June 18, 1940. L. K. DAVIS 2,204,793

THERMOSTAT

Original Filed Feb. 6, 1937 2 Sheets-Sheet 1

Fig. 3

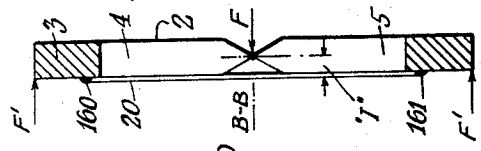


Fig. 2a

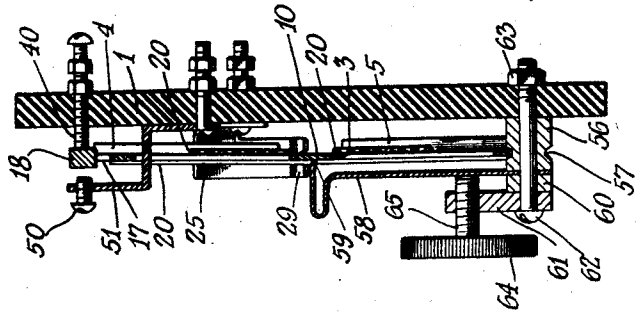


Fig. 2

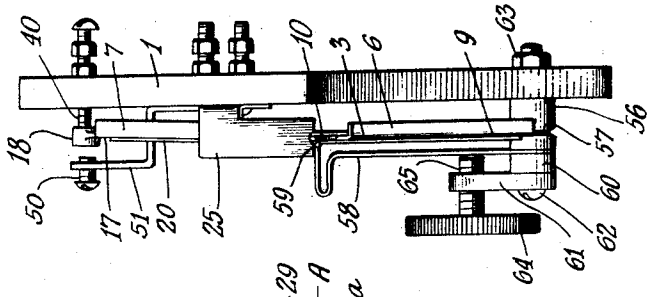
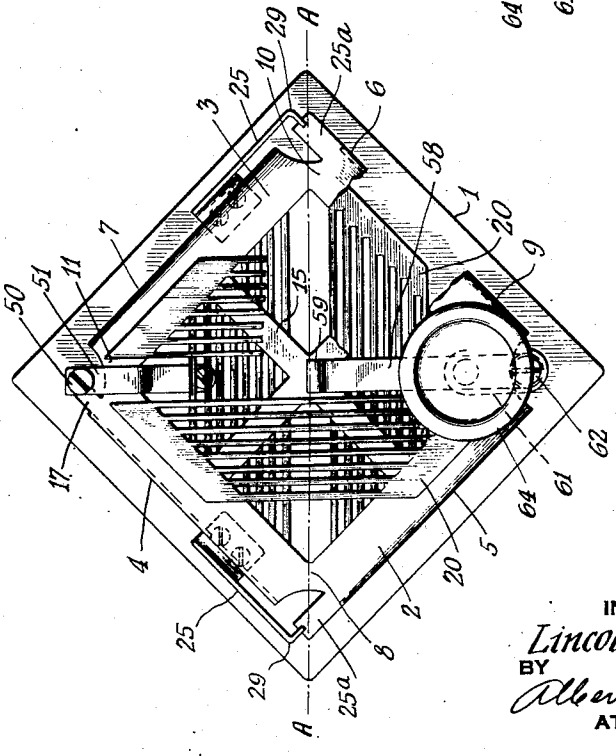


Fig. 1



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THERMOSTAT

Original Filed Feb. 6, 1937 2 Sheets-Sheet 2

Fig. 4

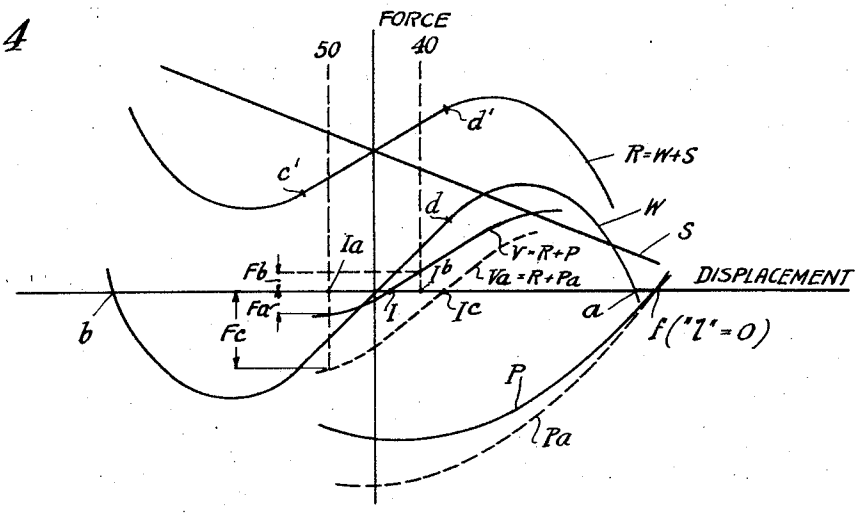


Fig. 5

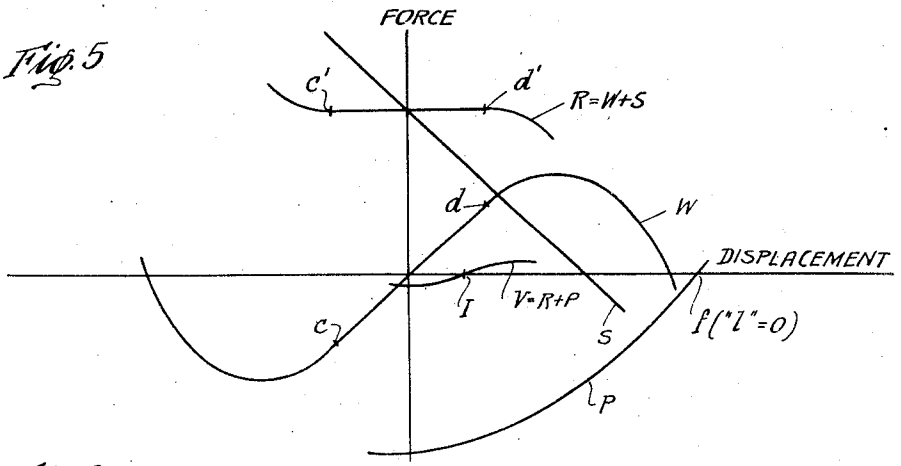
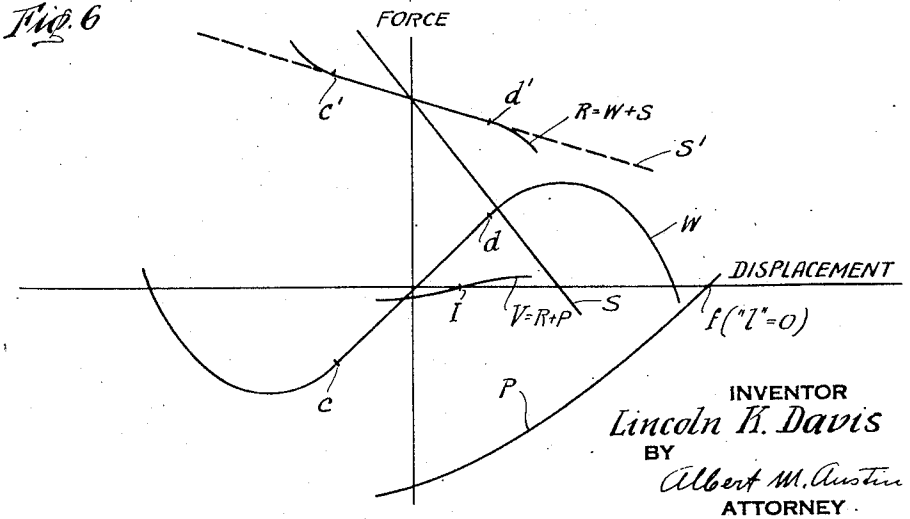


Fig. 6



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UNITED STATES PATENT OFFICE

2,204,793

THERMOSTAT

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Application February 6, 1937, Serial No. 124,371
Renewed May 3, 1939

14 Claims. (Cl. 297—11)

This invention relates to movement producing devices and, more particularly, to self-acting devices adapted to operate upon a change in the relative dimensions of the component parts in response to an external stimulus.

According to one form of the invention, a flat plate or frame may be provided so tensioned as to have an unstable flat position, the tendency of the frame being to move to stable positions on either side of the flat position. To this frame a suitable actuating element may be connected to make the frame responsive to change of external conditions, such as temperature or humidity. Opposing the stress of the actuating element, a control element may also be provided. This control element may be in the form of a leaf spring and may be adjustable to obtain various desired conditions.

The adjustment of the tension of the control spring and the manner of applying the actuating element may be such as to give the device, as a whole, a definite snap action upon change in condition. The spring adjustment may be utilized to adjust the temperature or humidity at which the device will operate. Variously sized springs may be used to adjust or control the sensitivity of the device.

In some cases where greater sensitivity is desired, the control spring may be arranged to neutralize the snap action of the frame. In this case, the proper application of the actuating element will give the device, as a whole, a snap action. Or, if desired, the frame may have no inherent snap action whatsoever, the control spring and the actuating element being so constructed and applied that a snap action is obtained in the resultant structure.

As illustrative of apparatus to which the principles disclosed in this invention may be applied readily, I have chosen the hyperbolic paraboloid frame type of movement producing device which is disclosed in my copending application Serial No. 77,941, filed May 5, 1936, now Patent No. 2,166,239, dated July 18, 1939.

The invention also consists in certain new and original features of construction and combination of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, and the manner in which it may be carried out, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Fig. 1 is a top plan view of an hyperbolic paraboloid frame type thermostat to which auxiliary spring force is applied;

Fig. 2 is a side elevation of the thermostat;

Fig. 2a is a section through Fig. 1 on the line B—B;

Fig. 3 is a diagrammatic sectional view of a thermostatic unit operating similarly to that shown in Figs. 1 and 2; and

Figs. 4, 5 and 6 are qualitative graphical representations of the force-displacement characteristics of the thermostat under different conditions.

In the following description and in the claims, various details will be identified by specific names for convenience, but they are intended to be as generic in their application as the art will permit.

Like reference characters denote like parts in the several figures of the drawings.

In the drawings accompanying and forming part of this specification, certain specific disclosure of the invention is made for purposes of explanation, but it will be understood that the details may be modified in various respects without departure from the broad aspect of the invention.

Referring particularly to Figs. 1 and 2, there is shown a thermostat of construction similar to that of the device which is the subject of said application Serial No. 77,941, which comprises a base 1, formed of suitable material, such as synthetic resin or other rigid and preferably non-warping insulating material, on which is suitably mounted a thermostatic unit 2, comprising a frame 3 and grids 20 attached thereto. The frame 3 is preferably square and formed from a thin metal sheet, the edge portions 4, 5, 6 and 7 being stiffened by bending down the edges of the sheet. The stiffened edge portions 4, 5, 6 and 7 terminate short of each corner of the frame, and the corners are cut so as to provide relatively flexible portions 8, 9, 10 and 11 connecting the stiffened side portions 4 to 7.

The side portions 4, 5, 6 and 7 are connected by a cross-shaped strap portion 15, hereinafter termed the cross, which is integral with or suitably attached to the side portions 4 to 7, and is placed under tensional stress, which may be done conveniently by hammering or peening the flexible portions 8 to 11 to lengthen them and thus the periphery so that the cross 15 is under tension, whereby it tends to draw the opposite sides of the frame toward each other. As the oppo-

site sides can approach each other only if the frame 2 departs from flatness either one way or the other, frame 2 warps so as to be curved oppositely about its principal diagonals, whereby it lies in either of two similar hyperbolic paraboloidal surfaces of opposite curvature, with the position of flatness between. Where the word "curvature" is used herein, it will be understood to mean the curvature of the surface in which the frame lies, rather than any curvature of the frame itself or portions thereof, unless otherwise expressly noted.

One corner of the frame is provided with an extension 17 which carries a contact button 18. Extending through the base 1 is a contact screw 40, so positioned as to be engageable with button 18. In line with contact screw 40 is a second contact screw 50 carried by an overhanging arm 51 fastened to base 1, and also engageable with button 18 on the side opposite to contact screw 40. Both contact screws 40 and 50 are adjustable to permit button 18 the desired range of motion.

Longitudinally perforated grids 20, made of sheet metal or other material of suitable character, are attached in pairs to the surfaces of frame 3 in such a manner that the axes of the grids on one surface are at right angles to the axes of the grids on the opposite surface.

The thermostatic unit 2, comprising the frame 3 and attached grids 20, is mounted on base 1 by means of a pair of mounting blades 25 secured to the base 1. Each blade has an arm 29 having a notch in its free end adapted to receive the extensions 25a of the adjacent side portions at points lying on the diagonal axis A—A, which passes through the center of the cross 15.

The corner portion 9 is adapted to seat in a groove 57 in a post 56, which carries a leaf spring 58, collar 60 and arm 61, and is fastened to base 1 by means of screw 62 and nut 63. Arm 61 is threaded to receive a knurled adjusting screw 64, the end 65 of which bears against spring 58, the latter having a hook-shaped end portion 59 which bears against the center of the cross 15, which is to say on the midpoint of the diagonal axis A—A.

Thus the frame 3 is supported in relatively fixed relation to base 1 at three corners, while the fourth corner, which carries contact button 18, is movable relative to the base, within limits determined by the positions of contact screws 40 and 50. The grids 20, being necessarily displaced from the median plane of frame 3 on account of the thickness of the latter, are thus capable of exerting a bending moment on the frame when any change in the relative dimensions of the grids and frame takes place, as it may if the grids, on the one hand, and the frame, on the other hand, are of different coefficients of thermal expansion and a change in temperature occurs.

Referring to Fig. 1, if the grids shorten relative to the frame, as in response to an external stimulus, the top grids tend to bend the frame about diagonal axis A—A in such a manner that diagonal axis B—B will be concave upward. At the same time, the grids on the underside tend to bend the frame about axis B—B so that axis A—A will be concave downward. Opposite concavities of the axes can exist together if the frame warps into an hyperbolic paraboloidal surface, which it does. Since warping results in relative movement of the parts of frame 3, and as three corners of the frame are fixed, the corner carrying contact button 18 moves so that the latter bears against contact screw 50.

If the grids lengthen relative to the frame, the bending takes place in the reverse direction about each diagonal, and the frame warps into another similar hyperbolic paraboloid, the curvatures of which are everywhere opposite to those of the first. Contact button 18 then bears against contact screw 40.

A study of Figs. 1 and 2 will reveal that any pressure exerted by leaf spring 58 creates a force tending to place the grids under tension. This will be more apparent upon consideration of Fig. 3, which is a schematic section of the thermostatic unit 2 of Fig. 1 taken on a line parallel to axis A—A, with certain dimensions greatly exaggerated. The grid 20, shown edgewise, represents one of the grids on the underside of frame 3 of Fig. 1, F' and F'' are the forces exerted by the mounting blades 25 when the frame is subjected to the force F exerted by the leaf spring 58, and B—B is an end view of the diagonal axis B—B of Fig. 1, which is an axis of flexure, as explained above. 160 and 161 are the points at which the grid 20 is attached to the frame 3, while I is the arm of the force exerted by the grid 20 about the axis B—B.

In Fig. 3, it will be seen that the force F tends to bend the frame about axis B—B so that it is concave toward the right, thereby increasing the tension of grid 20. If, as shown, no part of the frame between the points of attachment 160 and 161 interferes with the free lateral movement of grid 20, arm I becomes less as the concavity increases, and finally would reach zero if the design of the frame were such as to permit a sufficient degree of bending of the latter. It will be apparent that if some portion of the frame 3 or of the cross 15 is so located that the grid 20 strikes against it at some point or points between axis B—B and either or both of the points of attachment 160 and 161, the bending will have to proceed further before I becomes zero. In the preferred form shown in Fig. 1 the cross 15 does so interfere with the free movement of the grids, but its effect is quantitative only, as pointed out, and it has no relation to the principle of operation of the device.

Referring now to Fig. 4, a pair of coordinate axes is shown, the D-axis representing displacements and the F-axis the forces exerted by the free corner of a stressed and mounted hyperbolic paraboloidal frame, such as that described above. Considering the stressed frame alone, without grids or springs applied, W represents its characteristic warping curve when the stressing is symmetrical, as it is in all cases unless expressly noted otherwise. The origin of the graph represents the condition in which the frame is flat, and it is here in unstable equilibrium, for the slighest departure from flatness results in the release of a force which increases with and tends to aid the displacement in either direction. As the warping in either direction progresses, this displacing force increases to a maximum, and then, as the tension of the cross 15 is relieved, it falls off and reaches zero at the points *a* and *b*. The effect of the inherent stiffness of the flexible portions 8, 9, 10 and 11 is not considered here to avoid confusion. It will suffice to say that its effect on curve W is symmetrical, and that it affects the latter quantitatively and has no bearing on the principles disclosed herein. For a complete exposition of the effect of stiffness of flexible portions in like

devices, reference may be made to my copending application Serial No. 124,370, filed with this application.

Assuming that the frame is warped so that its free corner is in a position corresponding to *a*, if a force greater than the maximum positive ordinate of curve W, but in the opposite direction, is applied, the resultant forces will be directed toward the left, so that the frame will move to the left to position *b* with a snap action; the converse is equally true. The substantially straight portion of curve W between *c* and *d* and the portions adjacent thereto constitutes the useful part of the curve, and will be so termed hereinafter. Also, whenever motion of the frame is referred to, it is understood to mean motion of the free corner of the frame.

If now a spring force is applied, such as by the leaf spring **58** of Figs. 1 and 2, and represented by the linear curve S, it will combine with the forces represented by curve W to give a resultant R. It will be noted that the forces indicated by the useful part of R are all on one side of the displacement axis. If the grids are put in place under a certain tension, they will exert a force indicated by the curve P, the useful part of which is on the opposite side of the D-axis from the useful part of curve R. Curves P and R combine to produce a resultant V, which crosses the D-axis at point I, this being a position of unstable equilibrium, since departure from this point in either direction releases forces tending to increase the departure.

The effect of temperature change will now be taken up. Assume a temperature T at which the resultant V is located in the position shown. Assume that contacts **40** and **50** of Fig. 2 are adjusted to the positions indicated on the graph by I*b* and I*a* respectively, and that the grids are of a higher coefficient of thermal expansion than is the frame. It will be seen that the position of unstable equilibrium I, referred to above, falls between the contacts **40** and **50**, with the result that the frame will remain stable against either one, under these conditions. If the frame is against contact **50**, it will exert a force F*a* against it, or to the left, while if it bears against contact **40**, it will exert a force F*b* to the right. It will be assumed here that the frame bears against contact **40** initially.

If the temperature falls to a new value T*a*, the grids will contract more than the frame and their tension will increase, causing curve P to shift to a new position P*a*, and resultant V simultaneously to move to V*a*, the latter then crossing the D-axis at point I*c*, which is the new position of unstable equilibrium. During the progressive shift of V, the point I moves to the right along the D-axis and F*b* approaches zero. The instant point I passes point I*b*, F*b* becomes negative, or in other words, the force on the frame reverses in direction and the latter snaps against contact **50**, to bear against it with a force F*c*, to the left.

Conversely, if the frame bears initially against contact **50** and the temperature rises to a value T*b*, the negative ordinates of P will become less and V will move so that point I will shift to the left. The instant I passes I*a*, the forces will reverse and the frame will snap to the right to bear against contact **40** with a force dependent on the value of T*b*. The curves showing the effect of a rise in temperature are omitted to avoid complicating the graph unduly, but they are similar to those showing the result of a fall in temperature as discussed above. A complete explanation of the effects of temperature change on a similar device will be found in my copending application Serial No. 77,941, filed May 5, 1936, now Patent No. 2,166,239, dated July 18, 1939.

It may be stated in general that the frame will remain against either contact **40** or **50** as long as the position of unstable equilibrium is between the contacts. When it moves outside this range, the frame will either remain against the further contact, or will snap from the nearer to the further contact, depending on the initial position of the frame. In any case, the frame always takes a position as far removed as possible from the position of unstable equilibrium when the latter is not between the contacts.

In the case just described, W and S are considered as independent of temperature, producing a resultant R which is therefore also independent of temperature. The grid curve P is considered subject to temperature, so the final resultant V is a variable and dependent on the temperature. However, in the actual case, S is manually variable by means of adjusting screw **64** of Figs. 1 and 2, so that the final resultant V is subject to manual control, and regardless of the temperature, within the limits set by the design and stressing of the frame and grids, the position of unstable equilibrium I may be placed at any desired point. For instance, suppose that the temperature is T*a*, which is less than T, as seen above. Then the position of unstable equilibrium is at point I*c*. If now the adjusting screw is turned to increase the pressure of leaf spring **58**, the positive ordinates of curve S will become greater and will oppose the negative ordinates of curve P*a*, so that V*a* will change and I*c* will be moved back toward the left to the original position I or to any other desired. Following such adjustment, a still further drop in temperature beyond T*a* will be required to cause I to move to the right far enough to pass I*b* and so cause the frame to snap over against contact **50**.

If the adjusting screw **64** is turned so as to release the pressure of leaf spring **58**, the positive ordinates of curve S will become less and I will move to the right, so that an increase in temperature above T*b* will be required to cause the frame to snap to the right. Thus increase in pressure on leaf spring **58** decreases the operating temperature of the thermostat and decrease in pressure on leaf spring **58** increases the operating temperature.

The combination of the adjusting screw **64** and spring **58** thus provides a ready means of setting the device for operation at the desired temperatures, assuming a constant spacing of contacts **40** and **50**. A further control may be exercised by moving contacts **40** and **50**, but it is preferable to leave them in a fixed relation, or to move them only for the purpose of setting the temperature differential of the device. It is obvious that the smaller their separation, the smaller the temperature differential, that is, the smaller the change required to cause the position of unstable equilibrium to traverse the distance between them and thus cause operation of the frame. In practice the spacing is set at a certain value determined both by the differential desired and the character of the electrical circuit or apparatus to be controlled, the point on the temperature scale at which the differential falls being controlled by the adjusting screw **64** and varied as desired.

In the foregoing case, illustrated by Fig. 4, the final snap action of the device is the result of an inherent snap action in the frame, modified by

the effect of the applied spring force and also the force exerted by the grids. However, it is not essential that the frame possess a snap action, provided a suitable spring force is applied in the proper manner and grids of suitable characteristics are used, so that the resultant, representing the combined effect of the frame, spring and grids, crosses the D-axis in the manner required to give a position of unstable equilibrium. With the coordinate axes chosen, the resultant must slope upward toward the right where it cuts the D-axis, if the intersection is to indicate a position of unstable equilibrium, or a snap action characteristic.

Fig. 5 shows a group of curves similar to those of Fig. 4 and illustrates how a final snap action may be obtained when the snap action of the frame is neutralized by spring forces applied in accordance with the principles disclosed in my copending application Serial No. 124,370, filed herewith. Here in Fig. 5 the curve W represents the warping curve of the mounted frame alone. A spring is arranged to engage the frame in a suitable manner, it being preferably the leaf spring 58 of Figs. 1 and 2, with a characteristic S such that the substantially straight portion of curve W between points *c* and *d* combines with it to give a straight portion in the resultant R, indicated by the part between *c'* and *d'*. If the slope of the curve S is equal to that of the curve W between *c* and *d*, but in the opposite direction, the part of the resultant R between *c'* and *d'* will be parallel to the D-axis. Since this portion does not cross the D-axis, it indicates that the frame and spring in combination have no snap action, but exert a constant force between these limits.

Now, when grids, having a characteristic curve either crossing or approaching the D-axis in the proper sense, such as shown by the curve P, are attached, the curves R and P combine to give a resultant V which crosses the D-axis at point I, which is a position of unstable equilibrium, so that the device now has a snap action. It will be seen that the derivation of this snap action differs from that of the first case considered above, in that the frame itself does not provide it directly.

It is obvious that the leaf spring 58 may be chosen so that its curve S will have any desired slope, which may be combined with W to give a variety of characteristics to the curve R. For example, if the slope of S is less than that of W along its straight portion between *c* and *d*, and in the opposite direction, the resultant R will slope upward to the right and thus indicate snap action as in Fig. 4. If the slope of S is greater than that of W, the resultant will slope downward to the right and indicate spring action. In the case of spring action, motion in either direction will set up forces tending to oppose movement. In the case of snap action motion in either direction will release forces to aid further movement, as pointed out above.

Given grids of a certain characteristic, the final resultant V may be modified through the medium of curve R by the choice of the spring whose curve is S. Curve V may be given any desired slope to achieve either a small or great sensitivity of the device as a whole. For instance, if spring 58 is comparatively weak, the useful portion of resultant R will slope upward to the right and indicate snap action of the frame and spring in combination as in Fig. 4. If the grids have a characteristic such as shown by curve P, the average slope of the useful part of which also is upward and to the right, the resultant V, derived from addition of curves R and P, must have a slope in the same direction greater than either. Therefore, it will be seen that with a steep slope of resultant V a small change in displacement of the frame will release a relatively large force, or conversely, a relatively large force (requiring a relatively large temperature change) will be required to move the frame through a small distance, so that the sensitivity may be said to be low.

If spring 58 is relatively strong, the useful portion of resultant R may be parallel to the D-axis, as described in Fig. 5, or it may even slope downward to the right, indicating spring action, as explained. The effect of this is to lessen the slope of the final resultant V, so that a large change in displacement will release but a small force, or conversely, a small force will be sufficient to move the frame through a large distance, in a relative sense, and the sensitivity may then be said to be high. The practical result, when the device is used as a thermostat, is that contacts 48 and 50 may be set at an optimum spacing, and the sensitivity to temperature change predetermined within wide limits by suitable choice of leaf spring 58.

In my copending application, Serial No. 77,941, filed May 5, 1936, now Patent No. 2,166,239, dated July 18, 1939, I have shown how the leaf spring action of the grids themselves tends to flatten the resultant, thus increasing the sensitivity. The present case differs in that the resultant is deliberately flattened or lessened in slope by means of a chosen and readily variable or replaceable spring, whereas in the above referred to application the increase in sensitivity is determined by the initial characteristics of the grids and is not readily subject to alteration after the grids are attached to the frame.

In the example illustrated in Fig. 5 the device responds to temperature change in exactly the same manner as previously described in connection with Fig. 4, and the temperature range is also adjustable through the medium of the leaf spring 58 in the same way.

Reference to Fig. 3 may serve to clarify the distinction between the conditions illustrated in Figs. 4 and 5. In the form of Fig. 4, the snap action of the frame is not neutralized, and the grids do not of necessity possess a characteristic curve crossing the D-axis. In other words, I of Fig. 3 does not have to approach zero. In the form of Fig. 5, the snap action of the frame is neutralized, but the grids have a characteristic curve which approaches zero and must do so to produce snap action. In the form of Fig. 4 the frame may be imperforate, in which case I will remain constant as long as the warping is in such a direction that the grids are concave toward the frame, which means they will be in contact with it throughout their lengths. In the form of Fig. 5 the frame must either be perforate adjacent to the grids, whereby, as the warping progresses, the grids tend to pass from one surface of the frame to the other, thus causing I to lessen, or the grids must be spaced from the frame, or other means must be provided to permit I to approach zero.

It will be obvious that means other than leaf spring 58 may be employed to modify the final resultant V. For example, the flexible portions 8, 9, 10 and 11, or the cross 15, or both, may be given a "set" to achieve the same result. Likewise, the grids may be initially curved or bent in

such a manner that they will exert a leaf spring action after attachment to the frame. It is furthermore conceivable that the frame may be loaded with weights and so positioned as to take advantage of the force of gravity, instead of using a spring to accomplish a similar result, or magnetism or other suitable stimuli may be employed to exert a force on the frame, etc.

Fig. 6 illustrates conditions similar to those shown in Fig. 5, except that the force represented by curve S is of such magnitude that the useful portion of the resultant R slopes downward to the right and thus indicates spring action. This being the case, there is no reason why a force indicated by S', coincident with the useful part of curve R, cannot be employed directly, and the forces represented by curves W and S, which combine to form R, be entirely eliminated, thus giving the resultant V immediately by the combination of curves S' and P, the latter representing the force exerted by the grids, as before. The meaning of this is that the frame need not be stressed to produce a snap action, but may act simply as a support for the grids, and the cross 15 may be left out if desired. From previous explanation, it will be apparent that I must approach zero if a snap action is to be obtained. The force, of which the curve is S', may come from a spring, such as leaf spring 58, or it may be the result of a "set" in the frame, etc.

It is not intended that the principles disclosed herein be limited to application to an hyperbolic paraboloidal type of movement producing device. It is obvious that they may be employed in connection with any sort of apparatus having a suitable force displacement characteristic, whether possessing an inherent snap action which appears in the resultant, as illustrated in Fig. 4, or whether having its snap action nullified or overbalanced, as shown in Figs. 5 and 6, or having no snap action, as in Fig. 6. Such apparatus may comprise jointed or flexible levers or bars, or a non-developable snap acting disk, or other well-known form of mechanism, and it need not necessarily be incorporated in a thermostat. Their application to a thermostat, as described herein, has been chosen for illustrative purposes only, and is not to be construed in a limiting sense.

The above diagrams have been worked out on the basis of present knowledge of mechanical stresses occurring in the several parts and are accurate so far as present understanding is concerned. However, the stresses and strains set up in the several parts are quite complicated and for this reason the diagrams may not be absolutely correct. It should therefore be borne in mind that these diagrams are given solely to assist in an understanding of the invention and are not to be taken in any limiting sense.

While certain novel features of the invention have been disclosed and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. In a thermostat, a base, a frame having relatively stiff sides and flexible corners, a cruciform strap portion connecting opposite sides, means for rigidly fixing three adjacent corners of said frame on said base, leaving the fourth corner free to move, an actuating element secured to said frame in such manner as to cause it to warp out of flatness, a leaf control spring applied to the center of said cruciform strap portion and anchored on said base, an adjusting screw secured to said base for adjusting the tension of said control spring, and stop devices on opposite sides of said free corner to limit the movement thereof.

2. In a measuring instrument, a base, a warpable support having relatively stiff sides and flexible corners, means for rigidly fixing three adjacent corners of said support on said base, leaving the fourth corner free to move, an actuating element secured to said support in such manner as to cause it to warp out of flatness, a control spring applied to said support and secured to said base, and stop devices on opposite sides of said support to limit the movement thereof.

3. In an actuating device responsive to change in external condition, a base, a warpable quadrilateral support having relatively stiff sides and joints connecting said sides to permit relative angular movement therebetween, an actuating member attached to said support at spaced points and unattached between said points, a control spring applied to said support opposing the force exerted by said actuating member, means for mounting three corners of said support on said base to utilize the movement of the fourth corner with respect to said base.

4. In an actuating device responsive to change in external condition, a base, a warpable quadrilateral support having relatively stiff sides and joints connecting said sides to permit relative angular movement therebetween, an actuating member attached to said support at spaced points and unattached between said points, a control spring applied to said support modifying the tension exerted by said actuating member, means for mounting said support on said base to utilize the movement of said support due to change in external condition.

5. An actuating device according to claim 4 in which the quadrilateral support is stressed to exhibit over-centering action and the device exhibits snap action.

6. An actuating device according to claim 4 in which the quadrilateral support exhibits inherently no over-centering action, but said control spring and said actuating member are so related as to give the device snap action.

7. In an actuating device responsive to change in external condition, a warpable member capable of defining a warped surface, an actuating member attached to said warpable member at spaced points not on the same element of the warped surface and unattached between said points, a control spring applied to said warpable member and opposing the tension exerted by said actuating member.

8. In a device responsive to change in external condition, a member whose parts define a warped surface, said member being stressed to exhibit over-centering action, an actuating member attached to said first member at spaced points and unattached between said points, and a spring applied to said first member exerting a force opposing the force exerted by said actuating member.

9. In an actuating device responsive to change in external condition, a warpable member capable of defining a warped surface, said warpable member exhibiting inherent over-centering action, an actuating member attached to said warpable member at spaced points not on the same element of the warped surface but unattached be-

tween said points, the tension exerted by said actuating member opposing said over-centering action, a control spring applied to said warpable member and opposing the tension exerted by said actuating member, whereby the resultant device, when actuated by change in external condition, has a snap action.

10. In a device responsive to change in external condition, a member whose parts define a warped surface, said member exhibiting no inherent over-centering action, an actuating member attached to said first member at spaced points and unattached between said points, and a spring applied to said first member exerting a force opposing the force exerted by said actuating member.

11. In an actuating device responsive to change in external condition, a warpable member capable of defining a warped surface, an actuating member attached to said warpable member at spaced points not on the same element of the warped surface, a control spring applied to said warpable member and opposing the action of said actuating member, said warpable member exhibiting no inherent over-centering action, the spring actions of said control spring and of said actuating member opposing and combining in such a manner to give the device, as a whole, snap action.

12. In a thermostat, a set of first and second members having different temperature-response characteristics, each member being of substantially flat homogeneous sheet metal, said sheet metal members having limited areas of their flat faces in direct contact and being rigidly attached together at said areas, said first member holding said second member under compression, said second member having relatively stiff parts with a flexible joint therebetween, said areas being on opposite sides of said joint, said members being unattached between said areas, and an adjustable flat control spring disposed generally parallel to said first and second members and exerting a force thereon, whereby the temperature at which the thermostat operates may be adjusted.

13. In a thermostat, an overcentering element having parts in substantial alignment with a toggle point between, an actuating member substantially parallel to said parts and connected to said parts at spaced points on opposite sides of the toggle point and unconnected therebetween, an external adjustable control spring, said control spring, actuating element and overcentering element cooperating to provide snap action, said actuating member and said overcentering element having different temperature-response characteristics.

14. A thermostat comprising an overcentering element having parts in substantial alignment with a toggle point between and a spring element exerting a stress on said parts substantially parallel thereto, an actuating member substantially parallel to said parts and connected to said parts at spaced points on opposite sides of the toggle point and unconnected therebetween, and an external adjustable control spring, said overcentering element, said actuating member and said control spring cooperating to provide snap action, said overcentering element and said actuating member having different temperature-response characteristics.

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