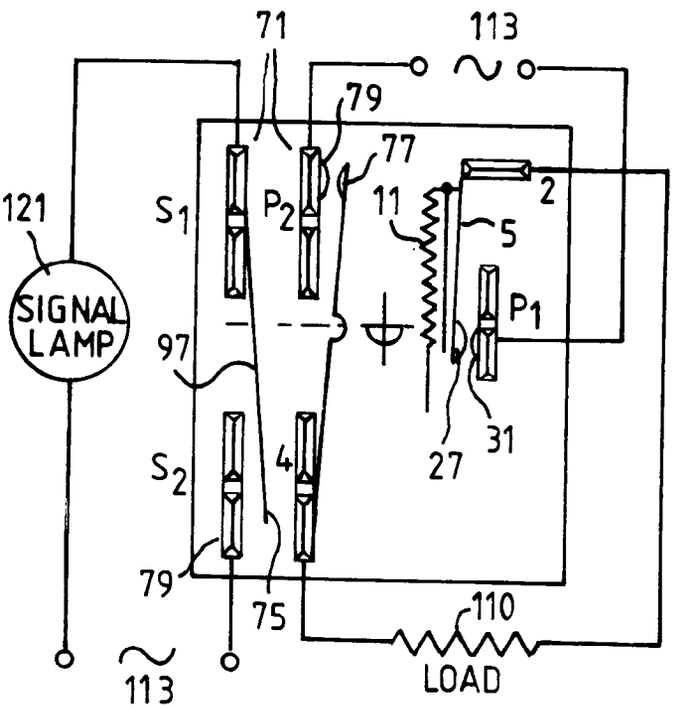


FIG 11

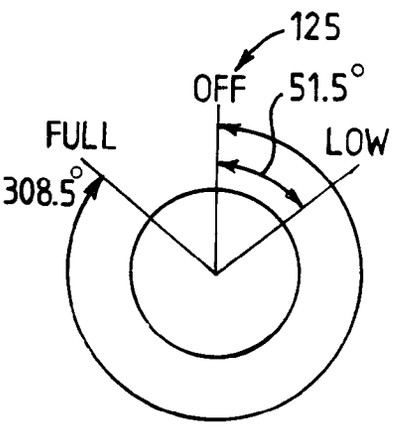


FIG.12