

[54] **UNITARY THERMAL REFERENCE SOURCE**
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3,394,259 7/1968 Brown..... 219/553 X
3,411,123 11/1966 Kydd..... 338/225 X

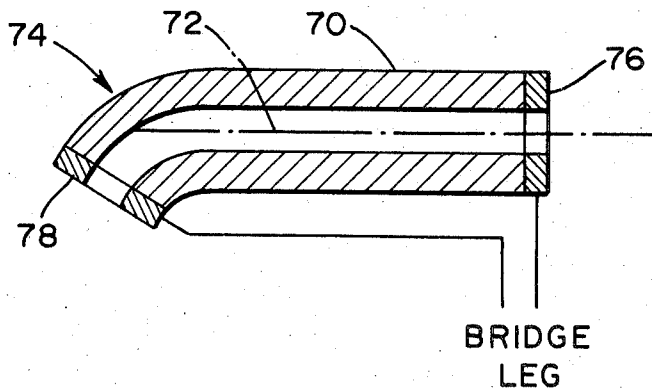
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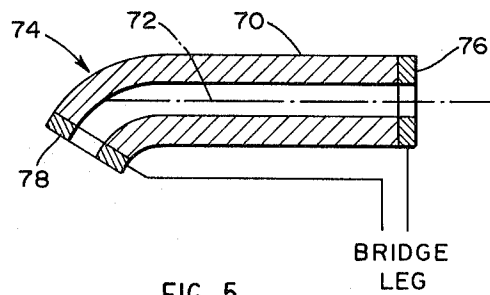
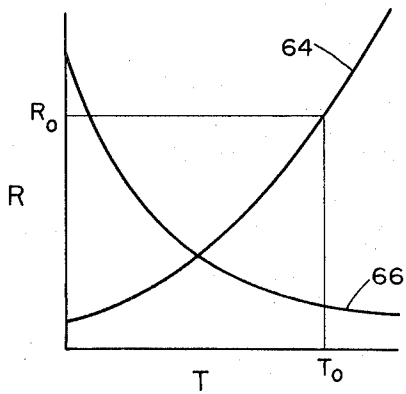
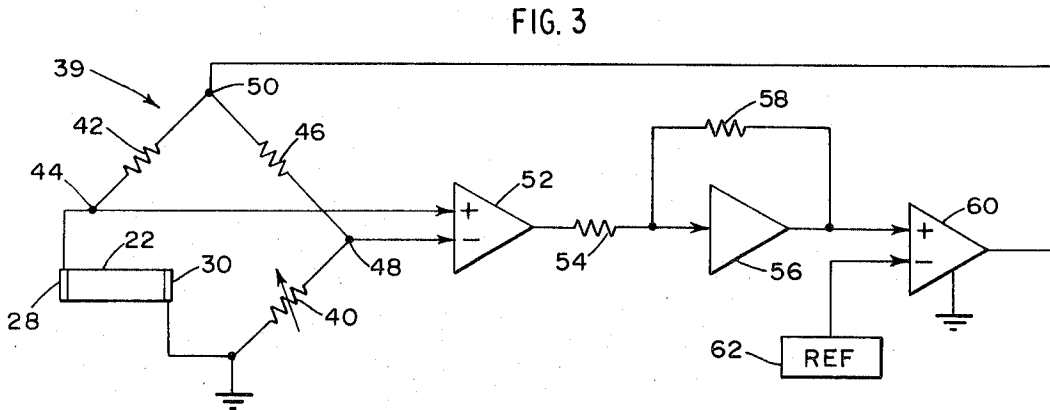
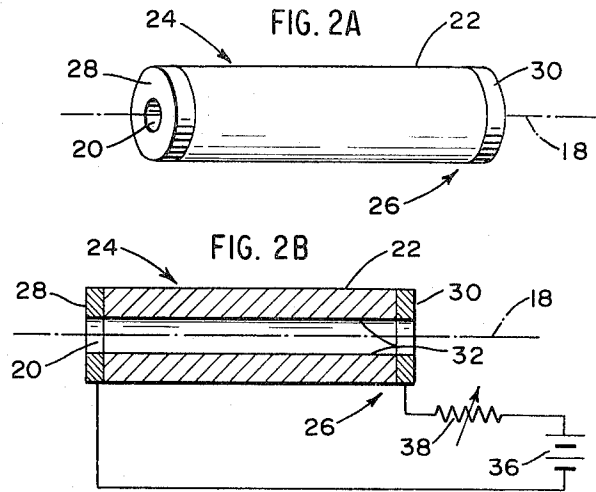
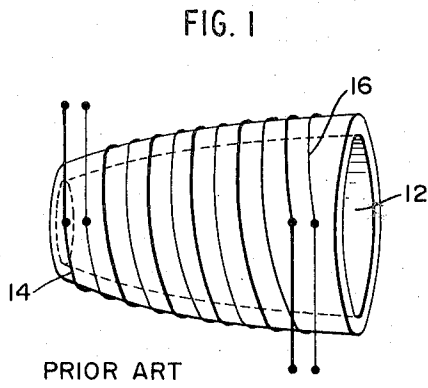
[52] **U.S. Cl.**..... **219/501, 219/504, 219/505**
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[58] **Field of Search**..... 250/84, 85; 219/300, 469,
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390, 427

[56] **References Cited**
UNITED STATES PATENTS
1,981,015 11/1934 Williams 219/427 X
2,952,762 9/1960 Williams et al. 219/553 X
3,215,818 11/1965 Deaton 219/499
3,263,016 7/1966 Branstetter et al. 219/553 X

[57] **ABSTRACT**
A thermal reference source in which the interrelated functions of heater, radiator, and temperature sensor are provided by a unitary and integrally formed structure. The reference is formed of a homogeneous, temperature sensitive resistive material shaped to define a radiative cavity and includes terminals for connection to an associated control circuit. Temperature changes are sensed in a substantially instantaneous manner and rapid control easily maintained.

4 Claims, 6 Drawing Figures





UNITARY THERMAL REFERENCE SOURCE

FIELD OF THE INVENTION

This invention relates to thermal reference sources and more particularly to a thermal source for providing an accurate and controllable thermal radiation standard.

BACKGROUND OF THE INVENTION

In thermal instrumentation it is often necessary to employ a reference source which provides thermal radiation at predetermined temperatures for monitoring, calibrating, or other purposes. Reference sources which accomplish these functions are known in the art and typically comprise a structure capable of radiating energy in a selected temperature range, the radiating structure being indirectly heated such as by separate electrical heating coils wound therearound. In order to maintain a predetermined operating level, the temperature of the radiating structure is monitored by one or more separate sensors attached to the structure. These sensors typically include a thermocouple affixed to the structure or a coil of temperature sensitive wire, such as platinum, wound therearound.

These prior art reference sources suffer several disadvantages which limit their utility. In addition to the complexity of making such sources, they have proved to be less than ideal in providing uniform and accurate temperature references. The indirect heating of the radiating structure from a number of separate coils or heated spots results in the inefficient transfer of heat from the coils to the radiating structure. Control of the temperature of this structure also depends upon indirect temperature monitoring from separate sensors. An inherent time delay exists in the transfer of heat from the heater coils to the radiating structure and thence to the thermal sensors and the speed and accuracy of temperature regulation is thus limited and requires expensive control electronics to even partially compensate. Moreover, variation in the properties of the separate heaters and/or sensors can contribute further errors to the level of output radiation. The indirect heating of a radiating structure from a series of discrete points also is likely to cause variation in the heating of the overall structure and radiation of temperatures outside the desired range.

BRIEF SUMMARY OF THE INVENTION

These and other problems of the prior art are overcome by a thermal reference which, according to a preferred embodiment of the invention, comprises a unitary radiative structure of a homogenous electrically resistive composition that integrally provides the functions of heater and temperature sensor as well as thermal radiator. Properties of the unitary structure directly provide the functions of heating, radiating and temperature sensing and thereby eliminate the inefficiencies of indirect heat transfer. There is thus no thermal gradient or time lag between heating and sensing or radiating and sensing.

The radiative structure typically comprises an electrically resistive material formed in a shape defining a radiative cavity and having electrical connections for application of energizing current thereto. To provide the directly coacting functions of heater, radiator, and sensor, a thermistor material is typically employed to pro-

vide a temperature sensitive electrical resistance for the structure material. Temperature regulation is achieved by connecting the unitary structure as one arm of an electrical bridge circuit which is excited to heat the structure to a requisite level. The temperature dependent device resistance is employed in a circuit to adjust the excitation current to maintain radiation at an intended temperature.

DESCRIPTION OF THE DRAWINGS

These and other features of the invention will be more fully understood by reference to the following detailed description of a preferred embodiment presented for purposes of illustration and not by way of limitation and to the accompanying drawings of which:

FIG. 1 is a prior art thermal source over which the present invention is an improvement;

FIGS. 2A and 2B are pictorial and sectional views, respectively, of a thermal reference source according to the invention;

FIG. 3 is a schematic diagram of circuitry useful in controlling the temperature of the thermal reference of the invention;

FIG. 4 is a graph illustrating typical resistance versus temperature characteristics of the thermal reference of the invention; and

FIG. 5 is a sectional view of a modification of the embodiment of the invention shown in FIGS. 2A and 2B.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a prior art device of conventional design for providing a thermal reference comprises a black body shell 12 defining a cavity and having an interior surface for radiating thermal energy in a spectral emittance band characteristic of a desired temperature. To excite the body to a predetermined temperature a plurality of turns of a heater coil 14 are wrapped around the exterior surface of the shell 12 and in intimate contact thermally. The coil 14 may be energized by a suitable current from a source not shown. A plurality of turns of a separate coil 16 are wound in bifilar manner around shell 12, this coil 16 being composed of a wire such as platinum, the resistance of which varies with temperature and which serves as a sensor for measuring the temperature of shell 12. The coil 16 may be connected to a controller for the source of current for heater coil 14 for control of the current passing through coil 14 in order to maintain a predetermined cavity radiating temperature.

As can be seen from FIG. 1 the ultimate goal of providing a predetermined radiation from body 12 is achieved through indirect heating and sensing of device temperature with distinct coils 14 and 16 respectively. Despite good thermal contact with the body 12 to minimize heat transfer losses, the efficiency of thermal transfer is still such as to cause a gradient between the coils 14 and 16 and the cavity resulting in a variation from point to point in the body and inaccuracies in the sensed temperature.

Not only do these inaccuracies exist in the prior art structure of FIG. 1 but the construction of such devices, requiring the interspersing of two coils having controlled spacing, is complicated and often demands hand fabrication.

Referring now to FIGS. 2A and 2B, pictorial and sectional views are presented of a thermal reference according to the invention and which provides combined heating, sensing, and radiating functions in a single structure which completely avoids the problems of heat transfer efficiency and temperature variations. About an axis of symmetry 18 a cavity 20 is defined by a cylinder 22 which is composed of a material having an electrical resistance that varies with temperature. On opposite ends 24 and 26, annular electrical contacts 28 and 30 respectively are secured in electrical contact with the material of cylinder 22. The material of cylinder 22 has an inner radiating surface 32 which creates an internal radiator that may be viewed through either end of cylinder 22.

Various types of compositions can be used for the material of cylinder 22. The significant characteristics for the material are that it have a resistance which varies with temperature, either a positive or negative temperature coefficient as indicated in FIG. 4 being acceptable. As an example, thermistor materials have generally been found satisfactory for use in forming the cylinder 22.

The electrical connectors 28 and 30 may be of any electrically conductive material which, when necessary, may be matched in its coefficient of thermal expansion to the substance composing the cylinder 22.

As indicated in FIG. 2B electrical excitation may be provided from a battery 36 to heat cylinder 22 through a variable resistor 38. It can be seen that once an equilibrium condition exists with current flowing from the battery 36 through the resistor 38 and cylinder 22, any change in temperature of the cylinder 22 will alter its resistance and vary the current and power flowing through the cylinder 22. By selecting an appropriate value of resistance in resistor 38 and resistance and temperature coefficient for cylinder 22, the temperature change will be counteracted by a change in power applied to the cylinder 22 in a sense tending to restore the original temperature equilibrium.

The utilization of the combined heating, sensing and radiating properties in the material of cylinder 22 for providing a well regulated temperature reference can be better described, however, by reference to FIG. 3. As indicated there, the cylinder 22 is connected into a bridge circuit 39 through its electrical contacts 28 and 30. In particular the contact 30 is connected to ground along with one terminal of a variable resistor 40. The contact 28 is connected to a fixed resistor 42 through a terminal 44 of the bridge. The ungrounded terminal of the variable resistor 40 is connected to a fixed resistor 46 through a terminal 48. The opposite terminals of fixed resistors 42 and 46 are tied together at a terminal 50.

The terminals 44 and 48 are applied to differential inputs of a high gain amplifier 52. The output of the amplifier 52 is applied through a resistor 54 to an operational amplifier 56 having a path of negative feedback therearound through a resistor 58 to cause the amplifier 56 to operate with a gain determined by the ratio of the resistor 58 to the resistor 54. A further differential amplifier 60 receives on a noninverting input the output of the operational amplifier 56, and on an inverting input the potential supplied by a reference 62. The output of the amplifier 60, as referenced to ground, is applied to the terminal 50.

To explain the operation of the circuitry of FIG. 3 it will be assumed that the material comprising the cylinder 22 has a positive temperature coefficient as indicated by curve 64 in FIG. 4 and that it is desired to regulate the temperature thereof at a temperature T_0 which produces a corresponding cylinder resistance R_0 . Initially the variable resistor 40 will be adjusted so that its resistance takes on the value R_0 . Assuming at initial turn-on that the resistance between the connectors 28 and 30 is substantially less than R_0 , the output of the amplifier 60 will be a large positive potential thereby increasing the voltage applied to the terminal 50 and correspondingly the current through the cylinder 22. At this point the cylinder 22 will begin to increase in temperature and in resistance. At a predetermined value of resistance, differing from R_0 by a small error, depending upon the gains and offsets of the amplifiers, an equilibrium condition is reached with the difference between the two inputs to the amplifier 52 as small as desired. As further embellishments, the amplifiers can be made of conventional saturating designs so that enormously high voltages are avoided. If resistor 58 is replaced with a capacitor, integrating control can be achieved or a combination employed.

If the material forming the cylinder 22 has a negative temperature coefficient such as in curve 66 in FIG. 4, it would be necessary to provide an inversion in the variation of current applied to terminal 50 with resistance. The circuitry of FIG. 4 could be readily modified to accomplish this function by an inversion of signal variations as is known in the art.

Referring now to FIG. 5 a modification of the thermal reference of FIGS. 2A and 2B is shown. A cylinder 70 is provided defining an inner cavity 72 and having a gradually curved elbow portion 74. Annular electrical contacts 76 and 78 are attached to either end as before to apply electrical current to the material of cylinder 70. When viewing the cavity 72 from the end of the contact 76, the elbow portion 74 optically closes the cavity 72 with a minimum of distortion to the uniformity of the cylinder 70 and without closing one of its ends. This facilitates providing a uniform heating to the cylinder 70. A similar result may be achieved by a shallow taper to the cavity 20 in FIG. 2B or by other techniques or curves.

While the thermal reference indicated above has been discussed with reference to particular cavity shapes and circuit configurations, modifications departing from these specific patterns may be employed. It is accordingly intended to limit the scope of the invention only as indicated in the following claims.

What is claimed is:

1. A thermal reference comprising:

a generally hollow, cylindrical structure open at each end and formed of an electrically resistive material having a significantly non-zero resistance temperature coefficient;

said cylindrical structure having an elbow curve in a portion thereof whereby an interior surface of said structure occludes the view through said cylindrical structure from end to end;

first and second terminals on said structure at said ends for receiving electrical current;

means for applying electrical current to said structure at said first and second terminals to provide a distributed current through said structure;

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the flow of electrical current through said structure being directly operative to simultaneously affect the temperature, radiation, and resistance of said structure.

2. The thermal reference of claim 1 further including: 5

means for sensing the resistance of said structure between said terminals; and

means for controlling the application of current to said structure to maintain a predetermined resistance for said material. 10

3. A unitary thermal reference source comprising:

an elongated unitary structure open at at least one end and formed of an electrically resistive material having a non-zero resistance temperature coefficient and having a cavity therein terminating at said at least one open end in an aperture from which thermal energy is radiated; 15

first and second electrical terminals affixed and in electrical contact with respective opposite ends of said elongated structure; and 20

means for applying electrical current directly to said structure at said first and second electrical terminals to provide a distributed current flow through said structure; 25

the flow of electrical current through said structure

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being directly operative to simultaneously affect the temperature, radiation and resistance of said structure;

said means for applying electrical current to said terminals further including means for controlling the current applied to said first and second terminals in response to the resistance of said structure between said terminals and operative to maintain said resistance of said structure at a predetermined value.

4. The thermal reference of claim 3 wherein said current controlling means further includes:

a resistive bridge having said structure as one leg thereof connected between said first and second terminals;

means for applying electrical current to a first pair of opposite nodes of said bridge;

means for sensing the potential difference between a second pair of opposite nodes of said bridge; and

means responsive to the sensed potential difference for regulating the current applied to said first pair of opposite nodes of said bridge so as to maintain said sensed potential difference at a predetermined value.

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