

Nov. 21, 1967

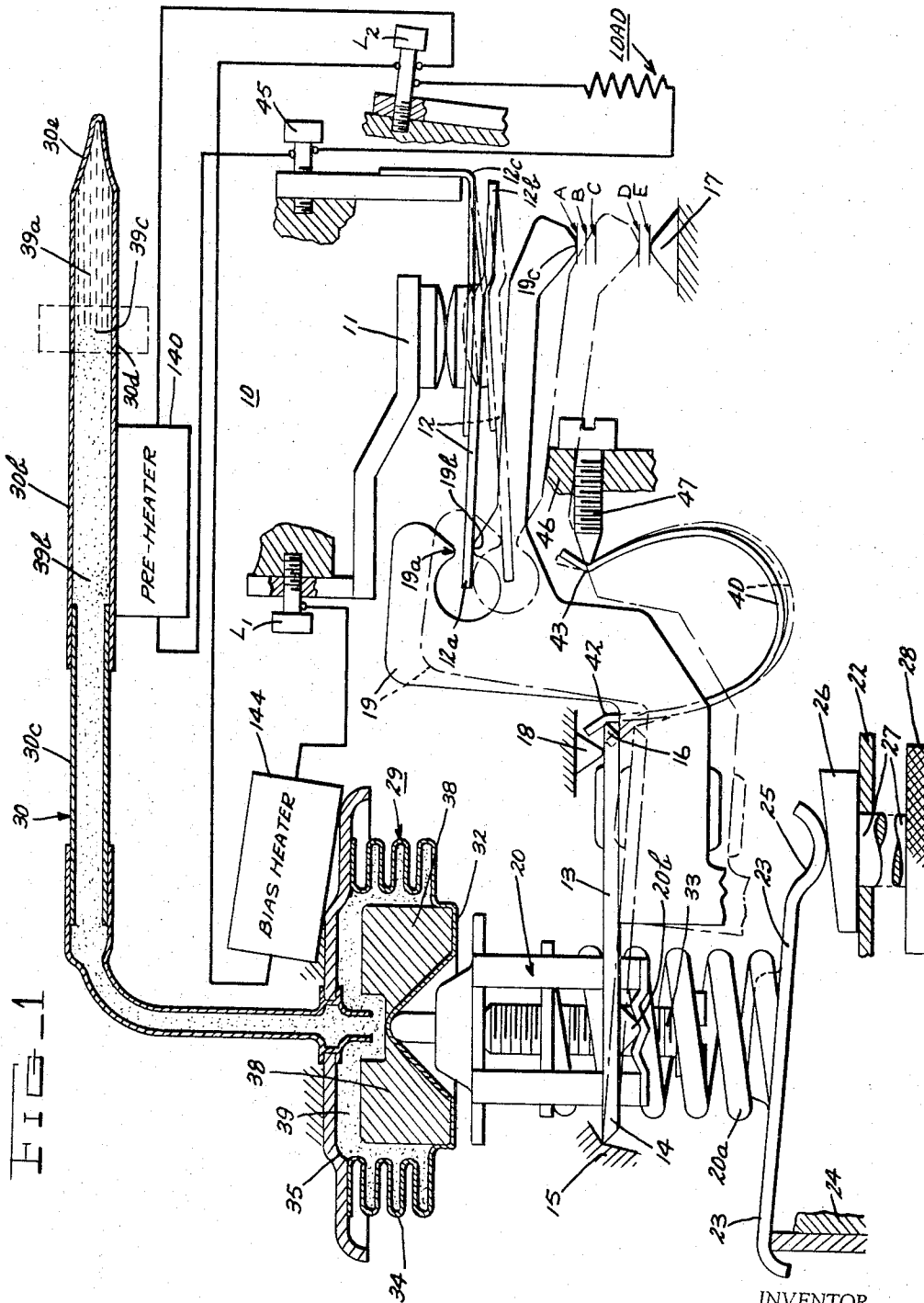
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3,354,280

CONDITION RESPONSIVE ELECTRIC SWITCH MECHANISM

Filed Feb. 8, 1966

6 Sheets-Sheet 1



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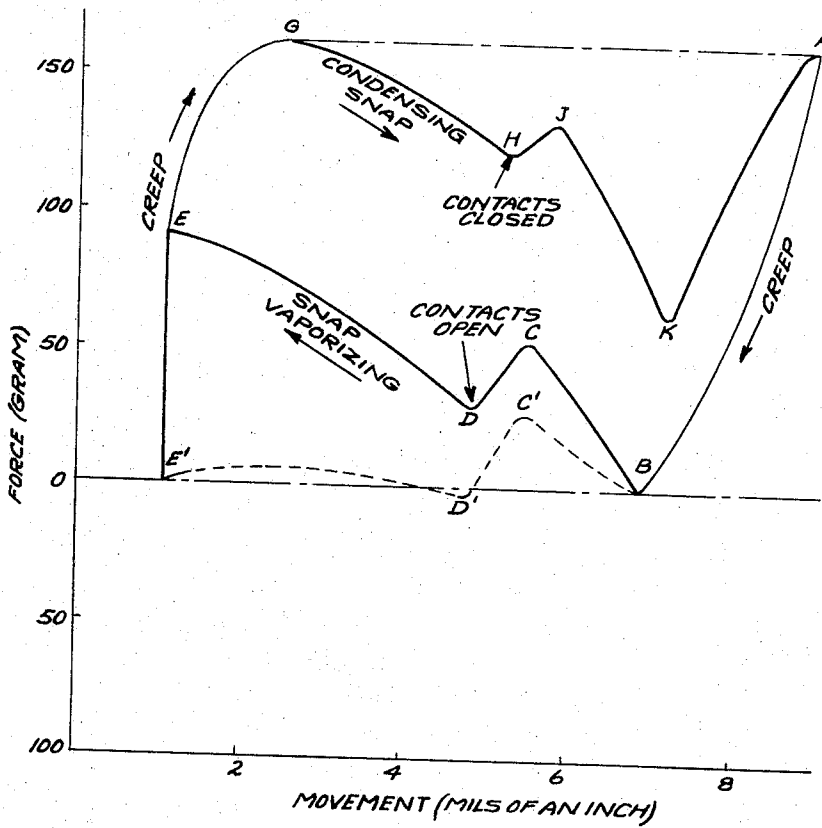
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CONDITION RESPONSIVE ELECTRIC SWITCH MECHANISM

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6 Sheets-Sheet 2

FIG. 2



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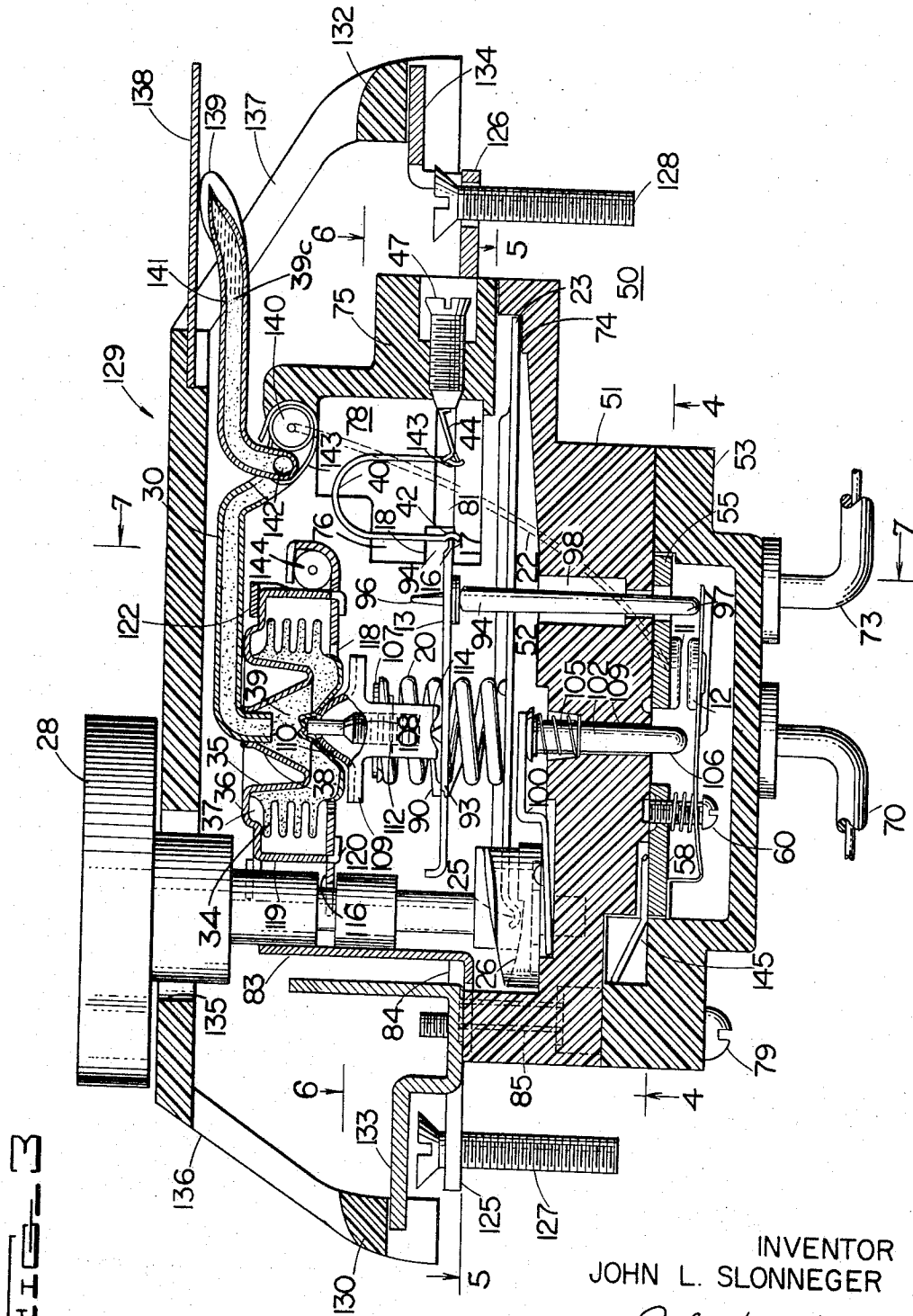
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CONDITION RESPONSIVE ELECTRIC SWITCH MECHANISM

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6 Sheets-Sheet 3



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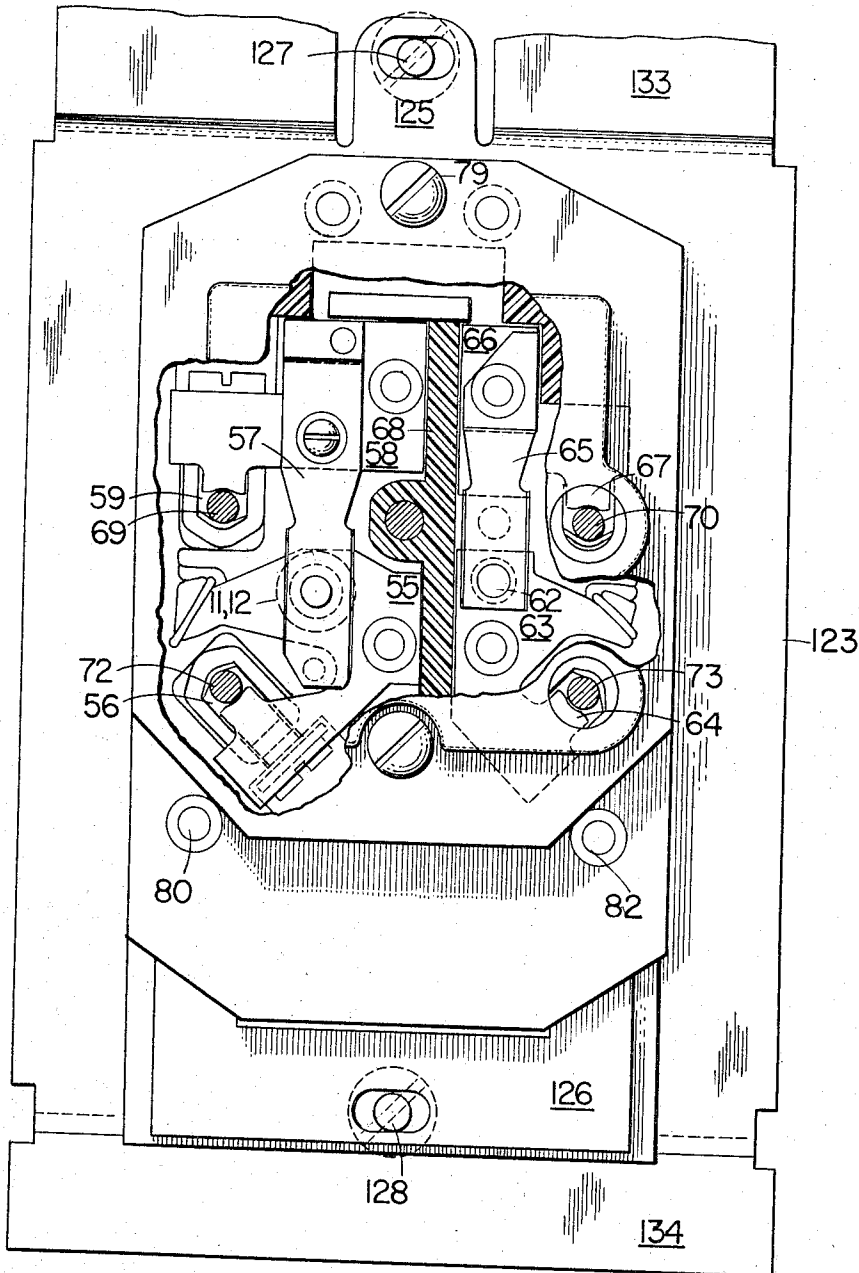
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CONDITION RESPONSIVE ELECTRIC SWITCH MECHANISM

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6 Sheets-Sheet 4

FIG. 4



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CONDITION RESPONSIVE ELECTRIC SWITCH MECHANISM

Filed Feb. 8, 1966

6 Sheets-Sheet 5

FIG. 5

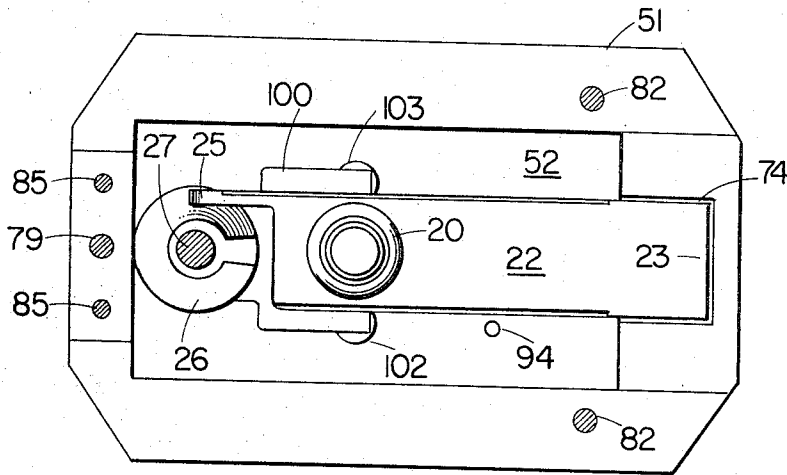
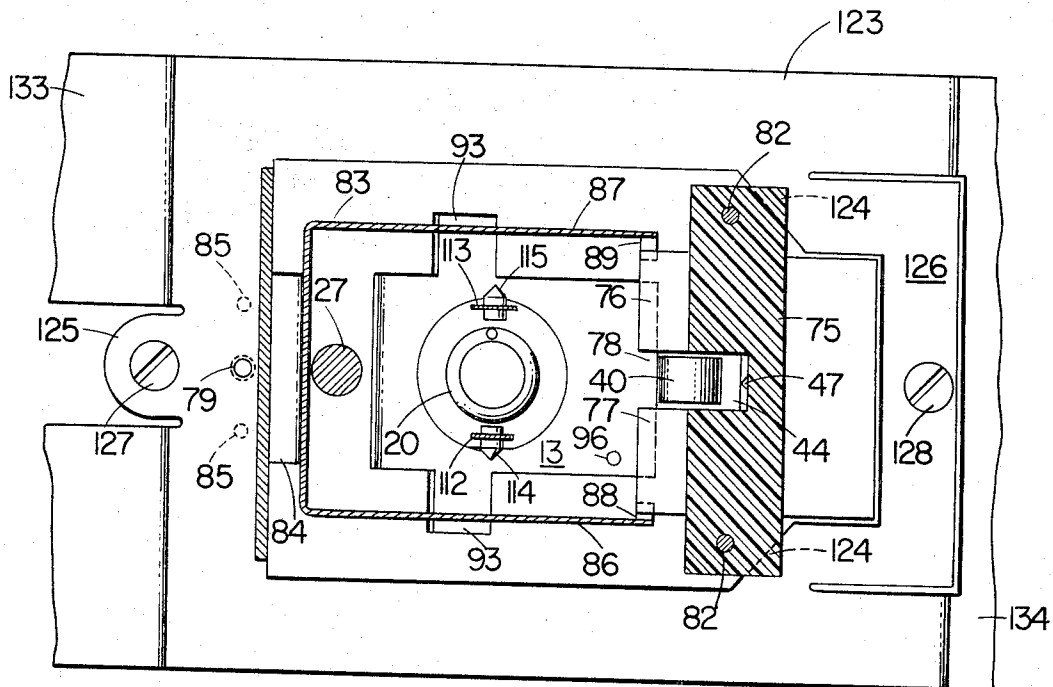


FIG. 6



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CONDITION RESPONSIVE ELECTRIC SWITCH MECHANISM

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 9 Claims. (Cl. 200-140)

ABSTRACT OF THE DISCLOSURE

A condition responsive electric switch mechanism has a switch actuator which moves switch elements between open and closed switch positions, with a spring being connected to the switch actuator to assist in effecting the transfer in response to a temperature change within a particular temperature range. A sealed expansible assembly of the mechanism has an expansible chamber connected to the switch actuator and a hollow temperature sensing section in communication with the chamber. Fluid is initially charged in the expansible assembly at a temperature which exceeds the temperature responsive range of the mechanism such that a partially saturated vapor and partially saturated liquid is provided in the temperature range. The temperature sensing section of the assembly has a heat transfer region in contact with liquid and adjacent vapor during both vaporization and condensation at that region. Further, the expansible chamber and heat transfer region have a temperature differential there between, with the higher temperature being at the chamber.

By virtue of this arrangement, the rate of heat transfer to and from the fluid occurs substantially at the heat transfer region at a relatively slow rate to produce a thermal damping condition in the temperature range which in turn causes the creation of resistive forces acting on the switch actuating member, a major factor in controlling the velocity of the operation of the member as it travels between two switch positions.

In addition, a heater is mounted in heat transfer relation with the expansible chamber for producing a super heated condition in the chamber, and maintain a temperature differential between the expansible chamber and temperature sensing section. A thermal barrier between the chamber and section may be furnished to insure the desired temperature differential between the chamber and the temperature sensing section. This construction is not only inexpensive to manufacture, but in addition provides a quiet operation of the switch components while eliminating the need for auxiliary dash pot and other viscous damping arrangements heretofore utilized in an attempt to control the velocity of the switch components as they are operated.

This invention relates generally to condition responsive electric switch mechanisms, such as thermostat units for use in connection with heating and cooling apparatus, and more particularly to temperature responsive thermostats incorporating a quick-acting switch assembly.

Conventional thermostats for heating and cooling applications incorporate a temperature responsive sealed vapor-filled bellows assembly and a spring both acting in opposite directions upon an operating member which actuates the switch contacts, the operating member

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being moved between first and second positions by expansion and contraction of the bellows in response to temperature changes. In order to furnish a differential between the temperatures at which the switch contacts are respectively opened and closed, a spring mechanism is conventionally provided which acts upon the operating member and produces a snap action movement of the member between its two positions.

One problem with such thermostats prior to my invention was the high noise level they produce during operation which is particularly noticeable and objectionable when the thermostat is employed for domestic applications in connection with the control of apparatus used in homes. It is therefore desirable to provide a snapping thermostat in which the operating noise due at least in part from the snapping action of the moving components be substantially reduced. The noise provided by the snap action is a function of the kinetic energy which must be dissipated when the snapping mechanism is stopped at the end of its stroke, this kinetic energy being in turn a function of the velocity of movement of the operating member from one position to the other. In studying this problem, I have determined that the major factors which control the velocity of the snapping parts are friction and inertia. While the addition of friction will reduce the noise of snapping for a given differential, it will also reduce the available static forces which are required for a good snap action. It is thus highly desirable to minimize friction in the snapping mechanism of such thermostats.

In the past, attempts were made to control the velocity of the snapping parts by use of various auxiliary dash pot arrangements employing viscous damping. Such arrangements, however, not only added appreciably to the complexity and cost of the device, creating additional problems in the satisfactory use of the thermostat devices but, further, did not completely solve the noise problem. It is therefore desirable that damping of the snap acting parts of the device be achieved in an economical manner without the necessity for incorporating auxiliary dash pot arrangements in the device.

It is accordingly an object of the invention to provide an improved condition responsive electric switch mechanism.

Another object of the invention is to provide an improved temperature responsive electric switch mechanism incorporating a fast acting type switch, which overcomes the problems and incorporates the desirable features mentioned above.

A further object of the invention is to provide an improved thermally responsive switch mechanism to the snap-acting type incorporating thermal damping.

It is yet another object of the invention to provide a sturdily built, yet economical and improved, condition responsive switch mechanism that is relatively compact and is capable of trouble-free and relatively quiet operation over a long period of time.

In carrying out the invention in one form, I have found that the velocity of the snapping mechanism in a thermostat device can be controlled to attain an unusually low noise level of operation by regulating the rate of heat transfer to and from the molecules of confined fluid in a vapor-filled bellows assembly, which I refer to as "thermal damping." Thus, in accordance with the one form of my

invention, a temperature responsive device in the form of an expandible or sealed bellows assembly, including an expandible chamber such as a bellows and an attached tube contains a fluid partially in the form of a saturated liquid and partially in the form of a saturated vapor at a preselected temperature range. The tube has a temperature sensing section which holds the liquid and a relatively small heat transfer surface where the liquid is adjacent the vapor. In addition, there is a temperature differential between the bellows and temperature sensing section of the tube which is constantly maintained. The bellows is operatively connected through a net negative spring constant spring means and a fast moving switch actuator member, movable between first and second positions, to the movable contact of a switch assembly. In operation, when the bellows is either initially expanded or contracted in response to the ambient temperature and the actuator begins to be driven between the positions by the spring means, the low rate of heat transfer occurring to and from the confined vapor and liquid at the heat transfer region produces a thermal damping condition and a resistive force in opposition to the force of the spring means, thereby controlling the rate of operating speed for the actuator member without appreciably affecting the static forces of such operation.

Among other advantages and features, a thermostat device which incorporates my invention is relatively economical to manufacture and is of simple construction, yet achieves controlled velocity of the movable contact in the switch of the device. In addition, the device is capable of unusually quiet operation for an extended period of time.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a side view, partly in cross-section, schematically illustrating one form of the invention;

FIGURE 2 illustrates force-movement operating characteristics of the mechanism seen in FIGURE 1 and is typical of such mechanisms which incorporate that form of the present invention;

FIGURE 3 is a side cross-sectional view illustrating a thermostat device embodying the preferred embodiment of the invention which has an operating characteristic similar to that revealed in FIGURE 2;

FIGURE 4 is a bottom view of the thermostat device of FIGURE 3, partly broken away generally along the line 4—4 of FIGURE 3;

FIGURE 5 is a cross-sectional view taken along the line 5—5 of FIGURE 3;

FIGURE 6 is a cross-sectional view taken along the line 6—6 of FIGURE 3;

FIGURE 7 is a cross-sectional view taken generally along the line 7—7 of FIGURE 3; and

FIGURE 8 is a schematic illustration of the electrical circuit for the thermostat device of FIGURE 3.

Referring now to FIGURE 1, there is shown a thermostat device, generally indicated at 10, which comprises stationary electrically conductive and movable switch contact elements 11, 12 of a cycling electrical switch adapted to be connected in the circuit of the load to be controlled, for example, the electric heating elements comprising an electric heating system. A switch actuator member has an operating arm section 13 pivotally mounted at end 14 on a stationary frame element 15 so that its other end 16 is movable between first and second extreme positions defined by suitable stops or limits 17, 18. Operating arm section 13 is coupled or operatively linked to the movable switch contact element 12 by an actuating section 19 which has shoulders 19a, b alternatively engageable with the free end 12a of movable element 12. Thus, the switch contact elements 11, 12 will be held in open circuit when the ac-

tuator member is in its lower position (as viewed in FIGURE 1) and its extension 19c engages stop 17. When the switch actuator member is in engagement with stop 18, the upper position shown in full in FIGURE 1, the contact elements will be in closed circuit or in engagement with each other.

In order to bias the switch actuator member continuously toward the direction of the closed contact position (shown in full in FIGURE 1) for elements 11, 12 and to provide fast movement or snap-like action of the member, a toggle spring 40 is furnished. The toggle spring has an indented end 42 in engagement with the knife edge 16 of arm section 13 while its other indented end 43 is in engagement with an adjustable temperature differential screw 47 which in turn is threadingly received through stationary frame part 46. Consequently, with ends 42, 43 being offset in the illustrated manner and mounted in continuous compression between the arm section 13 and screw member 47, the spring applies a continuous biasing force in a clockwise direction relative to the knife edge at 14 of arm section 13. Axial movement or adjustment of screw 47 will vary the biasing force supplied by the toggle spring thereby varying the temperature differential of the switch.

The provision of a continuous downward biasing force upon arm section 13 or counterclockwise moment about arm end 14 is provided by a bearing and range spring assembly 20 of the type more fully revealed and discussed in the R. W. Cobean Patent No. 3,064,320 issued Nov. 20, 1962. The lower end (as seen in FIGURE 1) of the range spring 20a of assembly 20 bears upon an annular surface of a cam follower 22 which has one end pivotally supported by stationary frame part 24 and the other end 25 cooperatively engaging cam 26 on control rod 27 mounted thereon. By manually turning knob 28 and hence cam 26, the compression of the range spring may readily be varied to adjust the temperature level at which the thermostat device operates. An action screw 33 directly receives condition responsive force from an expandible bellows 34 of a sealed bellows assembly 29 and the biasing force from the range spring 20a screw 33 transmitting the difference between these two forces to bearing 20b and hence to arm section 13 of the switch actuator member.

Turning now to a more detailed consideration of fluid confining vessel or bellows assembly 29, it will be seen from FIGURE 1 that a rigid and cup-shaped bottom wall 32 is in cooperative relation to screw 33 and is connected to one side of expandible bellows 34. The other side of the bellows is attached to flanged section 35 of stationary wall 36 through which extends one end of a temperature sensing tube 30 in communication with the interior of bellows 34. Tube end and wall 36 are suitably sealed as indicated at 37. For reasons to become more apparent hereinafter, tube 30 is formed by two spaced apart sections 30a, b fabricated from heat conductive material, such as copper, and a central section 30c which preferably has low thermal conductivity characteristics; e.g., stainless steel. Thus, section 30c functions as a thermal isolation between tubular section 30a and bulb section 30b. In order to reduce and control the total internal volume available for fluid 39 in the bellows assembly 29, a solid annulus 38 is positioned within the confines of bellows 34.

By one aspect of the present invention, bellows assembly 29 is formed such that heat transfer takes place over a relatively small surface area 30d or region of tube 30. With condensation and vaporization of fluid 39 occurring at that location to provide thermal damping of a magnitude sufficient to be the major factor in controlling the velocity of the fast acting components in the linkage between bellows 34 and movable contact element 11. To attain this end, before bellows assembly 29 is sealed, it should be initially charged with fluid 39 in the form of a gas having a temperature selected above the designed

operating temperature range for the thermostat device. For example, assuming the operating range to be 60°–90° Fahrenheit and the fluid butane, the charge gas should have a temperature in the order of 125° F. (approximately 60 p.s.i. gauge pressure).

In the selected contact cycling temperature range, such as between 70°–75° F., the fluid will be in the form of a mixture, partially a saturated liquid 39a and the far greater volume of assembly 29 having a partially saturated vapor 39b with both vaporization and condensation occurring at area 30d (e.g., $\frac{1}{16}$ inch diameter, $\frac{1}{2}$ inch length) which is one of the coldest regions of the assembly. As will be seen below, in order to function properly and provide the desired thermal damping, assembly 29 should have a temperature differential between bellows 34 and heat transfer region 30d in the contact cycling range, such as 2°–5° F. The significance of the above may be better appreciated from a consideration of the operation for the device shown in FIGURE 1. For purposes of discussion, it will be assumed that adjustable cam 26 is set such that the contact cycling temperature range is 70°–75° F. and fluid 39 is butane. At 70° F., the vapor pressure is approximately 17 p.s.i.g. and the components of the thermostat device are as shown in full (switch actuator at position "A"), with the switch contact elements 11, 12 being closed.

It will be further assumed that switch elements 11, 12 are utilized in the control of an electric heater, denoted by the legend LOAD in FIGURE 1 which may have a rating of 5,000 watts and 240 volts. As shown, the contact elements are connected in circuit with input terminals L₁, L₂ adapted to be energized from a suitable power source and the load is connected in circuit between movable contact element 11, through connector 45, and terminal L₂. Thus, the cycling of contact elements 11, 12 result in cycling of the heating load. With the elements 11, 12 in closed circuit (position A) and the load energized, the ambient temperature at tube 30 and fluid 39 will gradually increase within assembly 29. This in turn produces a slight increase in gas volume and expansion of bellows 34 until the net spring force on the actuator system becomes balanced and the switch actuator creeps to position B where actuator shoulder 19b becomes disengaged from the bottom surface of movable contact element 12. At this point, due to the fact that toggle spring 40 has a negative spring constant which increases more rapidly in the downward direction of movement than the other force rates in the system and the force of the toggle spring becomes the predominant force to drive the switch actuator and movable contact element to the fully open position E as determined by stop 17, through position C where actuator shoulder 19a initially engages the upper surfaces of element 12, and position D where the end of element arm 12b makes contact with contact element spring blade 12c and the contacts of the switch elements separate. Curve BCDE in FIGURE 2 is typical of the maximum downward forces available to move the switch actuator extension 19c in FIGURE 1 through positions B–E inclusive based upon a constant temperature for the liquid in the illustrated mechanism of a given size.

As the parts are driven from position B to E by the action of the toggle spring 40, the bellows assembly 29 creates a resistive or damping force on this movement which permits the snap type action to occur while the speed of the moving components is effectively controlled as they snap from the B to E positions. In particular, as the toggle spring and switch actuator move between these positions, they tend to run away from bellows 34 and a reduction in temperature of the vapor until it drops below that of the assembly walls. In an attempt to maintain a constant vapor pressure or pressure equalization within assembly 29, the liquid molecules at 39c in the region of 30d vaporize, causing heat transfer at that location where there is a latent heat of vaporization, which

converts liquid molecules into gas molecules. This absorbed heat is believed to come from the internal walls of region 30d. Due at least in part to the temperature differential existing between the bellows 34 and region 30d of the tube as well as the partial liquid and vapor saturation of the heat transfer fluid, region 30d is kept small and the heat transfer through it proceeds at a slow regulated rate.

It should be noted at this time that section 30c, which functions as a thermal wall barrier between heat transfer region 30d and the warmer bellows 34 assists in maintaining a temperature differential in the system.

In addition, to assure the proper temperature gradient and maximum thermal damping benefit to the present invention, a bias heater such as a $\frac{1}{2}$ watt resistor may be employed in heat exchange relation with bellows 34. This heater may be connected in circuit across terminals L₁, L₂ so that it will be energized whenever the thermostat is coupled to a suitable power source of energizing potential. This operates to super heat the vapor 39 in the bellows, to maintain saturated vapor condition near end of the tube 30, and to force condensate toward liquid 39a at 39c where excess liquid accumulates.

In order to provide contact weld-breaking action, a pre-heater in the form of a resistor, disposed between tube region 30d and bellows 34, is connected in circuit with the cycling switch elements so that it will be energized whenever elements 11, 12 are in the closed position. Should the cycling contacts 11, 12 fail to open due to sticking, the pre-heater will be energized to raise the temperature of assembly 29 without a corresponding increase in ambient temperature until the bellows expands and exerts sufficient force on the linkage to assist in opening the contacts.

Returning once again to a consideration of FIGURE 2, curve BC'D'E', it will be appreciated that forces to move the components of FIGURE 1 from B to E depend upon the rate of heat transfer to the fluid in the bellows and that by utilizing a relatively slow rate of heat transfer to and from a small surface of liquid, thermal damping resulting from the action of bellows assembly 29 can be made a major factor in controlling the speed of operation of the illustrated linkages and switch elements to produce a relatively silent snap action.

Turning now to operation of the switch elements from fully open position E to closed position A, once the ambient temperatures sensed by tube portion 30c is cooled to a predetermined value; e.g., 70° F. in the example, while the temperature gradient is kept generally instant between bellows 34 and regions 30d, the bellows 34 tends to contract until the forces on the linkage are once again balanced and the switch actuator creeps to position G (FIGURE 2) where snap action occurs to position A in a similar but inverse fashion to that already described above. During this controlled action, slow heat transfer occurs at relatively small surface region 30d, which may shift slightly from that illustrated, with condensation rather than vaporization taking place to produce the resistive force for opposing the driving force of spring 40.

Therefore, thermal damping is provided for both directions of operation which controls the velocity of the switch actuator linkage without changing the static forces needed for good snap action. In addition, the rate of heat transfer to and from the confined liquid 39a and vapor 39b mixture in assembly 29 will be the major factor in controlling the velocity, rather than friction and inertia, to produce quiet operation.

Referring now to FIGURES 3 through 8 inclusive, in which certain like elements are indicated by like reference numerals, there is shown a thermostat generally identified at 50 suitable for the control of domestic electric heating installations. Thermostat 50 comprises a base 51 having a cavity 52 formed in its upper surface. A switch box cover member 53 engages the bottom surface of base 51 and has a cavity 54 formed therein in which

the stationary and movable contacts 11, 12 are positioned. Stationary contact 11 is mounted on a bus bar element 55 to which a first load terminal 56 is connected. Movable contact 12 is mounted on a resilient contact strip 57 which is secured to a bus bar element 58 to which a first line terminal 59 is connected. A suitable adjusting screw 60 is provided for adjusting the contact pressure of the contacts 11, 12 in their closed positions.

Another pair of stationary and movable contacts 62 are provided with the stationary contact being mounted on a bus bar element 63 to which the other load terminal 64 is connected. The movable contact is mounted on resilient contact strip 65 which is connected to a bus bar element 66 to which the other line contact 67 is connected. A barrier wall 68 is formed on the base member 51 and extends into the cavity 54 in the switch box cover member 53 electrically to isolate contact elements 11, 12, which are the temperature responsive cycling contacts, and contacts 62 which provide an additional manual "Off" position as will be hereinafter more fully described. Input terminals 59, 67 may be coupled to a suitable source of power by leads 69, 70 and load terminals 56, 64 may be connected to a load to be controlled by suitable leads 72, 73.

Cam follower member 22 is positioned in recess 52 in the base member 51 with its end 23 pivotally seated in step 74 and its other end 25 cooperatively engaging cam 26 which is operated by shaft 27 and temperature setting control knob 28. Coil or range spring 20 α engages cam follower member 22 as shown, the coil spring being a part of spring and bearing assembly 20.

A toggle spring mounting member 75 is provided having a pair of projections 76, 77 which define a slot 78 therebetween. Toggle spring 40, having a net negative spring constant, is positioned in the slot 78 with its end 43 engaging member 44 which has its side edges seated in slot 81 formed in the inner facing surfaces of the projections 76, 77. Differential adjusting screw 47 engages the member 44, as shown.

Switch box cover member 53 and base 51 are held in assembled position by screws 79, 80, 82, screws 80 and 82 also holding the toggle spring mounting member 75 in assembled position on the base member 51. A generally U-shaped mounting member 83 is provided having a flange portion 84 secured to base member 51 by suitable screws 85 and having its side arms 86, 87 retained by tabs 88, 89 engaging suitable notches in the projections 77, 76 of the member 75. Side arms 86, 87 of the mounting member 83 have suitable notches 90 formed therein which pivotally seat pivot ears 92, 93 of the operating arm section 13 of the switch actuating linkage. Projections 76, 77 of member 75 have a transverse slot 94 formed therein which define the stops 17, 18. End 16 of the operating arm section 13 extends into the slot 94 and engages end 42 of the toggle spring 40. An actuating rod section 95 has its upper end 96 seated in a suitable opening in the operating arm section 13 and its lower end 97 depending downwardly through openings 98, 99 in the base member 51 and bus element 55 to engage contact strip 57 upon the movable switch contact element 12 is mounted.

In order to provide a manual "Off" position for the thermostat in one extreme position of the control knob 28, cam 26 has another cam surface formed on its bottom side cooperatively engaging an arm 100 which in turn engages a pair of pins 102, 103 which respectively extend downwardly through openings 104 in the base member 51. Pins 102, 103 are normally biased upwardly out of engagement with the respective contact strips 57, 65 by means of suitable springs 105. However, in one extreme position of control knob 28 and cam 26, member 100 is actuated by the cam 26 so as to depress pins 102, 103 against the springs 105 so that their lower ends 106 respectively engage the contact strips 57, 65 positively to open the cycling contact elements 11, 12 and the contacts 62. As soon as the control knob 20 is moved away

from its extreme position, cam 26 permits the member 100 to move upwardly under the influence of springs 105, thus moving the pins 102, 103 out of engagement with the respective contact strips 57, 65, thereby permitting the contact elements 11, 12 and contact 62 to open.

A spring seat member 107 is provided engaging the upper end of spring 20 α and having a threaded stud 108 connected thereto which engages the bottom wall 32 of the bellows assembly 29. A bearing member 109 is provided having an upper end 110 which likewise engages bottom wall 32 of bellows assembly 29 and which has a pair of ears 112, 113 respectively depending therefrom and respectively engaging knife edges 114, 115 formed on the operating arm 113. Bellows assembly 29 is supported between the side arms 86, 87 of the mounting member 83 by means of a transverse member 116 having tabs 117 engaging suitable slots 118 in the side arms 86, 87, the member 35 having an outer cylindrical portion 119 surrounding bellows 34 and having tabs 120 engaging suitable slots in member 116. Suitable tabs 122 on the side arms 86, 87 engage the annular portion 36 of the bellows assembly member 35, as shown.

A mounting plate 123 is provided secured at one end to base 51 by means of screw 79 and at its other end by portions 124 which engage suitable notches in the member 75. Mounting plate 123 has suitable tab portions 125, 126 formed thereon having screws 127, 128 seated therein for mounting the thermostat 50 in a conventional electrical outlet box. A cover member 129 is provided having end portions 130, 132 respectively mounted on ends 133, 134 of the mounting plate 123 with a snap-on relationship. Cover member 129 has an opening 135 formed therein through which the control shaft 27 extends, as shown. Cover member 129 is open at its opposite ends 136, 137, thereby fully to expose the bellows assembly 29 to the ambient and radiant heat. A metallic heat-conducting fin 138 is mounted on cover member 129 and extends outwardly therefrom, as shown.

The temperature sensing tube 30 has its extreme sealed end 139 engaging the underside of fin 138. Pre-heating resistor 140 is provided held in engagement with intermediate portion 142 of the tube 30 by a suitable clip 143. Resistor 140 is coupled across the load bus elements 55, 63 and is thus energized whenever both the cycling contact elements 11, 12 and the manual "Off" contacts 62 are closed and provides the contact weld-breaking action explained previously.

Bias heater resistor 144 is provided next to stationary wall 36 in the vicinity of bellows 34, the resistor having its ends connected across the input bus elements 58, 66. Thus, bias heater resistor 144 is energized at all times when the thermostat 50 is coupled to a suitable power source of energizing potential. The bias heater resistor 144 influences the bellows assembly 29 so as to superheat the vapor in the bellows 34 and tube 30 in the manner already outlined in connection with FIGURE 1. The bias heater resistor 144 thus functions to maintain a temperature gradient from the bellows 34 to the end 139 of the tube 30, this gradient assuring a superheat condition in the bellows and a saturated vapor condition at the end of the tube with the result that excess liquid in the assembly always accumulates at the coldest point, as shown at 141 in FIGURE 3, so that the vapor pressure in the assembly is always controlled at this point where there is always both saturated liquid and saturated vapor.

While the bias heat resistor 144 has been shown located next to bellows 34 for best heat exchange results, it will be understood that it may be located elsewhere in the device so long as it influences the bellows assembly 29. It will be observed that the fin 138 also functions as a heat sink to assure a proper temperature gradient from the bellows to the end of the tube, the bias resistor 144 establishing one end of the gradient and the fin 138 the other.

Since thermostat device 50 operates in a similar man-

ner to device 10 discussed above in connection with the mechanism of FIGURE 1, no further explanation will be set out here concerning its operation.

It will thus be seen that the velocity of movement of the operating arm section 13 during the snap is controlled by the rate at which the molecules of gas either enter or leave the bellows 34, this rate depending upon the regulated rate of condensation or vaporization of the gas near the oldest part of the tube, which in turn depends upon the rate of heat transfer to and from the gas in the bellows assembly. Thus, in accordance with the invention, the rate of heat transfer to and from the saturated vapor and liquid mixture in the bellows assembly is the major factor controlling the velocity of the snap-action mechanism. In addition, the device is relatively inexpensive to produce, relatively simple in construction while it attains the improved operating characteristics.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention. For instance, when incorporating the thermostat device to control cooling equipment, the cycling contacts should be closed during the cooling cycle rather than in the open position. Further, the actuator may be used to control a second set of contacts. Extension 19c in FIGURE 1 would be appropriate for this function. I, therefore, aim in the following claims to cover all such equivalent variations as fall within the true spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A condition responsive electric switch mechanism comprising switch means having open and closed switch positions; switch actuating means movable between first and second positions in actuating relation with said switch means for operating said switch means between said open and closed switch positions; spring means connected to said switch actuating means for transferring said switch means between said open and closed switch positions; and temperature responsive means, including a sealed expansible assembly connected to said switch actuating means, for producing a thermal damping condition at preselected temperatures to cause the creation of resistive forces acting on said switch actuating means in opposition to forces of the spring means as said switch actuating means is operated at least between said first and second positions, thereby controlling the velocity of said switch actuating means as it travels from said first to said second positions.

2. The mechanism of claim 1 in which the temperature responsive means has a predetermined temperature responsive range and includes an expansible chamber connected to said switch actuating means, a hollow temperature sensing section in communication with said expansible chamber, and fluid initially charged in said expansible assembly having a temperature exceeding the temperature responsive range and being a partially saturated vapor and partially saturated liquid in the temperature responsive range, with at least part of the liquid being disposed in said temperature sensing section; said temperature sensing section including a heat transfer region in contact with said liquid and adjacent vapor during vaporization and condensation of the fluid at that location; said expansible chamber and heat transfer region having a temperature differential therebetween, with the chamber having the higher temperature whereby the rate of heat transfer to and from the confined fluid at said region is a factor in controlling the velocity of said switch actuating means during its travel between said first and second positions.

3. The mechanism of claim 2 having heater means mounted in heat exchange relation with said temperature responsive means for forcing condensate of the vapor from the expansible chamber into the temperature sensing section and for producing a superheated condition at least part of the time in the expansible chamber.

4. The mechanism of claim 2 in which heating means is mounted in heat exchange relation with said expansible assembly to increase the vapor pressure therein.

5. The mechanism of claim 2 having means disposed between said temperature sensing section and expansible chamber and being formed of material having a lower thermal conductivity than said temperature sensing section for maintaining the desired temperature differential between said expansible chamber and temperature sensing section.

6. The mechanism of claim 2 in which heater means is mounted in heat transfer relation with said temperature sensing section and is connected in circuit with said switch means such that said heater means is energized whenever said switch means is in the closed switch position for raising the temperature within said temperature sensing section without causing a corresponding increase in ambient temperature thereby producing forces to act on the switch means and insure movement thereof to the open switch position.

7. A temperature responsive device having switch contact elements movable between open and closed positions; the device comprising a switch actuating member movable between first and second positions for operating the contact elements between the open and closed positions; first spring means mounted in the device for urging said member toward one of its positions; second spring means, having a net negative spring constant, connected to said switch actuating member for driving said switch actuating member rapidly between said first and second positions; and temperature responsive means including a sealed expansible assembly having an expansible bellows mounted in force-applying relation to the switch actuating member, the bellows and a temperature sensing tube being in communication with one another; said assembly having a fluid mixture of vapor and liquid in a predetermined temperature range, with said bellows being at a higher temperature than said tube to provide a temperature differential, and with said tube having a heat transfer region to produce thermal damping of said member for creating resistive forces acting in opposition to the force of said second spring means on said switch actuating member as said member is driven by said second spring means between said first and second positions, whereby the rate of speed for said switch actuating member is effectively controlled between said first and second positions.

8. The device of claim 7 having means mounted in the vicinity of said temperature sensing section in the device for maintaining the temperature differential between said bellows and heat transfer region.

9. A temperature responsive device having switch contact elements movable between open and closed positions; the device comprising an actuating member movable between first and second positions for operating the contact elements between the open and closed positions; means connected to said switch actuating member for driving said switch actuating member between said first and second positions; and temperature responsive means mounted in operative relation relative to the driving means and including a sealed expansible assembly having an expansible chamber and a temperature sensing element in communication with one another; said assembly having a fluid including vapor and liquid in a predetermined temperature range and a localized heat exchange region, with at least part of the liquid and vapor being disposed in contact with said region; said expansible assembly further having a temperature gradient between said region and another portion thereof such that during a change in volume of said expansible chamber in response to a change in temperature sensed by said temperature sensing element, heat exchange to and from said fluid as the fluid respectively vaporizes and condenses primarily occurs at said localized heat exchange region and the temperature gradient is maintained whereby thermal damping of said member is produced to create resistive forces in opposition to the

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force of the driving means as said member is being driven between said first and second position to effectively control the rate of speed of said actuating member between said first and second positions.

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