

UNITED STATES PATENT OFFICE

2,313,147

TEMPERATURE CONTROLLING DEVICE

James Hoekstra, Chicago, Ill., assignor to Universal Oil Products Company, Chicago, Ill., a corporation of Delaware

Application July 14, 1941, Serial No. 402,391

5 Claims. (Cl. 236—78)

This invention relates to improvements in means for controlling temperatures, and refers specifically to an electrical system for raising or lowering the temperature of a furnace, still or like apparatus in response to variations in temperature in said apparatus as detected by a thermocouple positioned in the apparatus.

Because of their small size, accurate reproducibility and other desirable properties, thermocouples are widely used as temperature-sensitive devices in the measurement and control of temperatures, especially high temperatures. However, the devices generally used with thermocouples for converting the variations of electromotive force of the thermocouples to physical actuations by which temperature control is actually effected are costly and delicate.

My present invention contemplates a device designed to control the operation of heating or cooling devices in response to changes in electromotive force of a thermocouple connected therewith, the device being characterized in that it comprises standard electrical parts such as resistances, capacitors, electronic devices and the like, and contains no delicate moving parts such as galvanometer suspensions or the like.

The objects and advantages of my invention will be apparent from the accompanying drawing and following detailed description.

The single drawing is a schematic, partially diagrammatic, view of my system for controlling temperatures.

In view of the fact that standard units such as power packs, oscillators and amplifiers may be employed with my invention, and that such devices individually are available in many modified forms, for purposes of clarity and simplicity these devices will not be described in detail, but will merely be referred to in terms of their function since their varied forms are well known to the art, and the operation of my device is not dependent upon any specific form of such units.

Referring in detail to the drawing, 1 indicates a conventional power pack, designated PP which may be connected, as at 2 to a source of alternating current, for instance, the usual 110 volt or 220 volt house current. The unit 1 is grounded as at 3. From the power pack 1 leads 4 may be drawn which carry low voltage current for the heaters of various electronic tubes which are employed in the system. Leads 5 drawn from the power pack 1 supply plate voltage for various electronic tubes used in the system. Leads 6 may supply filament or heater current to a power amplifier tube, if such is employed and leads 7

supply relatively high plate voltage for such amplifier tube.

The unit 1 may, of course, comprise a power transformer with accompanying rectifier tube or tubes and appropriate filters, or, if desired, the various plate and heater currents may be supplied from any other source of direct current of appropriate voltage.

The unit 8 comprises a generator of low voltage alternating current and may conveniently take the form of an oscillator of the electronic tube type which generates an oscillating low voltage current of about 1000 cycles per second. Of course, with a suitable change of constants of the system other frequencies can be employed, since the function of the unit 1, as will be hereinafter described, is merely to superimpose an alternating electromotive force upon the direct current component set up by a thermocouple.

If an electronic oscillator is employed, the heater current can be supplied through leads 9 which connect with leads 4 and the plate supply may be drawn from one of the leads 5, the cathode of the electronic oscillator tube being grounded at 10.

A thermocouple 11 is employed as a temperature sensitive device, one arm of the thermocouple being connected to a potentiometer 12 through the variable contact 13. The potentiometer 12 is grounded, as at 14, and carries a battery 12 or other source of direct current electromotive force, the battery being so connected as to normally render the thermocouple negative when no electromotive force is generated therein.

An electronic tube 15, such as the conventional 6SQ7 (duodiode high-mu triode) is connected into the system, the heater current being obtained through leads 16 which connect with the leads 4, and the cathode being connected through lead 17 to lead 18 which, in turn, connects with the positive side of the battery 12'. The diode plates and control grid of the tube 15 are connected together and are, in turn, connected, through the resistances 19 and 20, to the normally positive side of the thermocouple 11. A lead 21, carrying resistance 22 connects the oscillator 8 to a point, as at X, intermediate resistances 19 and 20. One of the plate current leads 5 connects through resistance 23 to the normally positive side of the thermocouple 11, and lead 5 also connects with the plate of tube 15 through resistances 24 and 25, the plate connecting through resistance 25 and condenser 26 to the cathode of the tube.

In operation, the thermocouple 11 is inserted in the furnace, still or other device whose tempera-

ture is to be controlled. For a predetermined temperature a predetermined electromotive force will be set up at the thermocouple terminals. By an appropriate setting of the arm 13 this electromotive force can be balanced so that there will be no direct current potential at the point X. If the temperature is slightly below the adjusted temperature, the thermocouple electromotive force will be less than that of the potentiometer 12 and the point x will have a negative potential with respect to the cathode of the tube 15. Superimposed upon this direct current component is the weak alternating current voltage from the oscillator 8. At x this is, therefore, a pulsating negative direct current potential. Since the grid and diode plates of the tube 15 have a very high impedance to negative potentials the voltage drop through resistance 20 is relatively slight and the electromotive force at x is applied with negligible loss to the grid of the tube.

The output of tube 15 is connected to an amplifier 27 which may comprise an electronic tube amplifier of conventional construction, preferably of the resistance coupled type, with any desired number of stages of amplification. A power amplifier tube is preferably employed in the last stage. The heater current for the amplifier tubes may be supplied from leads 4 and the heater current for the power amplifier tube may be supplied from leads 6. The plate supply for the power amplifier tube may be supplied through leads 7, and the plate supply for the prior stages may be supplied through the positive lead 5.

Connected in the output of the amplifier A, that is, in the plate circuit of the power amplifier, if an electronic tube amplifier is employed, is a relay 28, the armature 29 of which functions to connect or disconnect a power circuit 30 which includes a conventional control unit 31. The control unit 31 may comprise mechanism for opening or closing a valve to admit fuel, steam or other energy medium to the device whose temperature is to be controlled and in itself constitutes no part of my invention.

Reverting to the operation of the tube 15, when the grid becomes negative, as hereinbefore described, the pulsating component of the electromotive force applied to the grid is then amplified by amplifier 27 including the gain obtained in the triode section of tube 15. The amplified alternating component of this electromotive force excites the grid of the power amplifier tube comprised in unit 27 causing plate current to flow, thus energizing the relay 28 and turning on the heat supply.

If the temperature goes above the point at which the instrument is adjusted, the thermocouple electromotive force will exceed that of the potentiometer and there will be a positive potential at x. Of course, the alternating electromotive force supplied from the unit 8 will be superimposed upon the direct current thermocouple potential. Since the grid and diode plates of the tube 15 offer a relatively low impedance to a positive electromotive force, there will be a relatively large voltage drop through the resistance 20 and a negligible portion of the potential at x will be applied to the grid. The output of the amplifier will then be insufficient to excite the grid of the power amplifier tube in the unit 27 and the armature 29 of the relay 28 will open, thus turning off the heat.

It is obvious that with a predetermined setting of the potentiometer arm 13, a predetermined temperature may be maintained constant. To

change the temperature at which a constant condition obtains it is merely necessary to move the arm 13.

As an example of a system which has been found satisfactory, a duodiode high mu triode tube such as a type 6SQ7 tube may be employed as the tube 15. A 6Z7G tube connected as an oscillator may be employed in the unit 8. The amplifier unit may comprise 6SC7 (double triode amplifier) and an 885 tube (gas triode). With an arrangement of this type the power pack 1 may comprise a suitable power transformer and a rectifier with provision for supplying the heater and plate currents to the various tubes at the proper voltages.

Of course, other types of tubes, sources of low voltage alternating current and ultimate control mechanisms may be employed since my invention is broadly directed to the modulation of the direct current output of a potentiometer-thermocouple circuit and using the rectifying action of a suitable electronic tube in such a way that the alternating component of the modulated direct current potential is amplified only when the direct current potential is negative.

My invention is characterized in that: (a) it is economical to construct and maintain, (b) it is highly sensitive, since by modulating the output of the potentiometer-thermocouple circuit an amplifier can be employed having a much higher voltage gain than could be obtained with a direct current amplifier which would be necessary if alternating current modulation were not used, (c) it is conducive to safety since breakage of the thermocouple or tube failure results in the heat being turned off, and (d) the device is portable and can be readily moved from place to place without requiring leveling or special mounting.

I claim as my invention:

1. A device for controlling temperature which comprises a thermocouple, a source of direct current electromotive force of predetermined magnitude connected in opposition to electromotive force of substantially equal magnitude generated by said thermocouple when the latter is heated to a predetermined temperature, an electron tube having at least three electrodes, the opposite side of said source of direct current electromotive force being connected to the cathode of said tube, means connected with the opposite side of said thermocouple for superimposing an alternating current electromotive force upon the direct current electromotive force of said thermocouple, means connecting said last mentioned side of said thermocouple to the control grid of the tube to supply a pulsating potential to said grid, a resistance interposed in said last mentioned connecting means for controlling the grid potential in accordance with the relative magnitudes of said direct current electromotive force and the thermocouple electromotive force as the thermocouple temperature changes, means for amplifying the pulsating plate-cathode potential of said tube, and means connected in the output of said amplifying means for actuating a temperature changing mechanism to change the temperature of said thermocouple.

2. A device for controlling temperature which comprises a thermocouple, a source of direct current electromotive force of predetermined magnitude connected in opposition to electromotive force of substantially equal magnitude generated by said thermocouple when the latter is heated to a predetermined temperature, an electron tube having at least three electrodes, the opposite side

of said source of direct current electromotive force being connected to the cathode of said tube, means connected with the opposite side of said thermocouple for superimposing an alternating current electromotive force upon the direct current electromotive force of said thermocouple, means connecting said last mentioned side of said thermocouple to the control grid of the tube to supply a pulsating potential to said grid, means interposed in said last mentioned connecting means for controlling the magnitude of the grid potential in inverse proportion to the current flowing in the grid-thermocouple circuit, means for amplifying the pulsating plate-cathode potential of said tube, and means connected in the output of said amplifying means for actuating a temperature changing mechanism to change the temperature of said thermocouple.

3. A device for controlling temperature which comprises a thermocouple, a source of direct current electromotive force of predetermined magnitude having its negative side connected to the negative side of said thermocouple whereby said respective electromotive forces are in opposition and substantially equal to each other when the thermocouple is heated to a predetermined temperature, an electron tube having at least three electrodes, the positive side of said source of direct current electromotive force being connected to the cathode of said tube, means connected with the negative side of said thermocouple for superimposing an alternating current electromotive force upon the direct current electromotive force of said thermocouple, means connecting the negative side of said thermocouple to the control grid of the tube to supply a pulsating potential to said grid, a resistance interposed in said last mentioned connecting means for controlling the grid potential in accordance with the relative magnitudes of said direct current electromotive force and the thermocouple electromotive force as the thermocouple temperature changes, means for amplifying the pulsating plate-cathode potential of said tube, and means connected in the output of said amplifying means for actuating a temperature changing mechanism to change the temperature of said thermocouple.

4. A device for controlling temperature which comprises a thermocouple, a source of direct current electromotive force of predetermined magnitude connected in opposition and substantially equal to electromotive force generated by said thermocouple when the latter is heated to a predetermined temperature, an electron tube having at

least three electrodes, the opposite side of said source of direct current electromotive force being connected to the cathode of said tube, means connected with the opposite side of said thermocouple for superimposing an alternating current electromotive force upon the direct current electromotive force of said thermocouple, means connecting said last mentioned side of said thermocouple to the control grid of the tube to supply a pulsating potential to said grid, a resistance interposed in said last mentioned connecting means for controlling the grid potential in accordance with the relative magnitudes of said direct current electromotive force and the thermocouple electromotive force as the thermocouple temperature changes, adjustable means connected with said source of direct current electromotive force for changing the relative potential of the cathode and grid of the tube, means for amplifying the pulsating plate-cathode potential of said tube, and means connected in the output of said amplifying means for actuating a temperature changing mechanism to change the temperature of said thermocouple.

5. A device for controlling temperature which comprises a thermocouple, a potentiometer including a source of direct current electromotive force of predetermined magnitude, means connecting said latter through said potentiometer in opposition and substantially equal to electromotive force generated by said thermocouple when the latter is heated to a predetermined temperature, an electron tube having at least three electrodes, the opposite side of said source of direct current electromotive force being connected to the cathode of said tube, means connected with the opposite side of said thermocouple for superimposing an alternating current electromotive force upon the direct current electromotive force from said thermocouple, means connecting said last mentioned side of said thermocouple to the control grid of the tube to supply a pulsating potential to said grid, a resistance interposed in said last mentioned connecting means for controlling the grid potential in accordance with the relative magnitudes of said direct current electromotive force and the thermocouple electromotive force as the thermocouple temperature changes, means for amplifying the pulsating plate-cathode potential of said tube, and means connected in the output of said amplifying means for actuating a temperature changing mechanism to change the temperature of said thermocouple.

JAMES HOEKSTRA.