Sept. 7, 1943. D. G. TAYLOR 2,329,094

COMBINATION SWITCH

Filed Feb. 19, 1941 3 Sheets-Sheet 1

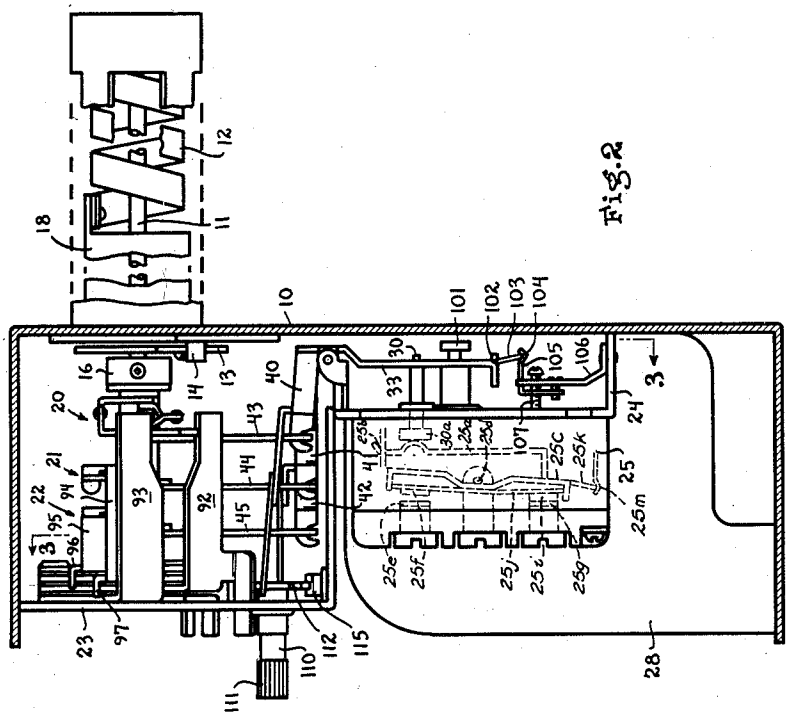


Fig. 2

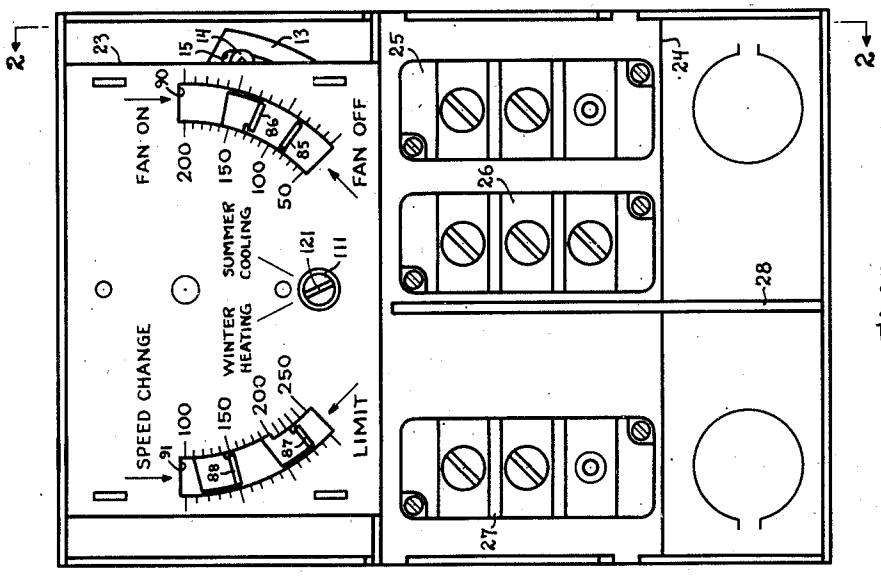


Fig. 1

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COMBINATION SWITCH

Filed Feb. 19, 1941 3 Sheets-Sheet 2

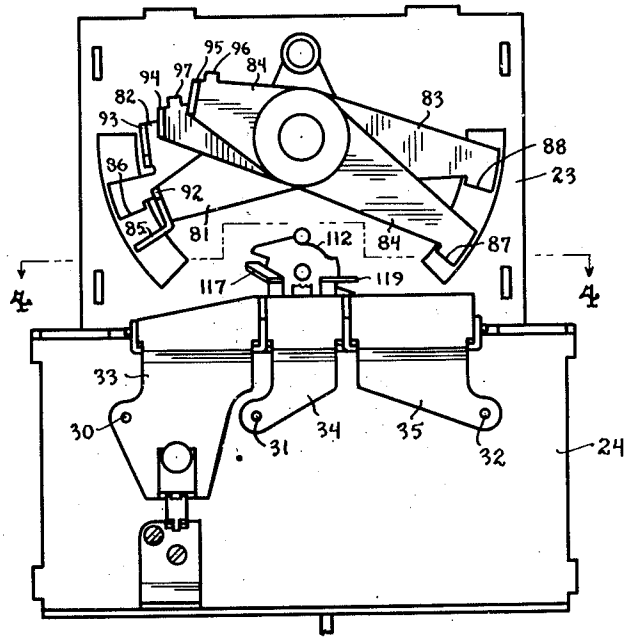


Fig. 3

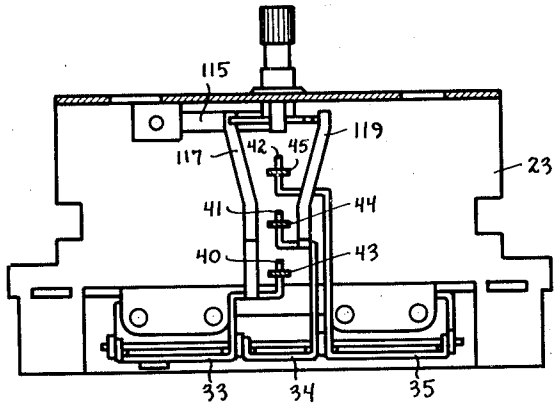


Fig. 4

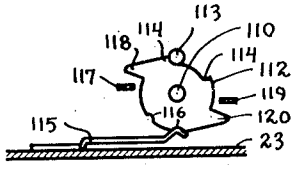


Fig. 5

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COMBINATION SWITCH

Filed Feb. 19, 1941 3 Sheets-Sheet 3

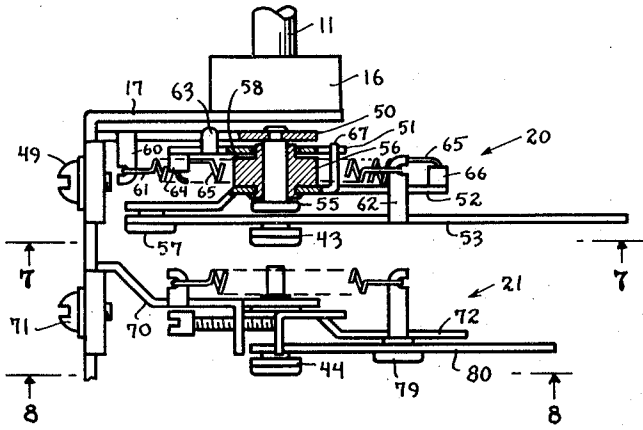


Fig. 6

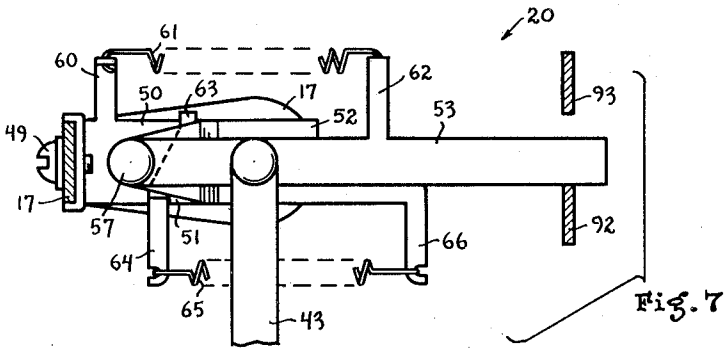


Fig. 7

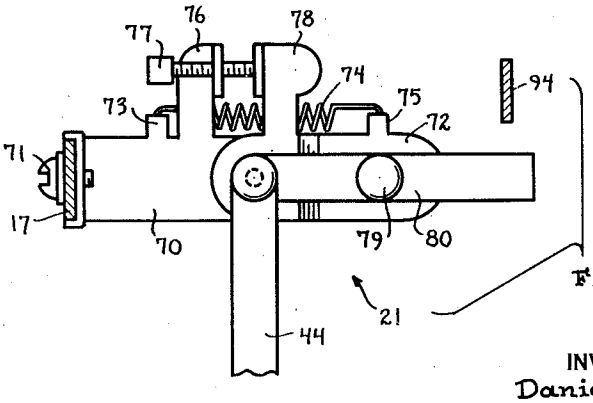


Fig. 8

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Patented Sept. 7, 1943 2,329,094

UNITED STATES PATENT OFFICE

2,329,094

COMBINATION SWITCH

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Application February 19, 1941, Serial No. 379,566

18 Claims. (Cl. 200—138)

This invention relates to automatic switching mechanisms, and one of its objects is to improve that type of mechanism wherein a plurality of switches are sequentially operated by a single condition-responsive element; such as, for example, a combination fan and high limit control actuated by a temperature responsive element.

Another object of this invention is to provide improved means for adjusting the values of the controlling condition at which the switches are actuated.

Another object of this invention is to provide an improved strain release connection between a condition-responsive element and a switch, whereby overrun of the element will not produce undue strain on the parts of the mechanism.

A further object of this invention is to construct a mechanism for operating by means of a thermostatic element, a snap-action switch of the self-return type having a fixed differential between the force required to actuate the switch to one position and the force required to hold the switch in that position. A still further object is to provide, in such a device, means to reduce the differential between the temperatures at which the switch is operated to its two positions below the temperature differential normally required by the thermal element to produce the force and motion needed to operate the switch. A still further object of this invention is to construct such a device in which the differential between the temperatures at which the switch is operated to its two positions may be varied at will, within predetermined limits.

A further object of this invention is to construct a combined fan and limit control operated by a thermostat, and having means for adjusting the switch operating temperatures, in which interlocking means is provided so that the fan control operating temperature may not be set higher than the limit control operating temperature.

A further object of this invention is to construct a combination control having a plurality of switches operable by a condition-responsive element, wherein a manual actuator is provided for simultaneously operating two of said switches independently of said element.

A further object is to provide, in a device having a plurality of switches operable by a condition-responsive element, improved means for calibrating the switches.

It has been proposed to use a mechanism such as that disclosed herein to control a hot air heating system provided with a fan to force the circulation of heated air through the house. In such a case the actuating thermostat for the control is placed in the bonnet of the furnace. The high limit switch is wired in series with the main controlling thermostat so as to shut down the heating system in case the temperature of the air in the furnace bonnet becomes excessive. One or more switches are provided to control the operation of the fan, depending upon the number of speeds at which the fan may be driven. There is disclosed herein a two-speed fan control system, having one switch controlling the energization of the fan and a second switch controlling the speed at which it is driven. These switches are usually arranged to keep the fan deenergized when the air in the furnace bonnet is cool. As soon as the air in the furnace becomes warm enough to heat the house, the main fan switch closes to start the fan in operation. At this time, the speed changing switch is normally in such a position that the fan will operate at low speed. If the temperature continues to rise, the speed-changing switch operates and the fan changes to high speed operation. If the temperature then decreases, for any reason, the thermostatic element, at a certain predetermined temperature, operates the speed changing switch so as to run the fan at a lower speed. At a lower predetermined temperature, the main fan switch opens, and the fan is shut off.

It has been found desirable, in order to provide a device which is readily adaptable to suit the requirements of different heating systems, to make the main fan switch closing and opening temperatures readily adjustable. It is also desirable to make the temperature at which the fan speed is changed and the temperature at which the limit switch opens adjustable. The operating differential of the speed-changing and limit switches, however, may be set at the factory at an optimum value with no inconvenience.

Since, in a device of this sort, the operating force supplied by the thermostatic element is small, it is essential that switches be used which may be operated with a minimum amount of force. I prefer to use switches of the self-return type such as that disclosed in the application of Albert E. Baak Ser. No. 307,991, filed December 7, 1939. It should be understood, however, that other switches of equivalent types may be used with the present device.

These and other objects of the present invention will readily become apparent as the following description is read in the light of the accompanying drawings, in which;

Figure 1 represents a front elevation of a combination fan and limit switch embodying my invention, with the cover removed,

Figure 2 represents a cross-section taken along the lines 2—2 in Figure 1, looking in the direction of the arrows,

Figure 3 represents a view taken along the lines 3—3 of Figure 2, looking in the direction of the arrows,

Figure 4 is a plan view taken along the lines

4—4 in Figure 3, looking in the direction of the arrows,

Figure 5 is a detail view of a manually operable cam mechanism for actuating two of the switches of my control device,

Figure 6 is a plan view, on an enlarged scale, of the strain release connection used in my device,

Figure 7 is an elevation taken along the lines 7—7 of Figure 6, and

Figure 8 is an elevation taken along the lines 8—8 of Figure 6.

In the drawings is shown a casing 10 adapted to be mounted on the bonnet of a furnace, and having a shaft 11 mounted on the back of the casing 10 so as to project into the interior of the furnace bonnet. A helical thermostatic element 12, of conventional type, is attached at one end to a collar 18 extending through the back of the casing 10 and fixed to a plate 13 inside the casing. The thermostatic element 12 surrounds the shaft 11, and the extreme end of the element 12 inside the furnace is attached to the end of the shaft 11. The construction is such that a change in temperature in the furnace causes a rotation of the shaft 11 by the thermostatic element 12. The plate 13 is mounted so as to be adjustable about the axis of the shaft 11, and its adjustment may be fixed by a bolt 14 which passes through an arcuate slot 15 in the plate 13.

The shaft 11 terminates inside the casing 10 in an enlarged hub portion 16, which carries an L shaped crank arm 17. Mounted on the crank arm 17 is a two-way strain release mechanism generally indicated at 20 and two one-way strain release mechanisms generally indicated at 21 and 22.

Supported in any suitable manner at the upper part of the casing 10 is a bracket plate 23 which carries means for adjusting the operating temperatures of the various switches. Mounted in the lower part of the casing 10 is a second bracket plate 24 which supports the switches themselves. The switch numbered 25 in the drawings is the main fan controlling switch while the switch numbered 26 is the speed changing switch for the fan. The limit switch is indicated at 27.

An insulating plate 28 is provided between switches 26 and 27. The limit switch is usually in a low voltage (e. g., 24 volt) control circuit, while the main fan and speed-changing switches are in a relatively high voltage (e. g., 110 volt) power circuit. The plate 28 guards against accidental connection of the two circuits. Of course, both circuits may be operated at the same voltage, if desired.

The switch 25 is operated by moving an actuating button 30 which projects from the back of the switch casing through the bracket plate 24. The switch 25 is internally biased so that the button 30 normally extends backwards to a greater distance than that shown in Figure 2. Similar actuating buttons 31 and 32 extend backwardly from the switches 26 and 27 respectively. The buttons 30, 31 and 32 may be depressed to actuate their respective switches by means of levers 33, 34 and 35 respectively. These levers are mounted pivotally near the top of the back of the bracket plate 24 and each has an arm projecting forwardly above the top of the plate 24. These arms are numbered 40, 41 and 42 respectively in the drawings. The forward extremity of each fo these arms is shaped so as to engage one end of a connecting link. These connecting links are numbered 43, 44 and 45 in the drawings, and their upper ends are operatively attached to the strain release connections 20, 21 and 22, respectively.

The two-way strain release mechanism 20, shown in detail in Figs. 6 and 7, contains a driving member 50 which is mounted at one end on the crank arm 17 by any suitable means such as the bolt and nut shown at 49. The other end of the driving member 50 extends over the end of the axis of the shaft 11, and has mounted thereon in line with the axis of the shaft 11 a hub member 55. Freely mounted for rotation about the hub member 55 are a link 51 and a link 52 separated by a spacing washer 56. Link 52 is rigidly connected to washer 56, so as to increase the length of the bearing surface of link 52 on hub 55. Washer 56 is provided with a shoulder 58 at its rear end on which a link 51 is pivoted. The purpose of the shoulder 58 is to bear against member 50 and prevent link 51 from being pinched by side thrust between washer 56 and member 50. The link 52 extends in a direction generally parallel to the driving member 50, and has mounted at its extremity nearest the crank arm 17 a hub member 57, on which is pivotally mounted an elongated link 53 which extends to the right of the other parts of the strain release mechanism 20 for a purpose to be described later.

On the driving member 50 at a point adjacent the crank arm 17 is an extension 60. One end of a tension spring 61 engages this extension 60 and the other end of the tension spring 61 engages a similar extension 62 projecting from the elongated link 53. Pivotally attached to the link 53 at a point in line with the axis of the shaft 11 is the upper end of the connecting link 43 which transmits the actuating force passing from the thermostatic element through the strain release 20 to the switch 25. It will be seen that the internal tension of the switch 25 acting through the lever 33, tends to move the link 43 downwardly and rotate the link 53 in a clockwise direction about the hub 57. The tension of the spring 61, on the other hand, tends to rotate the link 53 about the hub 57 in a counter-clockwise direction, and so opposes the effect of the internal spring in the switch 25.

The switch 25 used herein, as explained in detail in the Baak application Serial No. 307,991, previously referred to. The switch 25 has an enlarged portion 30*a* on the plunger 30 which cooperates with a raised portion of an actuating arm 25*a*. The arm 25*a* is of resilient material and is pivoted at 25*b*. A contact carrying rocker member 25*c* is pivoted on the central terminal post at 25*d* and is rocked thereabout by the arm 25*a*. Sets of cooperating contacts 25*e*, 25*f*, 25*i*, and 25*g*, are carried upon a resilient contact blade 25*j* which is suitably secured to the rocking member 25*c*. A toggle member 25*k* abuts the lower end of the rocker member 25*c* and is biased into engagement therewith by a biasing spring 25*m*. The angle between the points of contact of the member 25*k* with the spring 25*m* and the rocker member 25*c* does not pass over center with respect to the pivot point 25*d*. With such structure, a spring rate compensation snap action is obtained.

The operation of the switch 25 is as follows: When the button 30*a* is moved to the left, tension is stored in the resilient member 25*a*. This tension is resisted by the spring 25*m* which acts upon the toggle member 25*k*. This toggle mem-

ber engages the rocker member 25c at an angle. This angle and the tension in the spring 25m are so selected that they will resist the tension in the resilient member 25a to a predetermined extent. However, when the tension of member 25a overcomes the tension of spring 25m the member 25a begins to move toward the left, this resisting force will decrease at a rate more rapid than the decrease of force exerted by the member 25a. Because of this change in force relationship, the contacts will be snap actuated with what is termed a spring rate compensation snap action. In this type of action the tendency of the contacts to move together increases as they approach each other. This function could also be obtained by a magnetic snap action of the self return type in which the contacts are attracted together with a greater magnetic force as the contacts are brought more closely together. It is to be understood that other types of switches having a similar characteristic could also be substituted for the switch 25 without interfering with the operation of the present control device.

The switch 25 requires a certain force to hold the button 30 in its inward position (as in Fig. 2), and a greater force to move the button 30 from its outward position to its inward position. The spring 61 is chosen so that its tension is intermediate the values of these two forces. Therefore, when the button 30 is in its inward position, spring 61 exerts a force greater than the minimum required to hold the button in, so that it remains in that position. On the other hand, when the button 30 is in its outward position, the force exerted by spring 61 is not sufficient to overcome the internal tension of the switch 25. The switch therefore tends to remain in whichever position it may be, until some external force other than that of spring 61 is exerted upon the button 30.

The link 51, which is pivotally mounted on the hub 55 adjacent driving member 50, has a projection 63 extending rearwardly therefrom which serves to engage the driving member 50 and thereby limit the counter-clockwise rotation of the link 51 with respect to the driving member 50. The link 51 also has a downwardly extending projection 64 which carries one end of a tension spring 65. The other end of the tension spring 65 engages a downwardly extending projection 66 on the link 52. The link 52 also has a rearwardly extending projection 67 (see Fig. 6) which engages a portion of the link 51 so as to limit the clockwise rotation of link 52 with respect to link 51. It will be seen therefore that the spring 65 tends to hold the stop 67 in engagement with the link 51.

It should be noted that the tension of spring 61 also tends to rotate the link 53 about the end of link 43 as a fulcrum, and therefore exerts a counter-clockwise torque on the hub 57. This torque is transmitted through the link 52 and spring 65 to link 51, and thus tends to hold extension 63 against driving member 50.

The one way strain release mechanism 21, which is shown in detail in Figures 6 and 8, has a driving member 70 which is attached to the crank arm 17 by means of a bolt 71. Pivotally attached to the driving member 70 at a point in line with the axis of the shaft 11 is a link 72. On the driving member 70 is a projection 73 to which is attached one end of a tension spring 74. The other end of the tension spring 74 is attached to a similar projection 75 on the link 72. On the link 70 is another projection 76 through a portion of which is threaded a bolt 77 so as to engage a similar projection 78 on the link 72. It will be seen that the tension of spring 74 tends to rotate the link 72 in a counter-clockwise direction about the pivot on the driving member 70 but that its counterclockwise rotation is limited by the engagement of the bolt 77 with the projection 78. Pivotally mounted on the link 72 at a point 79 spaced from the axis of rotation of the shaft 11 is another link 80, which has one end extending to the right of the other parts of the strain release mechanism 21 and its other end overlying the end of the axis of the shaft 11. Attached to the link 80 at this end is the connecting link 44 which transmits motion passing from the thermostatic element through the strain release mechanism 21 to the speed changing switch 26.

The one-way strain release mechanism 22 is similar in detail to the strain release mechanism 21 and will not be described further.

Pivotally mounted on the back of the plate 23, are a plurality of adjusting members 81, 82, 83 and 84. These adjusting members are provided with forwardly extending projections numbered 85, 86, 88 and 87 respectively. The projections 85 and 86 extend through a slot 90 at the right hand side of the plate 23 and indicate on the scale adjacent that slot the temperatures at which the main fan switch will be actuated to its off and on positions, respectively, in a manner to be described later. The projections 87 and 88 extend through a similar slot 91 on the left hand side of the plate 23 and indicate on a scale adjacent that slot the temperatures at which the limit switch and speed change switch, respectively, will be actuated. These adjusting members 81, 82, 83 and 84 also have rearwardly extending projections 92, 93, 94 and 95 respectively, which project into the path of motion of the links 53, 80 and the link corresponding to 80 in the strain release mechanism 22. The member 84 is provided with a lug 96 which extends above the member 83 and prevents the limit switch from being adjusted at a lower temperature than the speed-changing switch. The member 83 is provided with a similar lug 97 which extends above the members 81 and 82 and prevents the main fan switch from being adjusted to turn on the fan at a higher temperature than that at which the speed is changed to high.

Means is provided for compensating the spring rate of the thermostatic element 12 so that it will not adversely affect the operation of the main fan switch 25. This means includes a stop member 101 which is mounted on the back of the bracket plate 24 and has a relatively narrow portion. The lever 33 is mounted so that a portion of it travels along this narrow portion and is limited in its motion in both directions by engagement with the enlarged portions. The lever 33 is provided at its lower extremity with a saddle 102 in which one end of a toggle link 103 is carried. The other end of the toggle link 103 is carried in a similar saddle 104 on a spring member 105 which is mounted for adjustment relative to the plate 24. The spring member 105 is attached to a flexible bracket 106. A bolt 107 passes through the bracket 106 so as to engage the back of the plate 24. By turning the bolt 107 the position of the bracket 106 and hence of the saddle 104 on the spring member 105 may be adjusted.

It is often desired, in heating systems having a fan for forcing circulation of air, to utilize the

fan for cooling purposes during the summer, when the furnace is not in operation. Means have therefore been provided in the present device for manually closing the fan energizing circuit and simultaneously moving the speed controlling switch to high speed position. A shaft 110 is journaled in the bracket plate 23, and extends forwardly thereof. At its forward end is a knurled knob 111, so that the shaft may be readily rotated by hand. Rigidly mounted on the shaft 110 just inside the plate 23 is a cam member 112, shown in detail in Fig. 5. A stop 113 mounted on the plate 23 cooperates with a pair of shoulders 114 on the cam 112 to limit rotation thereof in either direction. A spring member 115 mounted on the plate 23 cooperates with a pair of notches 116 on the cam to maintain it in either of the extreme positions to which it may be rotated. A spring arm 117, mounted on the lever 33, projects into the path of a shoulder 118 of the cam 112. A similar spring arm 119, mounted on the lever 34, projects into the path of a shoulder 120 on the cam 112. A groove 121 on the outer end of the shaft 110 cooperates with suitable indicia on the plate 23 to show whether the manual actuating means is set for winter heating or summer cooling.

Operation

The operation of the speed changing switch 26 through the one-way strain release connection 21 will first be described. Let it be assumed that the parts are in the positions shown in the drawings and that the furnace temperature is relatively low. At this time the switch actuating button 31 is held in its outward position by the internal bias of the switch 26. The forwardly extending arm 41 of the lever 34 is therefore in its lowered position, and the link 44 is in a position such that its upper end is at a position such as shown in Figure 8. The connections of the bimetallic element 12 are such that an increase in temperature will cause the crank arm 17 to be rotated in a counter-clockwise direction as viewed in Figure 8. Considering Figure 8, let it be assumed that the furnace temperature begins to rise with the result that the crank arm 17 moves in a counter-clockwise direction about the axis of the shaft 11. When the furnace temperature reaches the value for which the indicating finger 88 of the adjusting plate 83 has been set, the right hand end of the link 80 as viewed in Figure 8, will engage the projecting arm 94 which is a part of the adjusting plate 83. When this occurs, further counter-clockwise rotation of the crank arm 17 will cause the link 80 to turn about stop 94 as a fulcrum, and thus a lifting force will be applied to the upper end of the link 44. This force will be transmitted through link 44 and extension 41 of lever 34 and will oppose the internal bias of the switch 26. As the temperature continues to rise, this force will become sufficient to overcome the internal bias and will cause the lever 34 to move the switch actuating button 31 inwardly thus moving the speed changing switch 26 from its low speed to its high speed position. When the button 31 has reached the limit of its inward movement further upward movement of the link 44 will be prevented. The link 80 will therefore be held at both its ends. Further increase in the furnace temperature will cause the bolt 77 to separate from the projection 78 and will cause an increase in the tension of spring 74. It may therefore be seen that an increase in the temperature of the furnace beyond that at which the speed changing switch is set to be actuated will not place any undue strain on either the bimetallic element or the switch but will merely cause an increase in tension or stretching of the spring 74.

Let it now be assumed that the temperature in the furnace decreases from the relatively high value attained. This will move the crank arm 17 in a clockwise direction. As soon as the bolt 77 engages the projection 78, the driving member 70 and the link 72 will move clockwise together and the internal bias of the switch 26 will become effective to move the left end of link 44 downwardly, rotating the link 80 about the pivot 79 until the switch has reached its normal low speed position. Further counter-clockwise movement of the crank arm 17 will merely cause the link 80 to pivot about the upper end of the link 44 which is in line with the axis of the shaft 11.

Upward movement of link 44 is limited by the button 31 reaching its innermost position, while its downward movement is limited by the engagement of lever 41 with the bottom of plate 23. The parts are so proportioned that the total movement of link 44 is relatively small, and its upper end is always substantially in line with the axis of rotation of shaft 11.

The operation of the limit switch 27 is the same as that of the speed changing switch just described. In the case of the limit switch, the stop 95 on the adjusting plate 84 cooperates with the strain release connection 22 to determine the temperature at which the limit switch will be actuated.

The operation of the main fan switch 25 will now be described. Let it be assumed that the furnace temperature is below that at which the indicator 85 has been set to turn the fan switch off. The various parts will then be in the position shown in the drawings. It should be noted that the switch actuating button 30 has been pressed inwardly from the position to which it is biased by the internal spring of the switch 25. It should also be noted that the extension 40 on the lever 33 has been lifted from its normal position, and that the link 53 has been moved against the stop 92. The internal bias of the switch 25 acts, through the lever 33, downwardly on the link 43, tending to turn the link 53 in a clockwise direction about the pivot 57. This tendency is opposed by the tension of the switch spring 61 which tends to move the link 53 in a counter-clockwise direction about the pivot 57. This spring 61 is chosen so that its tension matches that of the internal bias of the switch 25. The resultant of these two tensions is therefore substantially zero.

Let it now be assumed that the temperature in the furnace begins to rise with a consequent counter-clockwise rotation of the crank arm 17 about the axis of shaft 11. This movement of the crank arm 17 will carry the driving member 50 with it, and the motion will be transmitted through the spring 61 and link 53 to the links 52 and 51. The whole strain release assembly shown in Figure 7, with the exception of the link 43 and the stops 92 and 93, will therefore tend to turn in a counter-clockwise direction about the axis of the shaft 11. This action will continue until the link 53 engages the stop 93. When this occurs further increase in temperature in the furnace will cause the link 53 to be pivoted counter-clockwise about the stop 93 as a fulcrum, thus moving the link 43 downwardly. The tension of the spring 61 will then be opposed by the

stop 93, and the internal bias of the switch 25 will move the switch actuating button 30 outwardly, thereby completing the energizing circuit of the fan and starting the fan in operation. If the furnace temperature continues to rise after the link 43 has reached its downward limit of movement, the link 53 will remain stationary since it is held by link 43 and stop 93, and the only effect will be stretching of the spring 61. The link 51 will be held stationary as the pivot 57 cannot move. The extension 67 will prevent counter-clockwise rotation of link 51 with respect to link 52. Therefore, link 51 will also remain stationary, and the stop member 63 will separate from the driving member 50.

If the furnace temperature now begins to decrease, the crank arm 17 will be moved in a clockwise direction. Until the driving member 50 engages the projection 63, the only effect of this motion will be to decrease the stretching of the spring 61. As soon as the driving member 50 engages the projection 63, the link 51 is also driven clockwise and a force is transmitted through the spring 65 to turn the link 52 clockwise about the pivot 55. This moves the pivot 57 and hence the link 53 in a clockwise direction. All the links 51, 52 and 53 are then moving together. Since the tension of the spring 61 balances that of the internal bias of the switch 25, no movement of the link 43 takes place, however, until the right hand end of link 53 engages the stop 92. Therefore the fan controlling switch 25 continues to keep the fan circuit closed until a temperature is reached which has been determined by setting the stop 92 through the movement of the indicator 85 adjacent the scale on the bracket plate 23. When this temperature is reached, further clockwise rotation of the link 53 about the axis of the shaft 11 is prevented by the engagement of its right hand end with the stop member 92. As the crank arm 17 and the pivot 57 continue to move clockwise the link 53 is pivoted about the stop 92 as a fulcrum, transmitting a lifting force to the end of the link 43. The resulting upward movement of the link 43 causes the lever 33 to press inwardly on the actuating button 30 and move the switch 25 to its off position.

If the temperature in the furnace continues to fall until the link 43 reaches its upper limit of movement as determined by stop 101, then the link 53 is held from further movement. Since the motion of the pivot 57 is stopped, the link 53 is also prevented from further counterclockwise rotation. The link 51 continues to be driven counterclockwise by the engagement of the projection 63 with the driving member 50. Stop 67 separates from link 51, and strain on the parts of the mechanism is prevented, by the stretching of the spring 65 to take up any additional motion of the crank arm 17.

It should be clear from the preceding description that I have provided a strain release connection which prevents strain on the mechanism after the driven member has been prevented from further movement in either direction. It should be noted that the link 43 is biased in a downward direction, and that the spring 61 has a dual function, first to oppose the bias of the link 43 so that the link 53 will remain in any position to which it is moved, and second to act as a strain release spring when the counterclockwise rotation of the link 53 has been stopped and the crank arm 17 is continuing to rotate in that direction.

Switches of the type disclosed in the description of the present instrument have a fixed differential between the force necessary to push the switch actuating button inwardly and the force needed to hold the button in an inward position. The minimum temperature differential normally obtainable between the fan off and fan on temperatures with the stops 92 and 93 moved as close to each other as possible, would, therefore, be equal to the differential between that temperature at which the helical thermostatic element 12 produces a force equal to the actuating force described and the temperature at which the thermostatic element produces a force equal to the holding force described plus the temperature differential required by the element 12 to move itself through the distance required for operation of the switch. It has been found, however, that the normal temperature differential thus obtained is too large to provide optimum operation of the present device, because in certain types of heating systems, it is necessary or desirable that the minimum temperature differential be adjustable to a value much smaller than this. The applicant has therefore provided means whereby the minimum temperature differential is reduced below this "normal" value. This means comprises the toggle link 103 and the spring 105, and its proximate function is to compensate the spring rate of the helical thermostatic element 12.

Consider the case of a flexible member, or spring, rigidly supported at one point and having a deflecting force applied at another point. For any given flexible member, a force of a certain magnitude will produce a certain deflection. An increase in the deflecting force will produce an increase in the deflection. The increment of the deflecting force, divided by the resulting increment of the deflection, is termed the spring rate of the member.

The helical thermostat element 12 is a flexible member which is so constructed that its spring rate is a constant.

The operation of this type of helical thermostatic element when subject to an external deflecting force is as follows. If the element is fixed at one end, and a deflecting force applied to its opposite end, the ambient temperature remaining constant, the deflection will be proportional to the deflecting force, and the proportionality will be determined by the same constant spring rate as before. Similarly, if both ends of the element are fixed, and the temperature changes, a force will be exerted at both ends of the element which is proportional to the temperature change. If, after such a temperature change, one end is released, that end of the element will deflect to a new position corresponding to the new temperature, and the external force exerted by the element will gradually decrease to zero as the deflection takes place.

Operation of switch 25 without spring rate compensation

Now consider the operation of the switch 25 by the element 12 as if the toggle link 103 and the spring 105 were absent. In order to simplify the present discussion, the action of the strain release mechanism may be disregarded except as it serves to change rotation of the arm 17 into translation of the link 43. Let it be assumed that the stops 92 and 93 are set to engage the opposite sides of the arm 53 simultaneously so that the device will operate with a minimum temperature differential between the "on" and "off" positions of the switch 25, and that the other

parts are in the positions shown in the drawings. It should be remembered that the switch **25** is internally constructed so that the force required to move the button **30** inwardly (from right to left in Fig. 2) is greater than the force required to hold the button in its inward position. The minimum force required to move the button inwardly past the operating point of the switch will hereinafter be referred to as force M, and the minimum force required to hold the button inwardly will be identified as force H. Obviously, M is greater than H with the switch button **30** in its inward position, as shown, the switch is open, and a force of a value between M and H is acting through the lever **33** to move link **43** downward. This force is opposed by an equal and opposite reactive force supplied by the element **12**. The element **12** is therefore deflected from the normal position it would assume if left free to move. Now let the temperature begin to rise. The construction is such that a rise in temperature will cause the reactive force supplied by the element **12** to decrease below H and the link **43** will therefore move downwardly. As link **43** moves, the switch button **30** will be moved to its closed position, paralleling the change in the position of the element **12** as the temperature increases. The difference in temperature needed to move the switch button **30** from open to closed position is therefore the temperature differences needed to move the element **12** through a distance corresponding to the travel of the link **43**. (As previously explained, the latter temperature difference is determined by the spring rate of the element **12**.) Let this temperature difference be designated as T_1.

After the switch has been moved to closed position because of an increase in temperature equal to T_1, let it be assumed that the temperature begins to decrease. This decrease in temperature causes the element **12** to deflect so as to move link **43** upwards. The force needed to move link **43** upward is now M, greater than H. The upward reactive force applied to the link **43** by the element **12** is at this moment slightly less than H. The difference between this momentary value and H may be neglected for all present purposes. As the temperature decreases, this upward force increases proportionally, but no movement of the link **43** takes place until it reaches the value M. Let the temperature difference required to increase the upward force exerted by the element **12** from H to M be designated as T_2.

After the force exerted by the element **12** has reached the value M, further decrease in temperature will cause the link **43** to move toward its upper position. The temperature difference necessary to complete this movement will be the same as that required for the downward movement, or T_1. The differential between the temperatures at which the switch is actuated to on and off positions is therefore equal to T_2 plus T_1.

Operation of switch 25 with spring rate compensation

Now consider the operation of switch **25** by the element **12** when the toggle link **103** and spring **105** are present.

As in the previous case, assume that the button **30** is in its inward position, and that the force H is acting to move the link **43** downward. The spring **105**, however, introduces a new force into the picture, having a component X, which opposes the force H. Therefore the upward reactive force which element **12** must supply in order to hold button **30** in its inward position is now only H minus X. Let the temperature now increase. This decreases the upward force supplied by element **12**, and link **43** starts to move downward. As soon as the link **43** starts to move downward, the lower end of lever **33** starts to move to the right. This changes the angle at which the toggle link **102** acts on the lever **33**, so as to reduce the component X which is effective to oppose force H. Although the change in the deflection of element **12** due to downward movement of link **43** causes an increase in the reactive force supplied by that element, the proportions of spring **105** and toggle link **102** are so chosen that the component X decreases faster than the reactive force increases, and hence the link **43** moves downward with a sudden snap. In other words, the rate of decrease of component X compensates for the rate of increase of the reactive force, which is governed by the spring rate of the element **12**. This action is known and described by the term "spring rate compensation."

After the toggle link **102** goes over center, the component of force due to spring **105** which acts on the push button **30** is no longer opposing force H, but aiding it, and the aid increases as the movement continues. This component which aids H will be referred to as force Y. The toggle mechanism may be adjusted so that the center position is at the center of travel of lever **33**, and X is equal and opposite to Y. The toggle mechanism is so designed that X and Y are small compared with H, and also the deflection of element **12** corresponding to the force X, or Y, is small compared to the deflection corresponding to T_1. The temperature increment necessary to secure a deflection corresponding to force X, or Y, will be designated as T_3.

After the switch has been thus moved to closed position let it be assumed that the temperature begins to decrease. The force needed to move the link **43** upward is now M plus Y. The reactive force of the element **12**, having been equal to slightly less than (H minus X) at the start of the downward movement, and having been increased by an increment Y during that movement, is now slightly less than (H minus X plus Y). Since X equals Y, the reactive force is slightly less than H, just as it was at this stage of operation without the spring rate compensation. As before, the slight difference between this momentary value and H may be neglected. As the temperature decreases, this upward reactive force increases proportionally but no movement of the link **43** takes place until it reaches the value M plus Y. The temperature difference required to change the force exerted by the element **12** from H to M has been designated as T_2, and the temperature increment required to secure the force Y has been designated as T_3. When the link **43** starts to move upward, the force Y decreases due to the change in angle of the toggle link **103** faster than the reactive force decreases due to the spring rate of the element **12**, and the switch **25** snaps to its open position with no further decrease in temperature.

Therefore the minimum temperature differential between open and closed positions of switch **25** is equal to (T_2 plus T_3) when the spring rate of the element **12** is compensated by the action of toggle link **102** and spring **105**. It was previously shown that the minimum temperature differential when the spring rate was uncompensated was T_2 plus T_1. Since T_3 is smaller

than T_1, as explained above, the differential has been decreased by compensating the spring rate of the element 12.

Sequence of operation

If the knob 111 is set, as indicated in Figure 1, for winter operation, and the actuating temperatures of the various switches are adjusted by setting the indicators 85, 86, 87 and 88 at the positions shown in Figure 1, then with the furnace temperature below the lowest of these settings, the fan switch will be open, the speed-changing switch in low speed position, and the limit switch will be closed.

Assume that a fire is started in the furnace under such conditions, as the temperature rises, the fan switch will be closed at approximately 130°, as shown by the indicator 86, and the fan will begin to run at low speed. If the temperature continues to rise to 150°, the speed changing switch will be actuated and the fan will operate at high speed. If the temperature continues to rise to 230°, the limit switch will be opened and the control system will operate to decrease the heat output of the furnace. The resulting drop in temperature will first cause the limit switch to be closed. If the temperature then continues to decrease, the speed-changing switch will change the fan to low speed operation at approximately 150°, and the fan will be turned off altogether at 90°. There is a small difference between the temperature at which the speed changing switch is actuated on a temperature rise, and the temperature at which it is actuated on a temperature drop, due to the inherent differential of the switch.

If the knob 111 is moved from its winter position to its summer position, the cam 112 will be rotated counterclockwise from the position shown in Figure 5, and the shoulders 118 and 120 will engage the arms 117 and 119. Engagement of arm 117 by shoulder 118 will force the lever 33 downwardly, moving the main fan switch 25 to on position. Engagement of the arm 119 by shoulder 120 will move the lever 34 upwardly, move the switch 26 to high speed position. The fan will then operate at high speed to circulate air through the house for cooling purposes.

Calibration

After the device has been assembled, the temperatures of the element 12 at which the fan switch 25 is actuated may not agree with those indicated on the scale adjacent the slot 90 by the fingers 85 and 86. The thermostatic element may be adjusted for calibration purposes by means of the bolt 14 and the adjustable plate 13. When the switch 25 has been calibrated in that manner, the speed-changing switch may be brought into calibration with its scale by means of the bolt 77, which changes the temperature at which the stop 94 is engaged by the link 80. A similar adjustment may be made in the strain release mechanism 22 associated with the limit switch 27.

Although I have described my invention in connection with a combined two-speed fan and limit control, other modifications will occur to those skilled in the art. For example, my device might be used with a single speed fan control, or low limit and overrun controls might be incorporated. My invention is to be limited, therefore, only by the scope of the appended claims.

I claim as my invention:

1. A condition responsive control device, comprising in combination, an element movable in accordance with the magnitude of a variable condition, a driving member connected to said element and rotatable about an axis upon movement thereof, control means operable between a first position and a second position, a driven member movable transversely to said axis and operatively connected to said control means, a link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link in each direction, and a two-way strain release between said driving member and said link, said strain release comprising a first flexible connection including spring means tending to rotate said link in a clockwise direction, and a second flexible connection including spring means tending to rotate said link in a counterclockwise direction, said spring means balancing each other so that said link rotates with said driving member until said stop means is engaged, whereupon one of said spring means is rendered ineffective, and the other spring means becomes effective to move said link transversely of said axis, thereby moving said driven member and operating said control means.

2. In a condition responsive control device, a driving member rotatable about an axis in accordance with the magnitude of a variable condition, a driven member movable transversely to said axis between a first position and a second position, a first link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link about said point in each direction, and a strain release between said driving member and said link comprising a second link pivotally attached to said first link at a point spaced from said axis and rotatably attached to a fixed pivot in line with said axis, a third link rotatably attached to said fixed pivot, a portion of said second link adapted to engage a portion of said third link so as to limit relative rotation between said links in one direction, spring means connecting said links and biasing said portions into engagement, a portion of said third link adapted to engage a portion of said member so as to limit relative rotation therebetween in the opposite direction, and spring means connecting said first link and said member and acting through said second and third links to bias said last-mentioned portions into engagement.

3. In a condition responsive control device, a driving member rotatable about an axis in accordance with the magnitude of a variable condition, a driven member movable transversely to said axis between a first position and a second position, a link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link about said point in each direction, and a strain release between said driving member and said link comprising a first flexible connection including spring means tending to rotate said link in a clockwise direction and a second flexible connection including spring means tending to rotate said link in a counterclockwise direction, said spring means balancing each other so that said link rotates with said driving member until said stop means is engaged, whereupon one of said spring means is rendered ineffective, and the other spring means becomes effective to move said link transversely of said axis, thereby operating said driven member.

4. In a condition responsive control device, a

driving member rotatable about an axis in accordance with the magnitude of a variable condition, a driven member movable transversely to said axis between a first position and a second position, means biasing said driven member to said first position, a link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link about said point in each direction, and a strain release between said driving member and said link comprising a first flexible connection including spring means tending to rotate said link in a clockwise direction and a second flexible connection including spring means tending to rotate said link in a counterclockwise direction, one of said spring means balancing the other spring means and said biasing means so that said link rotates with said driving member until said stop means is engaged whereupon one of said spring means is rendered ineffective, and the link is moved transversely of the axis under the influence of the other spring means and the biasing means, so as to operate said driven member.

5. A condition responsive control device, comprising in combination, an element movable in response to a variable condition, a pair of control devices, a housing for supporting said element and said devices, connections between said element and each of said devices, said housing having a pair of slots therein and a scale adjacent each slot, said connections comprising, for each said device, an adjustable member having a finger extending through one of said slots, means whereby the position of each said member determines the value of the condition at which the corresponding control device is actuated, and whereby each said finger indicates said value on the adjacent scale, and means for interlocking said member so that the actuating value determined by one finger is always lower than that dtermined by the other.

6. A condition responsive control device, comprising in combination, an element movable in response to a variable condition, a pair of control devices, a housing for supporting said element and said devices, connections between said element and each of said devices, a manual operator mounted so as to extend into said housing, connections between said operator and each of said devices so that both devices may be actuated simultaneously by manipulation of said operator, regardless of the position of said movable element.

7. In a condition responsive control device, a driving member rotatable about an axis in accordance with the magnitude of a variable condition, a driven member movable transversely to said axis between a first position and a second position, a link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link about said point, and a strain release between said driving member and said link comprising a second link pivotally attached to said first link at a point spaced from said axis and rotatably attached to a pivot on said driving member in line with said axis, spring means tending to rotate said second link relative to said driving member, and means for limiting the rotative tendency of said spring means.

8. In a condition responsive control device, a driving member rotatable about an axis in accordance with the magnitude of a variable condition, a driven member movable transversely to said axis between a first position and a second position, a link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link about said point, and a strain release between said driving member and said link comprising a second link pivotally attached to said first link at a point spaced from said axis and rotatably attached to a pivot on said driving member in line with said axis, spring means connected to said driving member and to said second link and tending to rotate said second link relative to said driving member, and stop means on said driving member for limiting said rotative tendency.

9. In a condition responsive control device, a driving member rotatable about an axis in accordance with the magnitude of a variable condition, a driven member movable transversely to said axis between a first position and a second position, a link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link about said point, and a strain release between said driving member and said link comprising a second link pivotally attached to said first link at a point spaced from said axis and rotatably attached to a pivot on said driving member in line with said axis, spring means connected to said driving member and to said second link and tending to rotate said second link relative to said driving member, and adjustable stop means on said driving member for limiting said rotative tendency, and for determining the relative normal positions of said member and said second link.

10. A condition responsive control device, comprising in combination, a flexible element movable in response to a variable condition, control means biased to a first position and having a fixed differential between the force required to move said means to a second position and the force required to hold said means in said second position, means operatively connecting said element with said control means, and a device to compensate the spring rate of said element.

11. A condition responsive control device, comprising in combination, a flexible element movable in response to a variable condition, control means biased to a first position and having a fixed differential between the force required to move said means to a second position and the force required to hold said means in said second position, means operatively connecting said element with said control means, a device to compensate the spring rate of said element, and a strain release to prevent strain of the parts due to overrun of said element after actuation of said control means.

12. A condition responsive control device, comprising in combination, a flexible element movable in response to a variable condition, control means biased to a first position and having a fixed differential between the force required to move said means to a second position and the force required to hold said means in said second position, means operatively connecting said element with said control means, a device to compensate the spring rate of said element, and means for independently varying the values of said condition at which each of said forces is transmitted to said control means.

13. In a condition responsive control device, a condition responsive driving member movable in accordance with the magnitude of a variable con-

dition, a driven member movable between a first position and a second position, means independent of said condition responsive driving member for biasing the driven member to said first position, a strain release mechanism operatively connecting said members and including spring means, said spring means acting on said driven member in a direction opposite to that of said independent biasing means.

14. In a condition responsive control device, a driving member movable in accordance with the magnitude of a variable condition, a driven member movable between a first position and a second position, means independent of said driving member for biasing the driven member to said first position, spring means connected between said driven member and said driving member, said spring means operatively connecting said members and opposing said independent biasing means so that said driven member remains in either of said positions to which it is moved by said driving member.

15. A condition responsive control device, comprising in combination, an element movable in accordance with the magnitude of a variable condition, a driving member connected to said element and rotatable about an axis upon movement thereof, control means operable between a first position and a second position, a driven member movable transversely to said axis and operatively connected to said control means, a link pivotally attached to said driven member at a point substantially in line with said axis, stop means for limiting the rotation of said link in each direction, a two-way strain release between said driving member and said link, said strain release comprising a first flexible connection including spring means tending to rotate said link in a clockwise direction, and a second flexible connection including spring means tending to rotate said link in a counterclockwise direction, said spring means balancing each other so that said link rotates with said driving member until said stop means is engaged, whereupon one of said spring means is rendered ineffective, and the other spring means becomes effective to move said link transversely of said axis, thereby moving said driven member and operating said control means, and manual means for actuating said control means regardless of the position of said element.

16. In a condition responsive control device, a driving member movable in accordance with the magnitude of a variable condition, a driven member movable between a first position and a second position, first spring means for biasing the driven member to said first position and opposing movement of said driven member to said second position in response to said driving member, second spring means opposing said first spring means and operatively connecting said driving member to said driven member for movement of said driven member to said first position, and third spring means opposing said first spring means and operatively connecting said driving member to said driven member for movement of said driven member to said second position.

17. In a condition responsive control device, a condition responsive driving member movable in accordance with the magnitude of a variable condition, a driven member movable between a first position and a second position, first spring means opposing independent movement of said driven member to the first position and operatively connecting said driving member to said driven member for movement of said driven member to said first position, and second spring means opposing independent movement of said driven member to the first position and operatively connecting said driving member to said driven member for movement of said driven member to said second position.

18. A condition responsive control device, comprising in combination, a flexible element movable in response to a variable condition, control means biased to a first position and having a fixed differential between the force required to move said means to a second position and the force required to hold said means in said second position, means operatively connecting said element with said control means, and a snap action spring member acting upon said connecting means in such a manner as to compensate the spring rate of said element.

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