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ELECTRICAL HEATING DEVICES

Filed Oct. 26, 1961

Fig. 1.

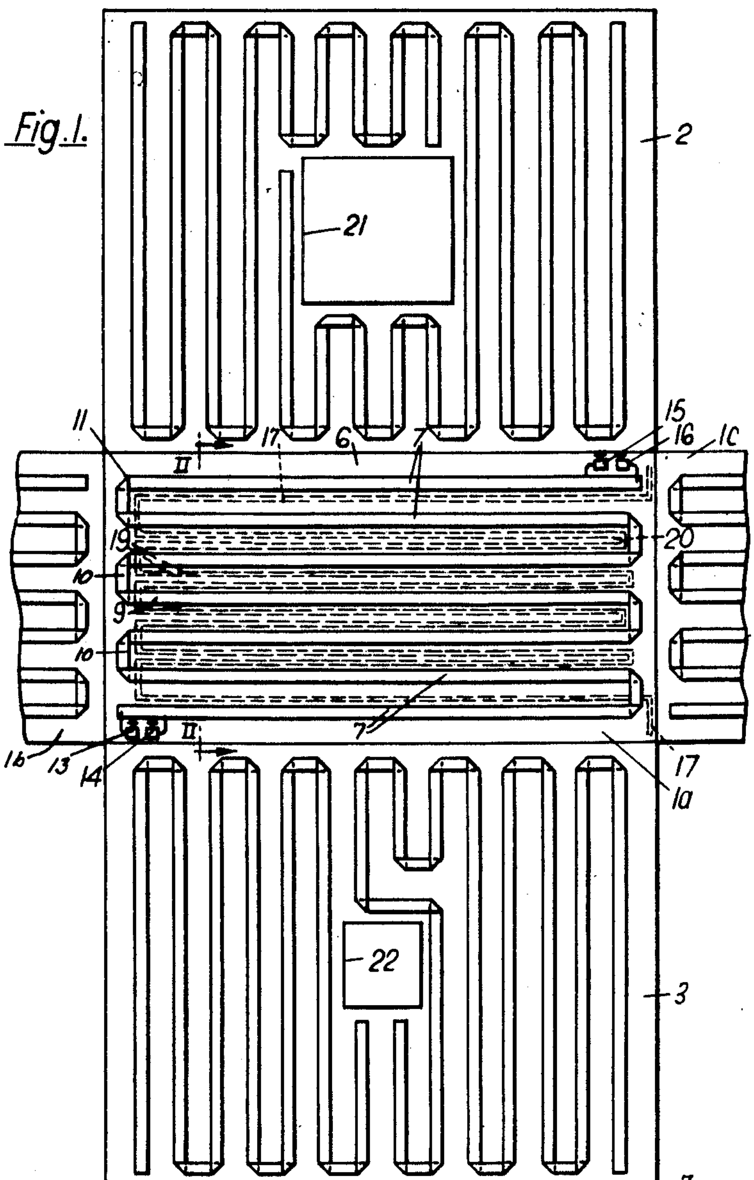
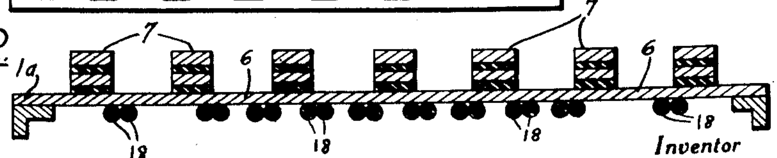


Fig. 2.



Inventor
LESLIE KEARTON PARKER

By [signature]

Attorney

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ELECTRICAL HEATING DEVICES

Leslie Kearton Parker, Beaconsfield, England, assignor to The Perkin-Elmer Corporation

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This invention relates to electrical heating apparatus and, more particularly, to electrical heating devices adapted for use with scientific instruments.

Electrical heating devices are known which are suitable for use in maintaining predetermined temperatures. However, such devices are not satisfactory for use with certain kinds of scientific apparatus since the heating, produced at intervals to maintain the temperature, is accompanied by magnetic fields which influence the apparatus.

It is, therefore, a primary object of the present invention to provide improved heating apparatus. Other objects are to provide such heating apparatus which is highly accurate; which is easily controlled; which produces a minimal magnetic field; and which is particularly well adapted for use with a nuclear magnetic resonance device.

According to the present invention, an electrical heating device is provided having one or more electrical heating elements made up of conductors arranged in pairs. The conductors of each pair are closely adjacent one another and conduct current in opposite directions, thus producing heat but negligible magnetic field. The device also has one or more electrically conducting elements which respond to changes of temperature produced by the heating. These elements are also made up of conductors arranged in pairs, the conductors of a pair being closely adjacent one another and arranged to conduct current in opposite directions. In use, the temperature-responsive elements are connected through a control circuit, for example, a standard bridge circuit, so as to control the application of current to the heating elements. Current is then applied when the temperature detected by the temperature-responsive elements falls below a predetermined level. Because of the arrangement of the parts making up the elements, no significant magnetic field is produced by the device.

Preferably each of the conducting elements is in the form of a resistance wire, the resistance of which changes with a change of temperature. Alternatively, however, there may be a number of such conducting elements making up one or more thermocouples.

Preferably, the heating elements are in heat-transfer relationship with, but are electrically insulated from, a heat-conducting screen. The screen supports the temperature-responsive elements so that the latter respond to temperature changes produced by the heating. The heating elements may be embedded in the screen, although in a convenient arrangement the heating elements are mounted on one of its faces. The temperature-responsive elements are mounted on the opposite face of the screen. In use, the screen is mounted with the temperature-responsive elements adjacent the apparatus whose temperature is to be controlled. The screen itself serves to spread out in a more uniform manner the heat produced by the heater element or elements and thus enables the apparatus to be heated more uniformly. The screen may be in the form of a continuous flat sheet, for example, of aluminum.

Preferably the conductors making up the heating elements are in the form of strips. The strips of a pair are substantially identical and are superimposed with their larger surfaces parallel to the larger surfaces of the screen. In this way a good heat-transfer relationship may be obtained between the elements and the screen, while the magnetic fields produced may be reduced to a desirably low level.

Preferably the heating elements extend over substantially the whole of the first face of the screen. In this way, substantially the whole of the screen provides a heating surface. Preferably also the temperature-responsive elements are in the form of resistance wires extending over substantially the whole of the second face of the screen. The wires may then be arranged to respond to an average temperature. In one convenient arrangement for example, the heating elements on the one hand, and the wires on the other hand, extend for the greater part of their length parallel to one another in the device. The resistance wires are disposed, however, not along the area of maximum heating (that is to say the area directly opposite the heating elements) nor along the area of minimum heating (i.e., the area directly opposite the centers of the spaces between the heater elements) but along intermediate areas. This is important since the difference between the temperatures at the areas of maximum and minimum heating varies with the ambient temperature, increasing as the ambient temperature falls. Thus, in one particular arrangement, the temperature varies substantially sinusoidally across the screen transverse to the length of the heating elements. The amplitude of these variations increases with falling ambient temperature, the maximum temperatures being relatively constant but the minimum temperature decreasing. By locating the resistance wires along areas intermediate to those of maximum and minimum heating (and thus temperature) it is possible to have these wires respond, irrespective of the ambient temperature, to a temperature which is an average of the maximum and minimum temperatures.

Conveniently each heating element and each wire is made up of relatively long parallel reaches and of relatively short cross reaches which connect the long reaches together in series.

A number of devices may be connected together to make up a box structure for housing the apparatus whose temperature is to be controlled. This box structure may have the heating elements arranged on the outside and the resistance wires arranged within and may have four walls, a top, and a bottom, each constructed in accordance with the invention. An opening may be provided to enable access to be gained to the interior of the box structure, and this opening may be closed by a door which itself constitutes a heating device in accordance with the invention.

One example of a device constructed in accordance with the invention will now be described with reference to the attached drawing wherein:

FIGURE 1 is a plan view of a box structure opened out and laid flat, but with one wall missing and two others only partially shown; and

FIGURE 2 is a cross-section along the line II—II of FIGURE 1.

The box structure comprises four side walls three of which are shown as **1***a*, **1***b*, and **1***c*, a top **2**, and a bottom **3**, each of these comprising an electrical heating device in accordance with the invention. These devices are basically very similar to one another and only one, the wall **1***a*, will therefore be described in detail. The wall **1***a* includes a heat-conducting screen in the form of a rectangular sheet **6** of aluminum ⅛" thick. Mounted on the outer face of this sheet **6** are two identical heating elements, in the form of thin aluminum strips, the outer strip **7** being superimposed exactly in register on the inner strip, with their large surfaces parallel to the larger surfaces of the sheet **6**. The two strips are insulated from one another and from the sheet **6** by thin layers of electrical insulation, conveniently of manila paper. This material permits heat to be transferred from the strips to the plate **6**.

Each strip is made up of relatively long parallel reaches **9** and of relatively short cross reaches **10** which connect the long reaches **9** together in series. The long and short reaches are integral with one another being connected together by bent over portions **11**. It will be appreciated that the reaches each comprise an outer and an inner strip. The strips are closely adjacent one another (being separated by a gap of, for example 0.004"). They are also able to conduct current in opposite directions, terminals **13—16** being provided on the sheet **6** to permit this to be done. Terminals **13** and **16** are permanently connected to the ends of the outer strip **7**, while terminals **14** and **15** are permanently connected to the ends of the lower strip. Thus, the passage of current through the two strips enables heat to be produced with negligible magnetic field, this heat passing through the sheet **6** which serves to spread it out in a more uniform manner.

Mounted on the inner face of the sheet **6** are a pair of resistance wires **18** which change resistance in response to changes of temperature produced by the heating and which are represented in FIGURE 1 by double dotted lines **17**. These two wires **18** are parallel to the strips and are electrically insulated from the sheet **6**. Wires **18** are also made up of relatively long parallel reaches **19** and relatively short cross reaches **20** which connect the long reaches **19** together in series. It can be seen that these reaches are arranged in pairs, and that the reaches of a pair are closely adjacent one another and able to conduct current in opposite directions. Terminals are provided on the sheet **6** to permit this application of current. In use, these terminals are connected to a standard bridge network which controls the application of current to the strips.

Despite the good conductivity of the sheet **6**, the temperature at its inner face is not the same at all points and the wires **18** are, therefore, arranged so as to be subjected to the average temperature irrespective of the ambient temperature. It is for this reason that these wires **18** are disposed not along the area of maximum heating nor along the area of minimum heating but along the intermediate area.

The other walls are the same as the wall **1***a*, the resistance wires not being shown in the drawing.

The top **2** and the bottom **3** are also similar to the wall **1***a* (although again the resistance wires which are arranged as before with respect to the heater strips, are omitted) but differ in that each is provided with two pairs of strips rather than one pair, and a central opening is provided. The opening **21** in the top **2** is to enable access to be gained to apparatus mounted within the box structure, while the opening **22** in the bottom **3** permits air to be circulated inside the box structure by means of an electric fan.

The illustrated structure is suitable for housing the large permanent magnet of a nuclear magnetic resonance apparatus, and is able to keep the magnet at a substantially uniform temperature to within a millidegree at a temperature of the order of 10–20° C. above the ambient temperature.

It is to be understood that the apparatus of this invention is subject to a number of variations and modifications without departing from the spirit thereof. The foregoing description is illustrative only, the scope of the

invention is to be construed as limited only by the scope of the following claims.

I claim:

1. A heater assembly which comprises an enclosure defined by 6 walls, each of said walls comprising a heat-conductive screen; first electrically conductive heating member means mounted on the outer surface of said screen and adapted to carry electrical current in a first direction; second electrically conductive heating member means closely adjacent said first heating member means but electrically insulated therefrom and adapted to carry electrical current in a second direction; first temperature sensing conductor means mounted on the inner surface of said screen and adapted to carry electrical current in a first direction; second temperature sensing conductor means closely adjacent said first conductor means but electrically insulated therefrom and adapted to carry electrical current in a second direction, all of said first and second heating member means and said first and second conductor means being in heat exchanging relationship with said screen but electrically insulated therefrom and an opening in one wall to permit air circulation inside the enclosure.

2. The apparatus of claim 1 wherein said screen is a flat metallic sheet, said first and second heating member means are superposed elongated ribbon-like strips, and the longitudinal axes of all of said heating member means and said conductor means are parallel.

3. Electrical heating apparatus comprising a flat heat conductive screen, a pair of superposed, coinciding electrically conductive heating members positioned on one side of said screen, and being electrically insulated from each other and from said screen, said heating members being adapted to carry current in opposite directions thereby minimizing resulting inductive effects, first temperature sensing conductor means adapted to carry current in a first direction, a second temperature sensing conductor means adapted to carry current in a direction opposite to said first direction, said first and second temperature sensing conducting means being disposed adjacent and insulated from each other and from the screen, the said first and second temperature conducting means being disposed on the opposite side of the flat screen from said heating members.

4. Apparatus as defined in claim 3 in which said flat screen is a metallic sheet.

5. Apparatus as defined in claim 3 wherein the longitudinal axes of said first and second conductor means are parallel to the longitudinal axes of said pair of heating members.

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