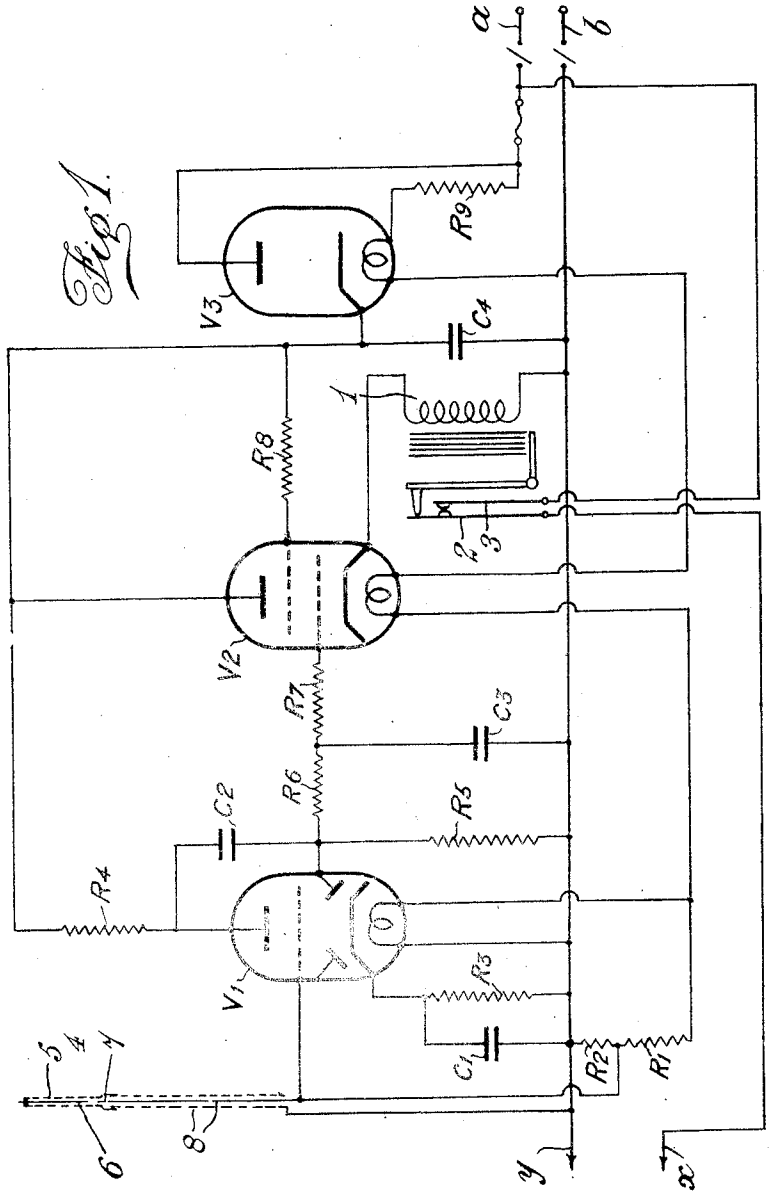
Aug. 12, 1952 H. B. W. HOLT 2,607,005

THERMIONIC TUBE CONTROL SYSTEM

Filed May 7, 1948 3 Sheets-Sheet 1

Fig. 1.



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THERMIONIC TUBE CONTROL SYSTEM

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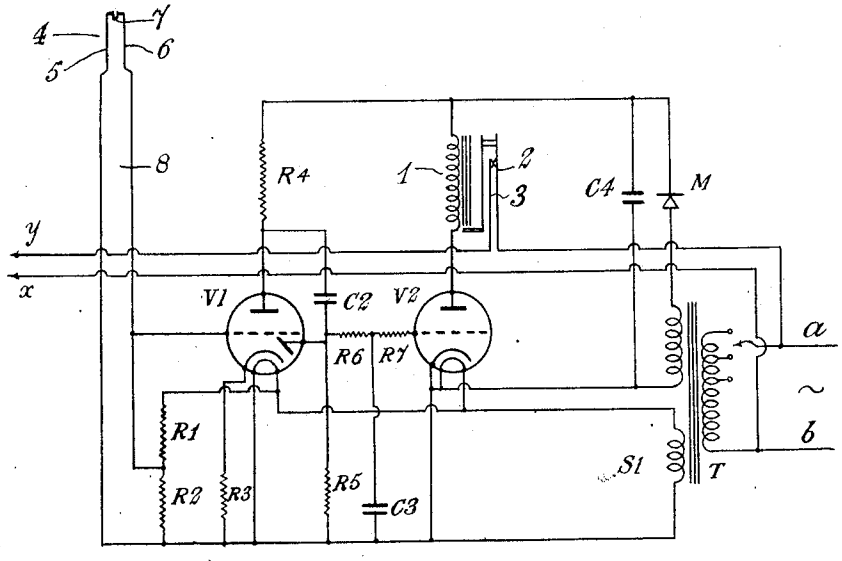


Fig. 2.

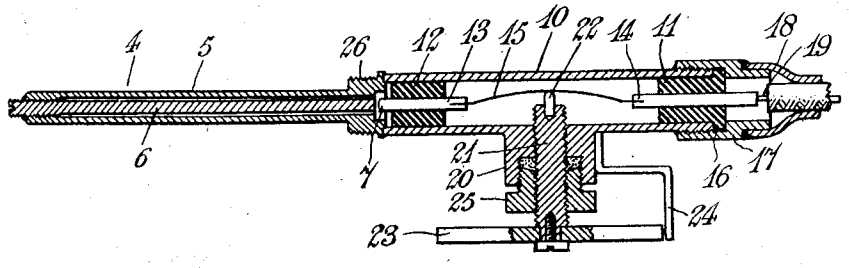


Fig. 3.

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THERMIONIC TUBE CONTROL SYSTEM

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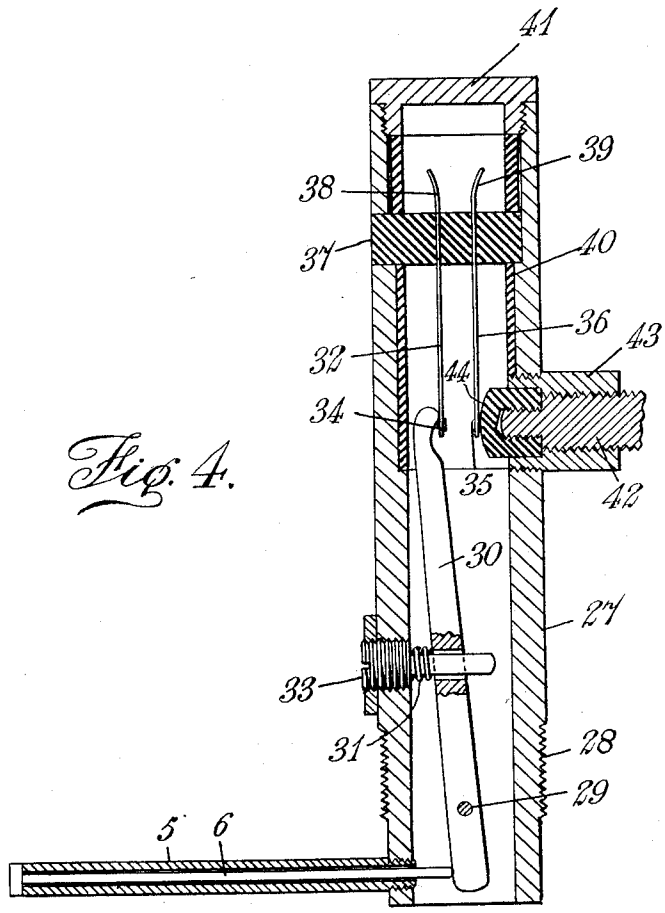


Fig. 4.

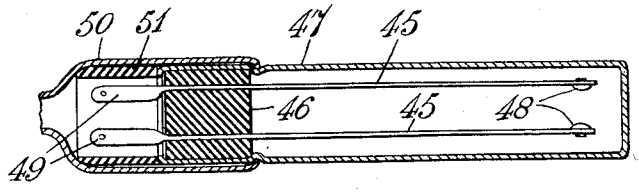


Fig. 5.

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UNITED STATES PATENT OFFICE

2,607,005

THERMIONIC TUBE CONTROL SYSTEM

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Application May 7, 1948, Serial No. 25,583
In Great Britain October 30, 1946

6 Claims. (Cl. 250—27)

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The invention relates to improvements in means for controlling temperatures of the type in which thermionic valve amplifying means are employed for controlling temperatures to a fine degree of accuracy. The chief object of the present invention is to provide temperature controlling means with thermosensitive switches whose dimensions can be considerably smaller than existing types and in which the switch contacts need not be sealed in evacuated envelopes to ensure stable performance, and to provide means whereby such small sensitive switches can be connected to the valve amplifying means by thin electrical conductors of any length, without producing harmful effects in the amplifier by reason of voltages which may be induced in such long leads from external magnetic fields.

With the amplifying means about to be described, the movements of the contacts actuated by bimetal strips or by rod and tube type bimetal elements which are required to operate the valve amplifier are extremely small, being of the order of .000002". For this reason, bimetal strips no longer than .25", or tube and rod elements no longer than 1" and $\frac{1}{16}$" dia. can be used to obtain temperature control to within 0.1° C.

Since such small movements are sufficient to actuate the amplifier special range control devices are required so that small enough movements of the adjustable contacts in the thermosensitive elements can be easily made by manual operation of a dial or knob.

In order that such small movements of contacts in the thermo-sensitive switches can be successfully used to actuate the amplifier consistently, it is necessary that no arcing should take place at those contacts and that dust particles in the vicinity of the contacts should not become electrically charged and adhere to the contact faces. It is also important that slight variations of the contact resistance should not affect the behaviour of the amplifier.

To prevent arcing it is necessary to arrange that the current broken by the contacts in the thermosensitive elements shall be very small, say, 0.05 milliamp. or less. To prevent the charging of dust particles it is necessary that the voltage across the contacts be kept low and alternating, 0.5 volt R. M. S. is found to be a satisfactory value. Since it is desired to connect the sensitive element to the amplifier by leads that may be very long, the frequency of alternation of the voltage must be kept at a value low enough to prevent the self capacity of the leads from affecting the operation of the amplifier, and the frequency should be such that it can be easily and cheaply generated.

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Heretofore in means for controlling temperatures of the type referred to the contacts of the sensitive element are arranged in series with the grid circuits of the valves but in the present invention these contacts are arranged to connect the grid of the input valve to earth when closed and an amplifying valve is provided between the valve controlling the heating circuit and the thermosensitive switch so that not only the current in the thermostat circuit can be kept low but the voltage in that circuit need be only a fraction of a volt.

According to the present invention the means for controlling temperatures of the type having a sensitive element and valve amplifying means controlling a heater through the medium of a relay includes a potentiometer consisting of a pair of resistances in parallel with the heater of the valve and is characterised in that the thermosensitive switch is so connected in the circuit that when its temperature is raised one of the resistances of the potentiometer is short circuited and the grid of the input valve of the said amplifying means is connected to earth, the signal applied to the grid of the valve when the contacts of the thermo-sensitive switch are open being amplified and rectified and the negative D. C. potential thus produced cutting off the cathode current to a second valve the cathode or anode circuit of this latter having the relay and is further characterised in that an amplifying valve is provided between the valve controlling the heating circuit and the sensitive element.

The invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a diagram showing one form of amplifying means for controlling temperatures;

Fig. 2 shows in diagram an alternative form of amplifying means in which a transformer and metal rectifier are employed;

Fig. 3 is a sectional elevation showing one constructional form of an adjustable thermo-sensitive device to provide a make and break suitable for use in thermo-plastic moulding machines;

Fig. 4 is a similar view of a modified construction and

Fig. 5 is a longitudinal section of a thermosensitive element suitable for controlling for instance room temperatures.

As shown in Figure 1 one form of the apparatus for remotely controlling temperatures comprises a sensitive element 4 conveniently consisting of a tubular member 5 and a rod member 6 secured at

one end and adapted to engage a contact member 7 and leads 8 connecting the tubular member 5 and the contact member 7 to valve amplifying means adapted to actuate a relay 1 controlling contacts 2 and 3 of a switch of a heating device of any suitable form and for any desired purpose. These contacts 2 and 3 control the current supply from 50 cycle A. C. mains *a* and *b* and the heater connected to the leads *x* and *v*. The circuit arrangement includes three valves V1, V2 and V3. The sensitive element 4 is of small size and may take several forms to be hereinafter described in more detail. In one form the tubular member 5 is constructed of metal having a low co-efficient of expansion and secured at one end of this member 5 is the rod member 6 having a high co-efficient of expansion. The free outer end of the rod 6 is adapted on expansion to contact the contact member 7 mounted in an extension of the tubular member. Conveniently this contact member 7 is connected to an inner conductor of a flexible single core screened cable and the outer coil of the cable is connected to the rod 6 through the medium of its tubular casing 5. Obviously the remote connection to the amplifying means may be effected by a two core screened or unscreened cable or a single core unscreened cable using earth connection as the return. The end of the rod 6 is formed with a flat face ground and polished and the end of the contact member 7 is preferably ground spherical and polished and the arrangement is such that an extremely small increase or decrease in the length of the rod member 6 will make and break a current of a few micro-amperes at a low voltage such as 0.5 volt without sparking or damage to the contact faces.

The operation of the amplifier shown in this diagram is as follows:

The cathode heaters of the valves are connected in series with the resistance R9 and to the mains *a* and *b*, one end of the heater of the valve V1 being joined to the earthed side *b* of the main. In parallel with the heater of the valve V1 is connected a potentiometer arrangement consisting of resistances R1 and R2. The sensitive element 4 is so connected that when its temperature is raised to the predetermined value, R2 is short circuited and the grid of the valve V1 is connected to earth. Before the sensitive element is heated it will be seen that a 50 cycle A. C. signal is applied to the grid of the valve V1. This signal is amplified and the amplified signal at the anode of the valve V1 is supplied to the diode anode in the envelope of the valve V1 by the coupling arrangement R4 and C2. The resistance R3 and condenser C1 are the bias resistance and decoupling condenser for the valve V1. The amplified signal applied to the diode anode is rectified by the diode the resistance R5 being its load resistance, and the negative D. C. potential thus produced between the diode anode and the cathode is applied through the filter network R6, R7, and C3 to the grid of the valve V2. This negative potential is sufficiently large to cut off completely the cathode current of the valve V2. V2 is a valve of such a type that its cathode current with normal bias is of the order of 40–50 milliamperes which current is sufficient to operate the relay 1 included in the cathode circuit of the valve V2. This relay 1 is so arranged that with no current in its winding the contacts 2 and 3 are closed and since these contacts are connected between the mains *a* and *b* and the leads *x* and *y* to the heating device, the temperature of which is desired to be controlled, it will be seen that until the expanding rod 6 in the sensitive element 4 has short circuited the grid and cathode of the valve V1 the relay contacts remain closed, and heat is generated in the heating device. When the temperature reaches the value at which control is desired, the expanding rod 6 in the sensitive element 4 makes contact with the member 7 and short circuits the grid and cathode of the valve V1 and no signal is applied to the diode. The grid of the valve V2 is thus deprived of the negative bias which was preventing flow of cathode current and so the cathode current of the valve V2 rises until the coil of the relay 1 is sufficiently energised to open the contacts 2 and 3 of the heater circuit. Since the relay coil is in the cathode circuit of the valve V2 its resistance is made to provide the normal operating bias for the valve and prevents the cathode current from becoming large enough to damage the valve. As the heater cools down the sensitive element contacts 6 and 7 open and in turn the relay contacts 2 and 3 close and further heat is generated by the heating device. The cycle repeats itself and so the temperature of the heating device is controlled. The resistance R8 is not required for some types of valves. The valve V3 is purely a rectifier providing D. C. anode current for the other valves, C4 being the reservoir condenser for the valve V3. Because of the low input impedance of the valve V1 the connection 8 between the sensitive element 4 and the amplifier can be of any length and unscreened without any undesirable effects being produced by the proximity of A. C. mains cables to the sensitive element lead.

In the form shown in the diagram, Figure 1, universal valves are used for the sake of cheapness, but the amplifier could be constructed to operate using a mains transformer and A. C. mains valves, such an alternative amplifier of lower consumption and arranged to isolate the sensitive element from the mains *ab* will now be described with reference to Fig. 2 of the accompanying drawings in which the same reference numerals are employed for similar parts:

In this diagram the thermo-sensitive element 4 is depicted as a pair of elements 5 and 6 of bimetal type to provide a make and break contact 7 instead of members having different co-efficients of expansion.

This circuit also consists of the valves V1, and V2 which together with all the resistors and condensers except C4 constitute the operative parts of the amplifier. The main transformer T, a metal rectifier M and a capacitor C4, together constitute the power supply for the valves. The valve V1 in this circuit is a diode triode in which the triode section operates as a normal low frequency amplifier, and the resistance capacity is coupled to the diode section. The diode section operates in conjunction with the resistance R5 as a half wave rectifier, the D. C. output of which is smoothed by the filter circuit R6, R7 and C3.

To consider the circuit operation let us ignore to begin with the resistances R1 and R2. If a low frequency alternating voltage or L. F. signal from any source is applied between the grid of V1 and earth, amplified voltage appears at the anode of V1 is transferred via C2 to the diode section anode where it is rectified and the smoothed D. C. negative potential thus produced is applied to the grid of V2. In the anode circuit of V2 is connected the operating coil of the

relay, the contacts of which are used to switch on or off the heater circuit.

It will be clear that if a signal of sufficiently large amplitude from any source is applied between the grid of the valve V1 and earth, the valve V2 will be biased negatively at its grid and the anode current will be cut off, thus de-energising the relay coil. If, however, the valve V1 is deprived of the signal by some means, the grid of the valve V2 will be unbiased and anode current will flow, thus energising the relay coil. Thus the thermo-sensitive switch 4 arranged to deprive the valve V1 of its signal when a predetermined temperature is reached will in turn energise the relay coil 1 and open the relay contacts 2 and 3 cutting off the energy supply to the object or chamber being controlled.

Let us now consider the method by which a suitable signal can be generated and the contacts of a suitable thermo-sensitive switch can be made to supply or deprive the grid of the valve V1 of the signal. It has been previously shown that a suitable signal should be of amplitude around 0.5 volt R. M. S. and of a convenient low frequency. Such a signal is derived from the arrangement of the resistances R1 and R2. These two resistances are connected in series across the heater winding of the mains transformer which is wound to supply 6 volts to the cathode heaters of the valves. One end of this winding is connected to the earth line and the junction of the resistances R1 and R2 is connected to the grid of V1. The other end of R2 is also connected to the earth line so that if the valves of R1 and R2 are chosen so that

$$\frac{R1}{R2}=\frac{5.5}{0.5}$$

a 50 cycle voltage of .5 volt R. M. S. will be applied between grid of the valve V1 and earth. If leads are taken from the grid of the valve V1 and earth and connected to the contacts of a thermosensitive switch in such a way that closing of these contacts will short circuit R2, the valve V1 can be deprived of the signal. In order to limit the current that will flow in the contact circuit, R1 should be as large as possible and since .05 milliamp. is a suitable value for this current the value of R1 is found from the relation

$$.05=\frac{6000}{R1}$$

from which R1 is calculated to be 120,000 ohms. From the previous relation R2 is found to be 10,909 ohms. By increasing the values of R1 and R2 in the correction proportion the signal voltage can be maintained at .5 and the current reduced to a lower value. It is convenient, however, to keep R2 as small as possible in order that it will swamp any voltages which may be induced in the leads connecting the thermosensitive switch to the grid of V1, if those leads are of considerable length and lie in close proximity to and parallel with A. C. supply mains or other source of alternating magnetic fields.

It will be appreciated that it is not necessary to deprive the grid of valve V1 of all the signal volts in order to reduce the bias on the grid of V2 to a sufficiently low value to allow enough anode current to pass to operate the relay. For this reason the contact resistance of the thermosensitive switch contacts and the resistances of the leads connecting the switch to the valve V1 need not be zero ohms.

It is possible therefore for the length of leads to be considerable and the contact resistance can vary within a few ohms without upsetting the operation or accuracy of the control.

It will be obvious that since the operation of the device consists in making and breaking a pair of small contacts by the use of heat the sensitive element may take various forms for different purposes and if desired they may be made adjustable.

In the apparatus above described the sensitive elements are made preset to control any desired temperature but if desired a range control device may be fitted to enable the user to select any temperature within a reasonably long range. One form of range control device is shown in Fig. 3. As previously described in the first arrangement the thermo-sensitive switch 4 comprises the tubular member 5 and the rod member 6 secured at one end and adapted to engage the contact member 7. The range control means are conveniently fitted between this sensitive element 4 and the leads 8 leading to the amplifying means and comprises a metallic tube 10 in the end of which are fitted insulating bushings 11 and 12. The bushing 11 at one end is secured and the bushing 12 at the other end is free to slide. The bushing 12 has a short metal rod 13 secured through its centre and this rod 13 provides the contact 7. The other bushing 11 has also secured therein a rod 14 and the inner or opposed ends of these rods 13 and 14 are connected together by a piece of flat steel spring 15. Conveniently the fixed bushing 11 is formed with a flange 16 on the outer end and held against the tube 10 by a union 17 screwed on the tube 10. This union connects a cable screen 18 to the tube 10 and is soldered or otherwise secured to provide one of the leads. An inner conductor 19 of the cable 18 provides the other lead and is connected to the outer rod 14 carrying the spring 15 so that the other rod 13 provides the contact 7 previously mentioned. Thus the thermo-sensitive switch is electrically connected to complete a circuit with the amplifying means when the end of the rod member 6 of the sensitive element contacts with the rod 13. Engaging in a fine pitch thread cut in a boss 20 extending at right angles in the wall of the tube 10 is a screw 21 fitted with an insulating tip 22 which presses on the centre of the flat spring 15. On the outer end of the screw 21 is mounted a manipulating disc 23 conveniently in the form of a dial graduated in degrees of temperature to be read against a fixed pointer or arm 24 mounted on the boss 20. The boss 20 is fitted with a gasket 25 suitably packed so as to render the range control device watertight. The contact face of the rod 6 is preferably ground flat polished and plated and the contact face 7 is ground spherical polished and plated as in the previous construction so as to provide for minute actuation. The enlarged end of the tubular member 5 is threaded at 26 for screwing for instance in a cylinder of a thermo-plastic moulding machine. In operation it will be seen that by turning the screw 21 to indicate the temperature desired and shown on the indicator the flat spring 15 will be bowed and the sliding insulating bushing 12 and rod 13 forming the contact 7 will be drawn up the tube 10. Since the spring 15 is deflected through a small angle only, a considerable movement of the screw 21 produces a small movement of the contact 7 and thus the make and break gap between the contact 7 and

the high expansion alloy rod 6 can be adjusted minutely. Obviously any other suitable means such as cam devices may be employed for bowing the spring 15.

In a modified construction as shown in Fig. 4 the rod 6 is of low expansion alloy and is secured at its outer end in a sleeve or tubular member 5 of high expansion alloy. This member 5 is secured at right angles in the end of a tube 27 carrying the range control means. This construction is particularly suitable for use in a thermoplastic moulding machine and the tube 27 is threaded at 28 for this purpose so that the sensitive element will lie in alignment with and in an aperture formed in the cylinder wall of the machine. Within the tube 27 is fulcrumed at 29 a lever 30 the lower end of which is adapted to contact with the end of the rod 6. This lever 30 is pressed by a coiled spring 31 to engage a spring strip 32. The spring 31 is adjustable and conveniently mounted on an adjusting screw 33 threaded into the side of the tube 27. The spring strip 32 is fitted with a contact 34 to co-operate with another contact 35 of a further spring strip 36. The spring strips 32 and 36 are mounted in an insulating plate 37 fitted in the tube 27 and the ends of these strips provide tags 38 and 39 respectively for the connection of the leads not shown to the amplifying means. The tube 27 is fitted with an insulating sleeve 40 and with a closure cap 41. The range control means comprises a control spindle 42 threaded into a boss 43 on the side of the tube 27. This spindle 42 is fitted with an insulating button 44 to contact with the strip 36 whereby the distance between the contacts 34 and 35 can be adjusted. The outer end of this spindle 42 is fitted with a suitable calibrated dial such as that described in the previous construction and the operation to vary the range of temperature at which the device will operate will be readily understood.

Figure 5 shows a further form of a thermo-sensitive element for air temperature control. In this construction a pair of bimetal strips 45 are mounted in an insulating block 46 fitted in the end of a protecting sleeve 47 preferably formed of copper. These strips 45 are fitted with co-operating contacts 48 and with terminal tags 49 for connection with the leads not shown to the amplifying means. The sleeve 47 is provided with a terminal cover 50 fitted with an insulating sleeve 51. It will be understood that when the strips 45 are actuated by the surrounding temperature to close the contacts 48 the amplifying means will be brought into operation to actuate the relay as previously described. If desired means such as an adjusting screw may be provided to vary the distance between the contacts for temperature range control.

What I claim is:

1. Controlling means operable in response to temperature changes comprising an electronic circuit including a thermo-sensitive switch, a plurality of valves and a load device, the first valve being of the diodetriode type and having its grid connected to one element of the switch, its cathode connected to ground and its plate connected to both the power source through a load resistor, and to its diode plate by means of a condenser, the second valve being of the triode type having its grid connected to the diode of the first valve, said connection including a filter network comprising a pair of resistors in series with their midpoint connected to ground through a condenser, the cathode of the second valve being connected to ground and the plate to the power source with the load device interposed therein, a pair of resistors in series and connected in parallel with the cathode heaters of the valves, the midpoint of the last named resistors being connected to the grid of the first valve, whereby when the switch is open, the signal applied to the first valve is amplified and rectified and applied to the grid of the second valve biasing the second valve to limit the current therethrough to a value below that required to operate the load device, and when the switch is closed by thermal action, the grid of the first valve is connected to ground, thus removing the signal from the grid of the second valve allowing the necessary current therethrough to operate the load device.

2. Controlling means as claimed in claim 1 wherein the thermo-sensitive switch is in the form of a tubular member having a low coefficient of expansion, a rod member having a high coefficient of expansion carried within said tubular member, and a contact member connected with the first valve, said rod member being held in spaced relationship to said contact member below the adjusted temperature of said switch.

3. Controlling means as claimed in claim 1 wherein the thermo-sensitive switch comprises a tubular member carrying a rod, each having different coefficients of expansion, a housing upon which said tubular member and rod are mounted, a flat steel spring in said housing having one end connected to a contact member slidably mounted in an insulating block in the housing and its other end connected to a line leading to the first valve, the other line being connected to the tubular member, said slidable contact being disposed adjacent but out of contact with said rod except at normal temperature, and means mounted on the housing for contacting the spring intermediate its length to bow it and thereby adjust its length to vary the normal temperature position of said slidable contact relative to said rod.

4. Controlling means as claimed in claim 3 wherein the means for adjusting the length of the spring comprises a manually operable finely threaded member carried by the housing at right angles to said spring and a calibrated dial mounted on said threaded member by means of which it may be rotated.

5. Controlling means as claimed in claim 1 wherein the thermo-sensitive switch comprises a tubular member having a high coefficient of expansion, a rod member of low coefficient of expansion carried by said tubular member, a tubular housing carrying said tubular member and being at right angles thereto, a spring pressed lever fulcrumed in the tubular housing and adapted to be engaged at one end by said rod, and a pair of spring strips mounted within said tubular housing having cooperating contacts and being connected to said first valve, one of said strips adapted to be engaged by the other end of said lever, and adjusting means carried by the tubular housing and engaging the other of said strips whereby the distance between the contacts can be regulated.

6. Controlling means according to claim 5 wherein an adjusting screw is carried by said housing and carries a coiled spring for engaging said lever whereby pressure on the lever may be adjusted.

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