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(54) Thermo-responsive electric switches

(57) A thermo-responsive electric switch includes a thermally expansible material 46 which acts on an elastomeric diaphragm 38 to effect movement of a movable spring contact 54 to or from a fixed contact 70 to close or open the switch in response to changes in temperature, the diaphragm 38 acting on the movable spring contact 54 via a force transmitting device 52, 58 having a convex surface 58 which is in engagement with the diaphragm 38 and which permits the diaphragm to stretch thereabout to allow for excessive expansion of the thermally expansible material 46 at a temperature above the predetermined temperature of operation of the switch.

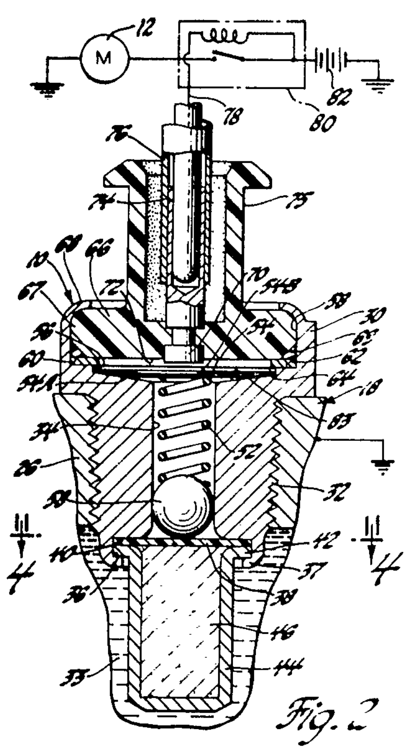

Fig. 2

GB 2 047 467 A

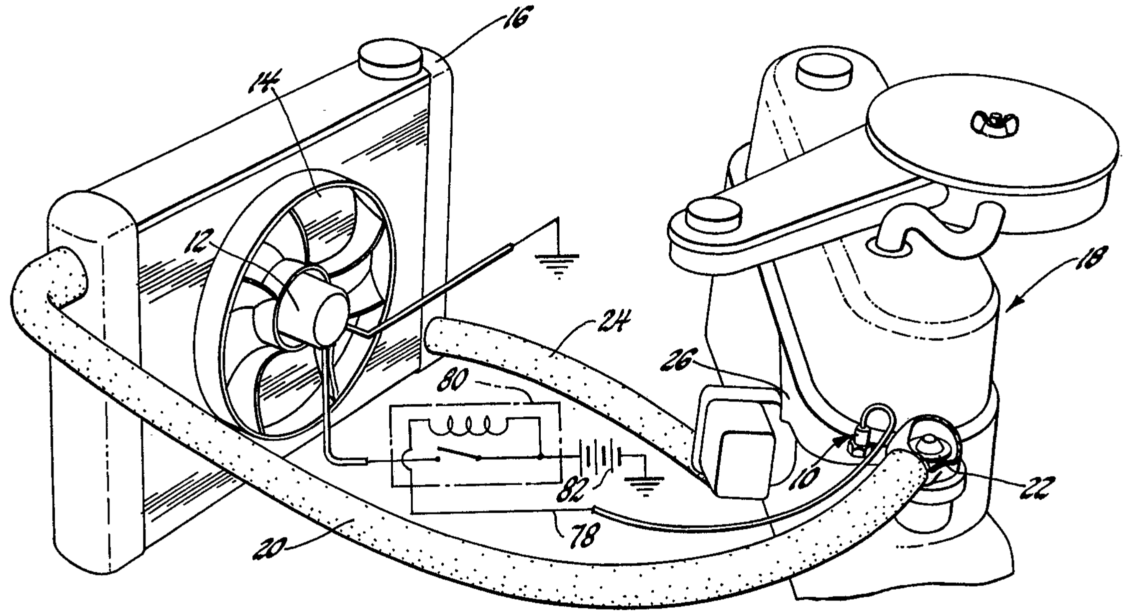

Fig. 1

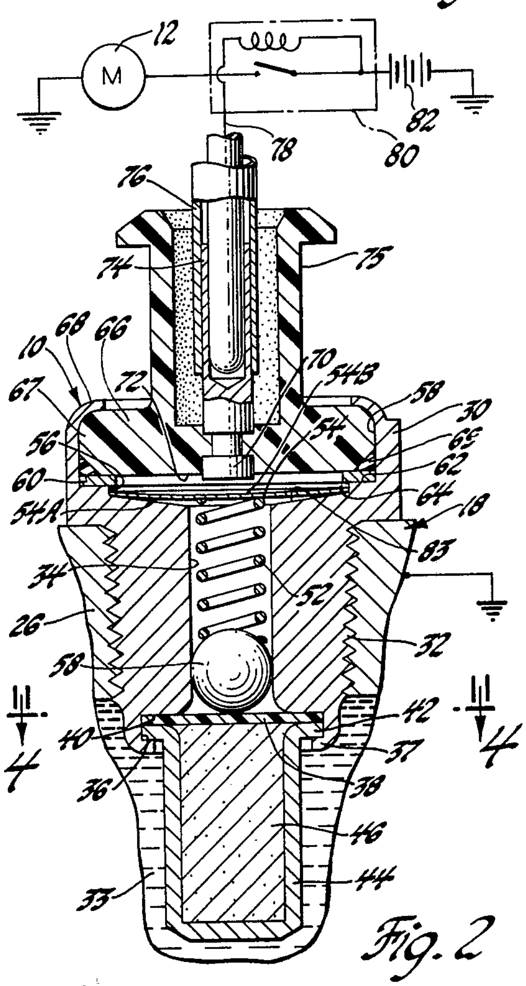

Fig. 2

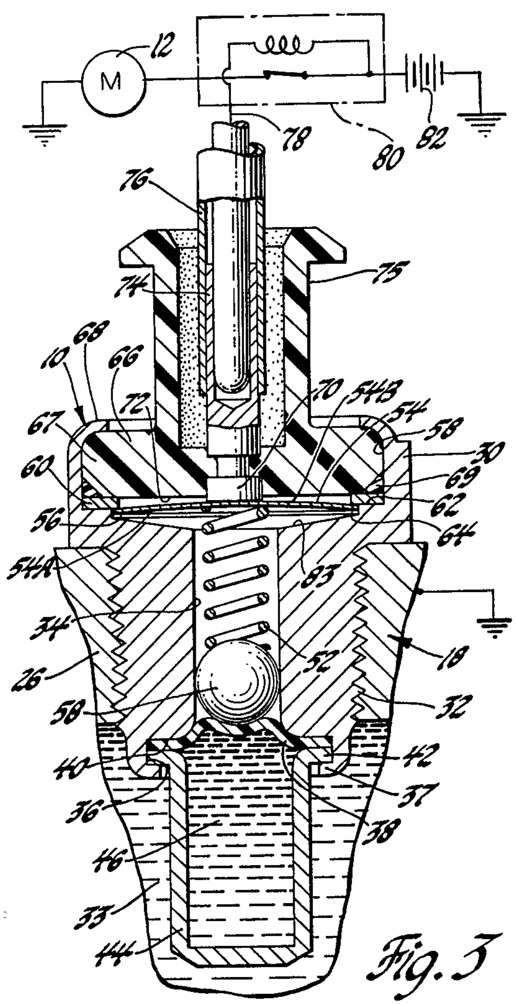

Fig. 3

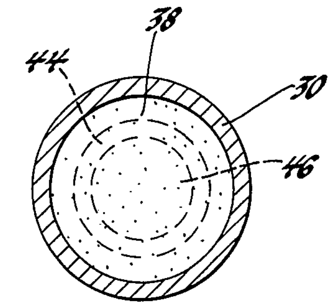

Fig. 4

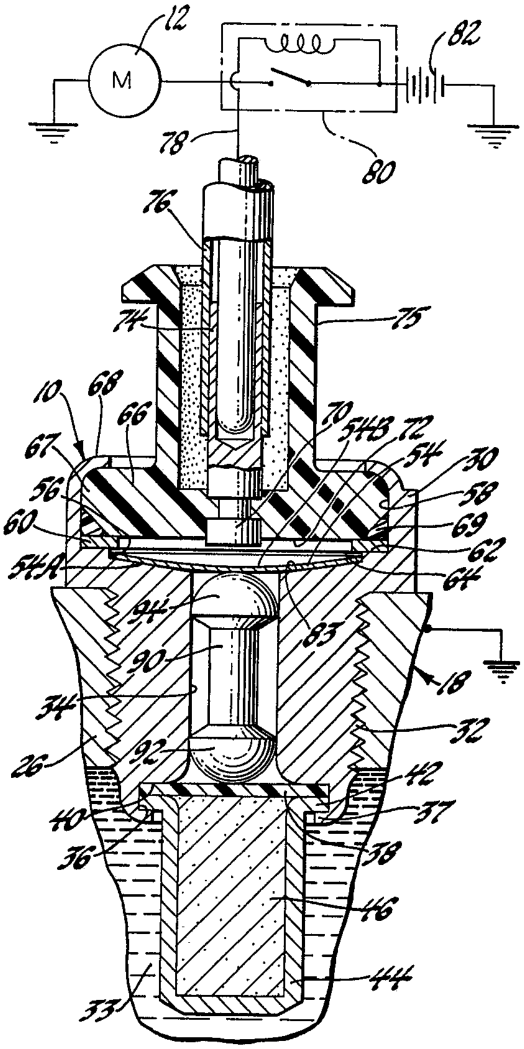

Fig. 5

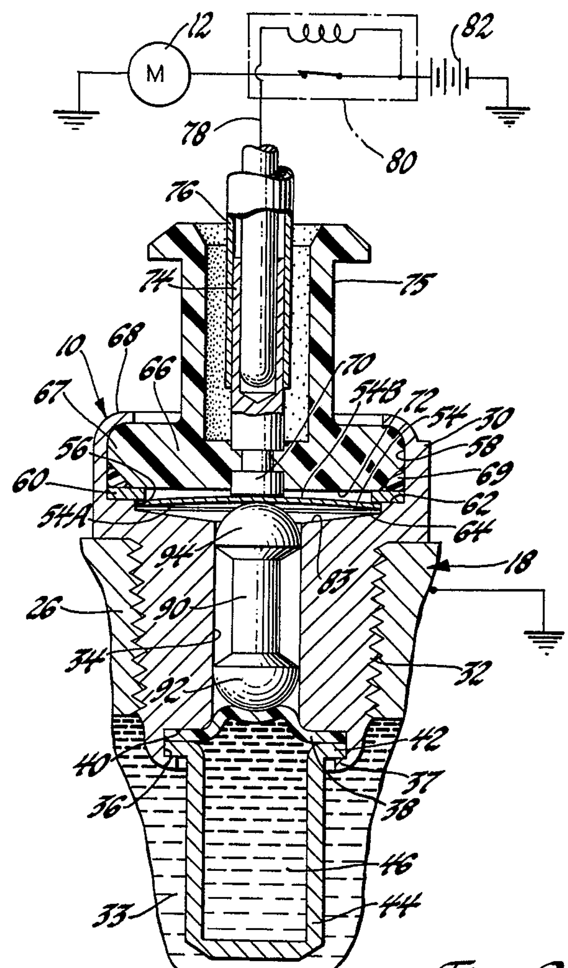

Fig. 6

SPECIFICATION

Thermo-responsive electric switches

This invention relates to thermo-responsive electric switches and more particularly to thermo-responsive electric switches which include a power element with a thermally expansible material acting on an elastomeric diaphragm to effect switch operation.

In systems where it is desired to accurately control a thermally responsive make and break electrical function where there is a relatively high electrical current delivery, it is common practive to use a bi-metal element to effect switching. However, such a switch normally exhibits a hysteresis or reset temperature differential which is substantially larger than that desired in some applications.

For example, in a typical vehicle cooling system, the thermostat may be calibrated to be wide open at 105°C and, therefore, it is desired that the fan be switched on only when the coolant temperature exceeds this level, by some required amount; this might be, for example, when the vehicle is at rest. The fan should switch off when the coolant temperature drops below this value so as to minimise the electrical power usage of the fan and, when the vehicle is moving, to reduce fuel consumption. A bi-metal switch exhibits a minimum reset temperature differential of about 5–10°C in use and if set to switch on at 110°C coolant temperature, it may not then switch off until the coolant temperature is about 100°C, which is substantially below that desired for optimum engine performance. Thus, not only is there wasted fuel consumption but the engine performance is also affected because of substantial delay before the coolant temperature again reaches the desired level. Furthermore, the switch reset temperature differential may then overlap with the operating temperature range of the thermostat, so that the fan could remain on indefinitely, with its consequent fuel consumption requirement, since the thermostat would not independently then know when to open wider, to decrease coolant temperature, but would instead be dependent upon the reset differential characteristics as relating to fan operation. On the other hand, if the switch-on temperature is raised to prevent such overlap with the thermostat, the fan operation is substantially delayed in meeting engine cooling requirements.

It is known that the use of a thermally expansible material and elastomeric diaphragm to operate a switch could diminish the temperature reset differential or hysteresis exhibited by a bi-metal switch. However, the known combinations thereof typically require a complex diaphragm design and/or switch elements and have limited versatility.

The present invention avoids the aforesaid problems by means of a thermo-responsive electric switch including a power element containing a thermally expansible material which acts on an elastomeric diaphragm to effect movement of a movable contact to or from a fixed contact to close or open the switch, in response to changes in temperature from a predetermined value, said movable contact being a spring member inherently biased towards engagement with a force transmitting device so as to effect movement of said movable contact from one to the other of its switch positions upon the expansion of said expansible material at said predetermined temperature value and to permit the movable contact to reset in said one position when the temperature falls below said predetermined value, said force transmitting device having a convex surface which is in engagement with said diaphragm and which is such as to permit the diaphragm to stretch thereabout to allow for substantial expansion of said thermally expansible material in the event of temperature changes above said predetermined value.

The force transmitting device permits the use of a diaphragm of uniform thickness which is easy to manufacture and assemble, as are the electrical elements of the switch. Preferably, the switch includes a housing to which a power element containing the expansible material is joined with the diaphragm therebetween and in which a fixed electrical contact, a contact connectible to earth, and an electrically conductive switch spring member are mounted. For use in a vehicle coolant system, the spring member is inherently held out of contact with the fixed contact and is adapted to be flexed into contact therewith to connect it with the earth contact to close the fan motor circuit. However, it will be understood that for other applications, these conditions can be reversed. The force transmitting device is also mounted in the switch housing and for this particular switch application operates to transmit force from the diaphragm to hold the switch spring element against the earth contact and also flex the switch spring member from its OFF to its ON condition as the expansible material expands while reaching the desired switch-on temperature, which becomes the calibration temperature of the switch. In one embodiment, the force transmitting device includes a ball engaging the diaphragm and a compression coil spring between the ball and the switch spring member to effect snap action of the latter and a resulting low reset temperature differential of about 5°C or less. Furthermore, the coil spring is yieldable in the switch ON condition to accommodate the highest anticipated over-temperature condition without bottoming-out and thereby over-forcing the switch spring member against the stationary contact during such an extreme temperature excursion. In another embodiment, the force transmitting arrangement comprises a rigid member which effects flexing of the switch spring member to its ON condition without snap action so that an even lower reset temperature differential of less than 3°C is obtained. This is obtained while still accommodating substantial temperature excursions of the thermally expansible material past the switch ON temperature by allowing stretching of the diaphragm about a convex surface which is formed on the end of this rigid member where it engages the diaphragm.

The invention is hereinafter particularly described with reference to the accompanying drawings in which:–

Figure 1 is a schematic view of a vehicle engine cooling system having an electrically powered fan operated by a thermo-responsive switch according to the present invention;

Figure 2 is an enlarged vertical section of one embodiment of the switch in its open condition;

Figure 3 is a view similar to Fig. 2 but with the switch shown in its closed condition;

Figure 4 is a section on the line 4–4 of Fig. 2;

Figure 5 is an enlarged vertical section of another embodiment of the switch, in its open condition; and

Figure 6 is a view similar to Fig. 5 but with the switch shown in its closed condition.

Fig. 1 shows a switch 10, according to the present invention, in use in a vehicle engine coolant system for controlling an electric motor 12 that drives a fan 14 to pull air through a radiator 16 for the engine 18 of the vehicle. Coolant which is being circulated through the engine by a pump, not shown, is either bypassed back through the engine or directed to the radiator through a hose 20 under the control of a thermostat 22. After being cooled by the radiator the coolant is returned to the engine by another hose 24. The thermostat 22 is mounted on the engine 18 in the coolant outlet and is of a conventional type which may be calibrated to be wide open when the coolant temperature at the outlet of the engine reaches a certain desired temperature such as 105°C. Should the coolant temperature thereafter tend to increase, it is desired that the fan be switched on to provide increased cooling at the radiator but then on coolant temperature decrease below 105°C, it is desired that the fan be switched off so as to eliminate its electrical power usage and thereby minimize fuel consumption. Furthermore, the switch reset temperature should not fall too far below or overlap with the wide open temperature setting of the coolant thermostat. Otherwise, the thermostat could then start to close and thereby tend to raise coolant temperature forcing the fan switch to remain on when the added cooling effect provided by the fan is not actually needed. For example, the fan operation may only be needed to meet the engine cooling reqirements when the vehicle is stopped but because of fan switch—thermostat temperature overlap may be caused to remain on when the vehicle is stopped and also when the vehicle is moving and forcing sufficient air through the radiator.

Fig. 2 and 3 show one embodiment of the switch 10 which is capable of switching the fan on with a reset temperature differential or hysteresis not exceeding 5°C and can thus be calibrated so as to turn the fan on at 110°C or only 5°C above the wide open temperature setting of the thermostat and then switch the fan off at 105°C before the coolant temperature decreases into the temperature range in which the thermostat closes to restrict coolant circulation. The switch 10 is adapted to be mounted directly on the engine 18 and comprises a hexagonal metal fitting 30 having a male pipe thread 32 which engages a threaded opening in the block 26 of the engine that is open to the coolant 33 close to where the coolant reaches the thermostat 22. The fitting 30 has extending therethrough a central bore 34 which joins with a counterbore 36 in the end 37 of the fitting exposed to the coolant. As shown in Figs. 2 and 4, the peripheral portion of a normally flat, circular diaphragm 38 of uniform thickness and made of elastic material is clamped between a radial shoulder 40 of the counterbore 36 and a radially outwardly extending flange 42 of a rigid cup 44 which is located in theh path of the coolant. The cap 44 is closed by the diaphragm 38 and is filled with a thermally expansible material 46 such as wax. The cup 44 is permanently joined to the fitting 30, and the diaphragm clamped therebetween, by clinch—the annular end 37 of the fitting over the cup flange. The wax is thus sealed in the cup to form a power element for operating the switch while the coolant is sealed from the bore 34 of the fitting 30.

A ball 58, which has a sliding fit in the bore 34, engages at opposite sides with the centre of the diaphragm 38 and one end of a compression coil spring 52 which is also mounted in the bore 34 but has substantial side clearance therefrom. The opposite end of coil spring 52 engages the under side 54A of a downwardly dished circular, electrically conductive switch spring element or member 54 which is made of a resilient material such as spring steel, The switch spring element 54 is mounted in the fitting 30 in a counterbore 56 at the end of the bore 34 opposite that adjoining the counterbore 36. The fitting 30 also has another counterbore 58 of larger diameter adjoining counterbore 56, a ring-shaped electrically conductive contact element 60 providing an earth connection with the fitting 30 is loosely fitted in the larger counterbore 58 and and against a radial shoulder 62 between these counterbores. The inner radius of the contact element 60 extends radially inwardly of the periphery of the switch spring element 54 and has a small axial clearance 64 therewith whereby the switch spring element is trapped in the fitting. A moulded cap 66 of non-conductive material has a shoulder 67 closely fitted in the counterbore 58 and the upper annular end 68 of the fitting is clinched over the peripheral portion of the cap shoulder 67 to secure the cap to the fitting and also compress an elastomeric ring 69 between the counterbore 58 and contact element 60 so as to seal the interior of the fitting at this end and also hold the contact element 60 tightly in place. A further, fixed, electrical contact element 70 is fixed to the cap 66 by being moulded in place therewith and extends from the inner face 72 of the cap so as to be opposite to, and engageable with, a centre portion of the other side 54B of the switch spring element 54, as shown in Fig. 2. The contact element 70 is formed with an integral socket terminal 74 which extends within a central collar 75 formed on the cap 66 and receives a plug 76 that is connected by an insulated wire 78 to a relay 80 in the fan motor circuit which is powered by a battery 82.

In the normally open condition of the switch, as shown in Fig. 2, the expansible material 46 is in a contracted condition and there is no preload on the coil spring 52 so that the diaphragm 38 remains relatively flat and the switch spring element 54 inherently retains its dished shape with its peripheral edge loosely held between the contact element 60 and a sloping shoulder 83 which joins the bore 34 and counterbore 56. In this state, the under, convex, side 54A of the switch spring element 54 is engaged by the coil spring 52 while its upper, concave, side 54B is spaced a substantial distance at its centre from the stationary contact 70, thereby effecting an open condition of the fan motor circuit. When the expansible material 46 expands in response to an increase in coolant temperature, the force transmitting means provided by the ball 58 and coil spring 52 transmit force from the diaphragm 38 so as positively to hold the peripheral portion of the side 54B of the switch spring element 54 against the contact element 60 and thereby connect it to earth through the fitting 30 and engine block 26. In addition, the force transmitting means also acts on the centre of the switch spring element 54, against the bias provided by its dished form, to urge its its side 54B toward engagement with the stationary contact 70. The switch is calibrated so that at the desired switch-on temperature, which in this case is 110°C, the force transmitted is sufficient to snap the dished switch spring element 54 into engagement with the fixed contact 70, as shown in Fig. 3 with its side 54B then having a convex surface while its other side 54A which is engaged by the coil spring 52 then has a concave surface. The fixed contact element 70 is thus connected to earth at the engine block 26 through the switch spring element 54, contact element 60 and fitting 30, the holding of the switch spring element against the contact element 60 assuring positive earthing, so as to close the fan motor circuit and energise the relay 80 to hold the fan motor ON. The expansible material 46 may expand further because of the coolant temperature continuing to rise although the fan is on, but such temperature excursions are prevented from harming the switch because the convex surface of the ball 58 permits the diaphragm to stretch thereabout within the bore 34 and also because the coil spring 52 is selected so that it remains contractible, i.e. it will not bottom out, the highest anticipated temperature excursion.

When the switch is in its ON or closed condition, as shown in Fig. 3, and the temperature starts to drop below the switch-on temperature, the expansible material 46 contracts and thus decreases the force of the diaphragm 38 on the ball 58 and coil spring 52 and, accordingly, on the switch spring element 54, until the switch spring element 54, under the bias inherent in its dished formation, is permitted to return and reset itself in its previous downwardly dished condition, and break the electrical connection between contacts 54 and 70 and restoring the switch to its OFF condition, as shown in Fig. 2. It is possible to control and in particular lower the reset temperature differential by choice of the expansion rate of the expansible material 46, the spring rate of compression spring 52 and/or the spring force of the switch spring element 54.

For example, the reset temperature differential may be decreased by selection of expansible materials having progressively higher expansion rates and with the materials commercially available, the switch embodiment in Figs. 2 and 3 is easily capable of operating with a reset temperature differential of 5°C or even less. On the other hand, the compression spring 52 may have a higher spring rate requiring less expansion from the expansible material used and thus less temperature change to obtain the force required to snap the switch spring element to its closed condition. Conversely, a lower spring rate will require more temperature change to reduce the spring force acting on the switch spring element sufficiently to allow reset and breaking of the electrical contact. The switch spring element 54 may also be selected so as to require a lower snap force and thus less temperature change than a spring switch element which requires a higher snap force, because less compression of the compression spring 52 is required to switch on. With this capability for control of the reset temperature, the Fig. 2–3 embodiment in the radiator fan motor application shown may readily be calibrated to switch the fan ON at 110°C to switch the fan OFF without overlapping with the thermostat operation and without substantially delaying operation of the fan when required.

The switch shown in Figs. 5 and 6 can have a reset differential of an even lower value, for example, a reset temperature differential of less than 3°C. This is accomplished with a simple change in the force transmitting means, as shown in Figs. 5 and 6, wherein parts corresponding to those shown in the Fig. 2, 3 and 4 embodiment are identified by the same numbers and the substituting structure identified by new numbers. In Figs. 5 and 6, the force transmitting means is simply a rigid member 90 which is a sliding fit in the bore 34 in the fitting 30 between the diaphragm 38 and switch spring element 54. The member 90 has a dumbell shape with a rounded head 92 at one end which engages the centre of the diaphragm 38 and a rounded head 94 at the opposite end which engages the centre of the switch spring element 54. In this embodiment and with the switch in its open or OFF condition as shown in Fig. 5, there is again no preload on the force transmitting means, namely, the rigid member 90, and the switch spring element 54 is in the same condition as in the Fig. 2 embodiment. When the expansible material 46 expands, the rigid member 90 is forced by the diaphragm 38 to act directly on the switch spring element 54 to hold it against the contact element 60 while forcing it toward engagement with the stationary contact element 70. However, in this embodiment, which does not include the use of a compression spring, the amount of expansion and contraction required for the switch-on and switch-off is decreased and is directly related to reset differential. The switch spring element 54 in Figs. 5 and 6 need not be such as to snap into engagement with the fixed contact 70 and is easily capable of resetting with a temperature differential of less than 3°C so that the fan could then be switched on at 107°C or only 3°C above the wide open setting of the thermostat and then switch off at 105°C to prevent overlap with the thermostat and with even less delay in restarting the fan when required. Furthermore, the convex surface 92 of the rigid member 90 permits the diaphragm 38 to wrap thereabout as shown in Fig. 6 to absorb continued expansion of the thermally expansible material 46 during temperature excursions beyond the switch-on or calibration temperature when the switch spring element 54 is against the fixed contact element 70 and the rigid member 90 is thereby stopped from moving further.

It will be understood by those skilled in the art that although both embodiments have been disclosed as switching ON or closed with temperature increase and resetting to OFF or open upon temperature decrease, the fixed contact in both cases may be rearranged relative to the switch spring element so that the reverse operation is obtained, i.e. switching ON or closed upon temperature decrease and resetting to OFF or open upon temperature increase, for use in other applications.

For example, the fixed contact 70 could have a stem which extends through a central opening in the switch spring element 54 and terminates in a head, of larger diameter than such opening, so as to be engaged by the under side of the spring element 54 when the material 46 contracts and to be disengaged from the spring element 54 when the material 46 expands. With such an arrangement the rounded upper end of the rigid member 90 in the embodiment of Figs. 5 and 6 would have to be replaced by a configuration which would engage the under side of the spring element 54 with clearance around said head.

CLAIMS

1. A thermo-responsive electric switch including a power element containing a thermally expansible material which acts on an elastomeric diaphragm to effect movement of a movable contact to or from a fixed contact to close or open the switch, in response to changes in temperature from a predetermined value, said movable contact being a spring member inherently biased towards engagement with a force transmitting device so as to effect movement of said movable contact from one to the other of its switch positions upon the expansion of said expansible material at said predetermined temperature value and to permit the movable contact to reset in said one position when the temperature falls below said predetermined value, said force transmitting device having a convex surface which is in engagement with said diaphragm and which is such as to permit the diaphragm to stretch thereabout to allow for substantial expansion of said thermally expansible material in the event of temperature changes above said predetermined value.

2. A thermo-responsive electric switch according to claim 1, in which said diaphragm is of uniform thickness, said movable contact is of disc shape and is biased out of contact with said fixed contact, a further annular contact member adapted to provide an earth connection being arranged so that movement of said movable contact in response to expansion of said expansible material effects engagement of the peripheral portion of said disc with said annular contact member and flexure of said disc through the open centre of said further contact member into engagement with said fixed contact.

3. A thermo-responsive electric switch ac-

cording to claim 1 or 2, in which said force transmitting device comprises a compression spring and a rigid member arranged in series with each other, said rigid member having thereon said convex surface.

4. A thermo-responsive electric switch according to claim 1 or 2, in which said force transmitting device is a rigid member having said convex surface.

5. A thermo-responsive electric switch constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as shown in Figs. 1 to 4 of the accompanying drawings.

6. A thermo-responsive electric switch constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as shown in Figs. 1, 5 and 6 of the accompanying drawings.

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