Oct. 19, 1937. R. WILLIAMS 2,096,571

THERMOELECTRICAL APPARATUS

Filed April 17, 1936

Fig. 1.

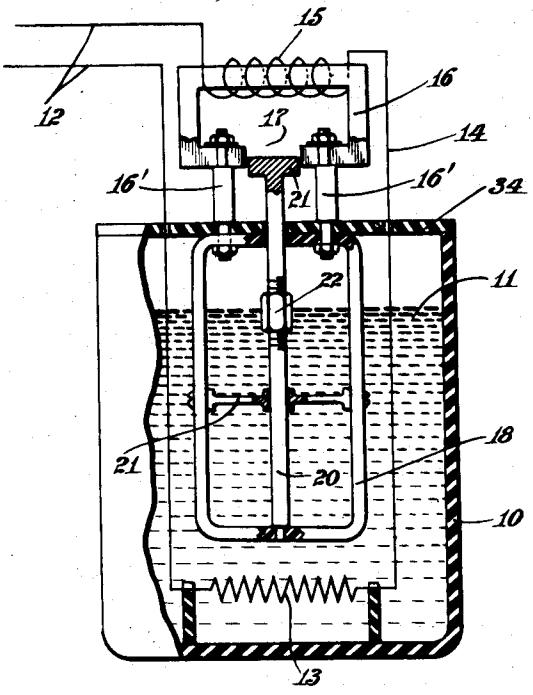


Fig. 2.

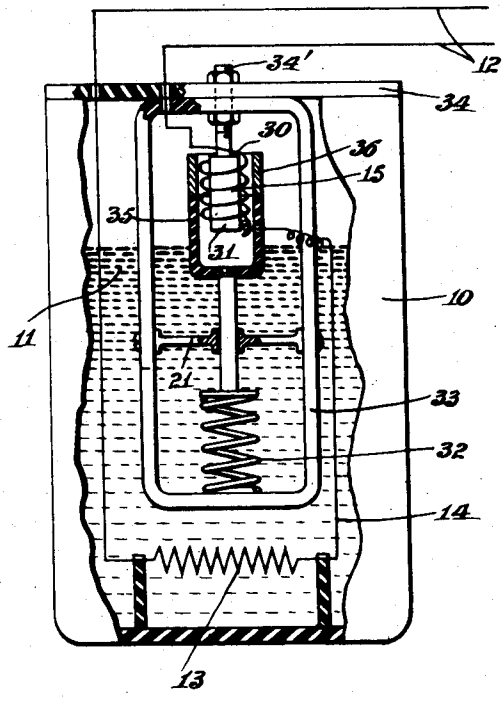


Fig. 3.

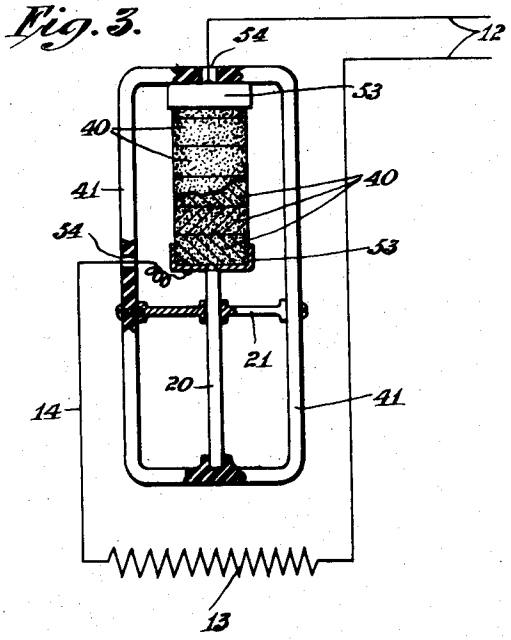
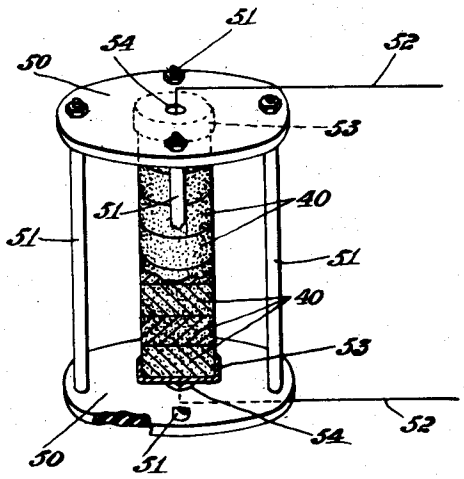


Fig. 4.



INVENTOR

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2,096,571

THERMOELECTRICAL APPARATUS

Roger Williams, New York, N. Y.

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10 Claims. (Cl. 219—20)

The present invention deals with electrical apparatus responsive to thermal changes. More particularly my invention is directed to means and methods for causing expansion or contraction of a body, according to the differing degrees of heat to which it is subjected, to effect changes in the impedance of an electrical circuit.

My invention is particularly applicable to cases where the electric current causes the heating of materials, which it is desirable to keep within certain limits of temperature.

One purpose of my invention is to control the temperature of liquids which are heated by electrical means and to keep the temperature of such liquids within close limits, notwithstanding that such liquids may be subjected to a wide variation of temperature due to their movement, for example, through the heating chamber.

More particularly my invention is especially suited for controlling the temperature of liquids which are heated while passing through a chamber, in which they may remain only a comparatively brief length of time.

Several embodiments of my invention are shown in the drawing hereunto appended, where:

Fig. 1 represents one form of my invention employing an electro-magnetic form of control.

Fig. 2 represents another form of my invention where an inductor of variable impedance is employed as the controlling element.

Fig. 3 shows a form of this invention using a variable resistor as the control element.

Fig. 4 shows a form where a single element functions both as control and as heating element.

Referring now to Fig. 1 I have here shown a container 10 which may be of any suitable material, in which is held, or through which passes the liquid 11, which it is desired to maintain at a given temperature.

The leads 12 represent a supply of alternating current from any suitable power source. One of these leads is directly connected to one end of a resistance element 13, which is submerged in the liquid 11. The other end of heating element 13, is connected by a conductor 14 to one end of the winding 15, and the other end of this winding is connected to the other conductor 12, thus completing an electrical circuit wherein heater element 13, and winding 15 are connected in series with one another across the power source.

Element 16, represents a core of any suitable magnetic material such as laminated iron or other magnetic alloy of high permeability. This core is in the form of a rectangle, one of whose sides is provided with an opening 17 and which core has the winding 15 embracing one or more legs.

The element 18 represents a supporting frame work which may be made of any suitable material of sufficient rigidity and preferably of non-magnetic material. This frame 18 is open so as to afford free circulation for the liquid 11 therethrough, and may be fastened to the core 16 by any suitable mechanical device such as the clamps 16'. It is desirable that frame 18 and core 16 be fastened together with sufficient rigidity so that their relative position may not easily be subject to variation.

This supporting frame 18 is held by cover 34 and is supporting a rod 20 which may rest upon the bottom portion of frame 18 and which may pass through an opening in a suitable guiding member 21, affixed to frame 18.

Rod 20 has at its upper extremity and firmly affixed thereto a piece of magnetic material 21 such as iron or the same alloy of which core 16 is formed.

Rod 20 may conveniently be divided into two portions which are oppositely threaded into a bushing 22, and the rotation of this bushing will serve to vary the over-all length of rod 20.

The material of which rod 20 is composed is chosen so that its coefficient of expansion will be greatly different from the coefficient of expansion of frame 18.

In the operation of this form of my invention, the values of resistance 13 and winding 15 are so chosen that the current passing through resistance 13 will maintain liquid 11 at approximately the desired temperature. The effective length of rod 20 is then adjusted until the gap 17 is only partially closed by element 21. Under these conditions the reactance of the choke coil formed by winding 15 and core 16 will have a certain value.

If the temperature of liquid 11 rises, for any reason, rod 20 and frame 18 immediately expand to an unequal degree. For purposes of illustration, let us assume that rod 20 is made from a material whose temperature coefficient is greater than that of frame 18. Under such circumstances rod 20 will then tend to expand to a greater degree than frame 18 and accordingly will cause element 21 to enter farther into the opening 17. This reduction of the air gap between element 21 and core 16 will cause the effective reactance of the inductor as a whole to increase, due to the increased permeability of its magnetic circuit thus brought about.

The increased impedance of the inductor will

cause a reduction of the current flowing through heating element 13, and thus tend to lower the temperature of liquid 11, thus compensating for the increase in temperature which has been considered to have occurred previously.

A decrease of temperature in liquid 11 will cause the contraction of rod 20, a widening of the air gap between elements 21 and 16, a decrease in the reactance of inductor and consequent rise in current and heating effect of element 13.

Since the effective reactance of an inductor of the type just described may be very greatly changed by a relatively small air gap introduced into its magnetic circuit, it is evident that comparatively slight temperature changes will cause comparatively large changes in the current passing through such an inductor.

While I have shown element 21 as having a rectangular shape and the opening in core 16 as having a corresponding shape, yet it is evident that other forms and openings may be employed, and that by properly choosing the form of opening, the effective response of the inductor may be made to vary, relatively to the temperature changes, in almost any desired fashion. For example, either a straight line or a logarithmic response curve may be obtained. In many cases a logarithmic response may be desirable where the liquid 11 is apt to change suddenly or to a great degree.

Referring now to Fig. 2, chamber 10, liquid 11, and heating element 13 may be similar to these elements as shown in Fig. 1. The alternating current energy derived from leads 12 energizes heater 13 through a control element formed by a winding 30 embracing a core 31, of suitable magnetic material.

In place of the straight rod 20 in the form previously described, there is here shown an expansive element in the form of a helix 32, whose lower end is supported upon a frame 33. Frame 33 is similar in function to frame 18 of Fig. 1 and is affixed by any suitable mechanical means such as bolt 34' to core 31 of the inductor element. Helix 32 bears at its upper end a cylinder 35 formed partly of conducting material such as copper.

Cylinder 35 is arranged so that its conducting portion 36 partly embraces winding 30 of the inductor and the expansion of helix 32 will cause this conducting portion to move upwardly so as to uncover a similar portion of winding 30, thereby increasing the effective reactance of this winding and lessening the current through heater 13. A cooling of liquid 11 will reverse the effects just described and in this fashion a temperature control similar to that exercised by the form of Fig. 1, may be secured.

The forms of my invention shown in Figs. 1 and 2 are applicable only to alternating current as a power source, but in Fig. 3 I have shown another form of my invention suitable for use either with alternating or direct current. In this form I have omitted the heating chamber and liquid for purposes of clarity and the power leads 12 may be assumed to be carrying either direct or alternating current in this case.

In series with the power leads and heater 13 are a series of carbon blocks 40. The frame 41 is fastened to the uppermost block and expansion rod 20 is interposed between the bottommost block and the bottom of frame 41. In this case it is assumed that rod 20 is chosen to have a temperature coefficient of expansion much less than that of frame 41. Under such circumstances, an increase of temperature of the liquid in which this device may be submerged, will cause frame 41 to expand to a greater degree than rod 20, thus decreasing the pressure exerted upon the carbon blocks held between the upper end of rod 20 and the upper end of frame 41. This will increase the resistance offered by the carbon blocks and thus lessen the current flowing through heater 13, thus giving the desired regulating effect. The reverse action taking place upon a fall of temperature will be readily apparent. Conducting cups 53 allow the wires passing through holes 54 to make contact with the carbon blocks.

Many variations of the forms of my invention herein shown will be apparent to those skilled in the art. For example the expansive element may be not only of the rod or helical forms shown, but may be cone-shaped or spiral or of any other suitable shape. It will be apparent that a helical or spiral shape will give a greater expansion for a given change of temperature, due to the greater effective length thus available.

The variable inductor described may manifestly take the form of a two-winding transformer and the variable magnetic gap of Fig. 1 may also be used as a shunt magnetic circuit instead of the series circuit shown.

The means for adjusting the effective length of rod 20 may take on forms other than the bushing shown in Fig. 1 and in some cases it may be possible to dispense entirely with mechanical adjustments and the expansion rod, and in lieu thereof to interpose a rheostat or other control device of an electrical nature in series with the leads 12, or heating element 13 may be made capable of adjustment by means of suitable taps therefrom.

In Fig. 4 I have illustrated yet another modification of my invention, where a single element furnishes heat and at the same time is varied by the temperature of the liquid around it so that it will produce more heat if the liquid becomes colder or less heat if the liquid becomes hotter.

In this form of construction, the expansion rods 51 are arranged around the periphery of two end discs, 50, so as to form an open cage. These elements may be of insulating material as shown, or may be of metal, provided that suitable insulation is interposed between, so that they will not afford a short-circuited path. Leads 52 connect directly, or through any suitable switch (not shown) to a power supply, either A. C. or D. C.

Conducting cups 53 afford connection to leads 52 which pass through holes 54 is discs 50, and also hold firmly therebetween the series of carbon blocks 40, which may be similar to those shown in Fig. 3.

In order to illustrate the action of this form of my invention, let us assume that rods 51 have a greater coefficient of thermal expansion than do carbon discs 40 and that leads 52 are supplied with a voltage which may be adjusted to a suitable value by any suitable external means such as a rheostat, variable choke coil, or the like.

If the liquid surrounding rods 51, and being heated by carbon blocks 40, should become warmer than normal, rods 51 will expand more than will blocks 40, and accordingly the pressure on the stack of blocks 40 will decrease, thus increasing its effective resistance, lessening the current flowing therethrough and consequently the heat produced thereby. A reverse temperature change will cause a reverse series of reactive effects.

I have thus provided a self-adjusting heating

element, which will tend to minimize temperature changes in the fluid in which it is immersed and which it is heating and which fulfills the dual role of a heater and a thermostat, with the additional advantage of affording continuous control, instead of the intermittent control of the usual electrical thermostats, which actually make and break an electrical heating circuit.

While I have shown and described liquids as the matter to be heated, it is apparent that gases or even solids may be so heated and controlled, by making suitable modifications in the apparatus herein shown. For example, if the form of Fig. 4 be used to heat gases, some shield should be interposed between the heating element and the expansion rods, to prevent radiated heat from directly influencing these rods.

While I have shown means for adjusting the length of the expansion rods only in the case of Fig. 1, yet it is to be understood that adjusting means similar to those shown in Fig. 1, or of any other suitable character may be provided in the case of the other forms of my invention illustrated in the remaining figures. Likewise it is to be understood that the adjustments of my device for a given temperature of the liquid may be accomplished not only by means of changing effective length of the expansion members, but also it may be accomplished by using an external electrical device such as a rheostat, choke-coil, potentiometer, or similar device.

In the form of my invention employing a magnetic controlling element, I prefer to use some material of extremely high permeability, in order to give the greatest possible range of adjustment for the minimum motion of the expansion elements. In the case of the magnetic controls, it is also possible to make any adjustments desired by the use of an auxiliary winding upon the same core, but carrying D. C. current. Such a winding acts to vary the permeability of the core in accordance with well known principles.

It is apparent that various means may be used to magnify the thermostatic action of my device. For example, some magnifying mechanical motion such as a lever may be interposed between the expansion rod and the actual controlling elements, such as element 21 of Fig. 1, or element 36 of Fig. 2.

Since the expansion of the rod is small in degree, but represents a considerable amount of actual pressure, and since the motion of the controlling element proper does not call for the dispersion of any considerable amount of energy, such magnifying device will not decrease the sensitivity of response of my device. Alternatively, electrical amplifying device, may be employed between the variable impedance member, and the heating circuit. Such amplifying devices, including electronic relays are well known in the art, and a further description thereof is considered unnecessary.

Another modification of my invention may consist of using some form of bi-metallic thermostatic element in place of the expansion member herein described. Such bi-metallic element will cause a lateral motion, rather than the vertical motion of the expansion rod. The adaptation of such a lateral motion for actuating the controlling element proper will be apparent to one skilled in the art.

It is to be understood that the various elements shown in the form of my invention herein illustrated, are to be suitably insulated from one another, so that short-circuits will not occur. For example, in the case of the type shown in Fig. 3, it will be apparent to one skilled in the electrical art, that if rod 20 and frame 41 were both constructed of conducting material, the current would pass through these two elements in series with one another, from the conducting cup 53 on one end of the pile of carbon blocks, to the cup on the other end of the pile.

Accordingly it would be necessary in such case, to interpose insulation somewhere along this short-circuiting path. For example, either one or both cups might be insulated from contact with the expansion rod on the frame.

I claim:—

1. An electrical heating system comprising electrothermal conversion means placed in direct contact with the material to be heated, electrical impedance means controlling the electrical energy supplied to said conversion means, said impedance means including at least one member whose continuous displacement of relative position to a very slight degree will cause relatively large continuous variations in the electrical value of said impedance means, a solid expansion member also in close thermal contact with the material to be heated and means for thermally shielding said expansion member from said electrothermal conversion means and said impedance means, and relatively short, rigid and direct mechanical coupling means uniting said displacement member of said impedance with said expansion member into substantially a single unitary structure without substantial flexure or moving joints, whereby relatively slight expansion or contraction movements of said expansion member are transmitted without lost motion to said displacement member and result in relatively large variations of the electrical energy supplied to said electrothermal conversion means.

2. An electrothermal conversion and control system according to claim 1, characterized in that the displacement member and electrical impedance means lie wholly without the material to be heated.

3. A system according to claim 1, characterized in that said impedance means is constituted by an inductive reactance of the iron core type and the displacement member is constituted by a portion of the core of said impedance, said core being of a material of relatively high magnetic permeability and said displacement member being of the air-gap type and so disposed that its movement varies the effective permeability of the total magnetic circuit of said core.

4. A system according to claim 1, characterized in that said electrical impedance means is substantially entirely reactive in nature.

5. A system, according to claim 1, characterized in that said electrical impedance means is substantially entirely resistive in nature.

6. Thermo-electric apparatus including a heater, means for supplying current thereto, a thermostat of solid material responsive to the effective thermal output of the heater, a variable reactance control element of the air-gap type in series with the current supply and the heater and rigid continuously effective mechanical means coupling the thermostat and the control element into a unitary structure so as to increase the reactance thereof when the effective thermal output of the heater increases.

7. A combination heater and thermostat comprising a plurality of pieces of poorly conductive material stacked together, said material being of a nature so that the effective resistance of the

stack will be a function of the holding pressure exerted upon the ends thereof, means for holding the ends of the stack of said pieces of material and thermally expansive means joining said holding means located at opposite ends of said stack and determining the effective pressure of said holding means upon said stack, said stack serving as a heater by virtue of its poor conductivity and as a thermally responsive rheostat by virtue of the varying pressure exerted upon the ends thereof, said stack and said expansive means having therebetween free space for circulation of fluid to be heated.

8. An electrical heating system comprising a variable impedance and a solid expansion element, rigid means for continuously and uninterruptedly coupling said elements into a single unitary structure so that the expansion element will continuously increase the effective impedance of the variable impedance when said expansion element is subjected to an increased temperature, and a heating element in circuit with said variable impedance and a source of electric current and also comprising means for thermally shielding said impedance and said expansion element from one another, said expansion element and the variable portion of said impedance being arranged linearly with respect to each other, whereby these two elements constitute a single rigid and unitary structure.

9. A combination heater and thermostat adapted to be immersed in a fluid, comprising two plane surfaced blocks, thermally expansive rods joining said blocks substantially at their outer edges and determining the distance therebetween, a heater comprising a stack of blocks of material whose effective resistance is a function of the pressure thereupon, clamped between said plane blocks, and means for affording electrical connections to the respective ends of said stack, said expansive rods and said stack of blocks having therebetween free space for circulation of said fluid.

10. An electrical heater including a stack of carbon blocks immersed in a medium to be heated and means to vary the pressure upon said blocks inversely according to the temperature of said medium, said blocks and said pressure-varying means having therebetween free space for circulation of said fluid medium.

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