Jan. 19, 1954 I. J. BARSY 2,666,799

TEMPERATURE-SENSING METHOD AND UNIT

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Fig. 1

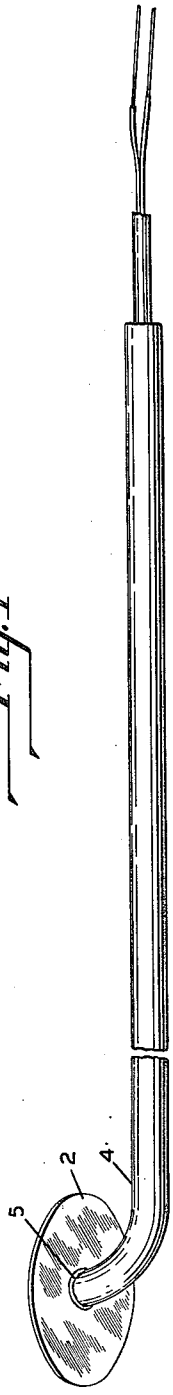
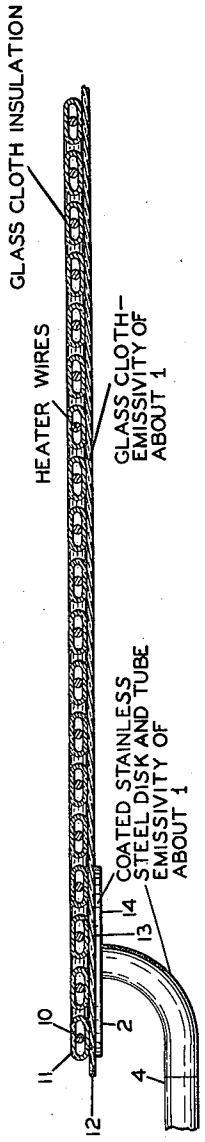


Fig. 2



Fig. 3



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TEMPERATURE-SENSING METHOD AND UNIT

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5 Claims. (Cl. 136—4)

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This invention relates to a temperature-sensing method and unit and is concerned particularly with temperature sensing for radiant heater temperature indication and/or control. Radiant heaters have been developed for industrial applications, and one such application is in the floor covering industry where a foundation or carrier of saturated felt is coated or printed with a film of paint or the like which constitutes the wearing surface of the covering, such paint layer being heated with radiant heaters to fuse, set, or cure the film. In such an application, the control of the temperature at the painted surface is important and cannot be readily effected by conventional sensing units which engage the surface, the temperature of which is to be measured and controlled, for the paint is in a fluid or semifluid condition at the time of heating, and contact therewith is not feasible because such contact would mar the surface of the finished product. As a consequence, it is necessary to effect temperature control by sensing the temperature of the surface of the radiant heater or intermediate the radiant heater and the surface of the material, and it is in this field that the present invention finds particular usefulness.

One type of conventional radiant heater unit is made up of a supporting framework for heater wires which are insulated by being surrounded by tubes of Fiberglas, glass fabric, with a facing of glass fabric stretched tightly over the framework, close to the heater wires and their insulating tubes and interposed between the heater wires and the surface of the material to be heated. This glass fabric layer constitutes a radiating surface. The wires are disposed in turns disposed generally parallel with respect to the direction of travel of the material to be heated, with the heater turns being spaced about five turns per inch. The wire may be Nichrome (nickel-chromium alloy), B & S gauge No. 19, about .036" in diameter. The facing cloth may be woven with twenty-six threads per inch in both the warp and woof directions. The heater wires may be effective for elevating the temperature at the radiating surface of the glass cloth facing within the range of 500° F. to about 750° F. With such temperatures a printed surface disposed closely adjacent to the surface of the glass cloth facing, about two inches therebelow, may attain a temperature within the range of about 300° F. to 350° F. in a short time, depending upon the extent of the radiating surface and the distance from the radiating surface to the printed surface.

In order to maintain a desired temperature at the printed surface, the current input to the

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Nichrome wire heater element may be controlled in accordance with the temperature existing at the radiating surface of the glass fabric layer. Attempts have been made to effect sensing and temperature control with radiant heaters of the spaced turn type by the conventional practice of positioning a thermocouple or a plurality of thermocouples in contact with the glass cloth facing at spaced locations. Since a thermocouple is responsive to the temperature at its thermal junction, accurate control cannot be effected by use of such conventional sensing units for the reason that if the thermocouple junction is disposed within the glass fabric, closely adjacent to a heater wire, the temperature at such point will be substantially higher than the temperature at a point on or within the glass cloth facing spaced intermediate adjacent turns of the heater wire. Such difference may be as much as 50° F. to 75° F. when working in a temperature range between 500° F. and 750° F. at the radiating surface. An average temperature which would be directly correlative to the temperature at the surface of the film of paint being heated thus is not attained.

In order effectively to sense the average temperature at the radiating surface which may be directly related to the temperature at the surface of the film to be heated, it is necessary to have a unit which is effective for sensing the temperature over a plurality of turns of the heater wire and the intervening spaces therebetween and presenting a reproducible average temperature therefrom, regardless of the location of the sensing unit on the effective radiating surface.

Any sensing unit whose indications are wholly or partially dependent upon the transfer of heat by radiation will vary in its response characteristics with any variation in the total emissivity of the unit and will, of course, lead to indications which will not properly establish the temperature existent at the surface of the material to be treated. Such variations in emissivity arise through changes in the characteristics, including color, texture, and composition of the surface of the unit, such changes frequently resulting from oxidation of the surface, enhanced under high temperature operating conditions.

It is an object of my invention, therefore, to provide a sensing unit which will not be subject to variations in response characteristics due to variation in the emissivity of the unit.

It is another object of my invention to provide a temperature-sensing device which will be responsive to an average temperature existent at the surface of a radiator, the temperature of which is nonuniform.

An additional object of the invention is to provide a temperature-sensing method and unit which will operate on the basis of averaging the temperature over a predetermined area of radiating surface, with the averaging means possessing an emissivity substantially equal to that of the radiating surface at which temperature sensing is accomplished.

Another object of the invention is to provide a method of temperature sensing which will provide a thermal response to the average temperature of a radiating surface and will not be subject to deviation due to fluctuation in emissivity of the sensing unit.

Other objects of the invention will become apparent from a consideration of the following description of an embodiment of the invention which is illustrated in the attached drawing and in which:

Figure 1 is a perspective view of a sensing unit embodying the present invention;

Figure 2 is a longitudinal sectional view, partially broken away, of the sensing unit of Figure 1; and

Figure 3 is a diagrammatic view illustrating the practice of the method of this invention in connection with a radiant heater which has been schematically shown.

Referring to the drawing, there is shown a disk of heat-conducting metal 2 having secured thereto a thermal junction 3 and a protective metal tube 4 surrounding the junction 3 and secured to the disk 2, preferably by soldering as indicated at 5. The thermal junction 3 may be formed by joining together an iron wire 6 and constantan wire 7 to form an iron-constantan thermocouple and welding the thermal junction to the disk by a nickel weld, for instance. The wires both may be B & S gauge No. 24, Leeds & Northrup calibration. The individual wires 6 and 7 may be insulated by an asbestos-glass covering 8, and the two wires may be encased within a single outer layer 9 of insulating material such as glass fiber.

The disk may be of circular or other form in outline and should be made of a material which does not change essentially in its physical and chemical characteristics upon heating within the range to which it will be subjected in use. With a device for sensing temperatures in the range between 500° F. and 750° F., as mentioned above, the disk 2 is preferably formed of stainless steel having a chromium content of about 17% to 27%. It may be about ¾" in diameter where the heater turns are disposed about five to the inch, as in the example given above, and the disk may be about .007" thick. It can be thinner, but for practical commercial application, the disk must be of such thickness as to permit handling without excessive distortion, in order to insure good contact with the radiating surface, the temperature of which is to be sensed. If disks of considerably greater thickness are employed, then inadequate speed of response to temperature changes becomes an important factor.

The protecting tube 4 may also be made of stainless steel, 17% to 27% chromium content, having an outside diameter of about ⅛" and a wall thickness of about .020".

The stainless steel disk in its original condition, having a generally mat finish and not highly polished, probably will have an emissivity of about 0.4, estimated from other known emissivities. However, this emissivity factor changes over a period of usage as the disk is heated and cooled,

due primarily to oxidation at the surface; and where accurate sensing is essential, such changes in the emissivity are a factor of importance and must be eliminated or compensated for in the unit responsive to the sensing device. This would require rather complicated compensating arrangements, and it is preferred, therefore, to provide a disk which is substantially stable and does not materially change in emissivity.

Such a disk can be obtained by first providing a substantially uniform surface on a stainless steel disk by etching the disk in a solution composed of 10 grams of ferric chloride, 33 cc. of concentrated hydrochloric acid, and sufficient water to make a total mixture of 120 cc. The stainless steel disk, preferably after attachment to the supporting tube, is dipped in the etching solution, permitted to remain there for about one minute, is then removed, rinsed with distilled water, and dried. Thereupon, the cleaned and finished surface is subjected to treatment in a bath of molten sodium dichromate. Such material heated to a temperature of about 745° F. is effective for changing the surface of the stainless steel, when immersed therein for about twenty to thirty minutes, to a bluish-black surface which has an emissivity of about 1. Where the supporting tube for the disk is of relatively large surface area, it is desirable to provide a similar finish on it in the area of the disk. This may be effected by treating the disk and tube in the molten sodium dichromate subsequently to assembly to provide a surface which has an emissivity of about 1 on both the disk and the desired portion of the tube, as indicated in Figure 3.

In place of a stainless steel disk, a silver disk may be employed which may be plated with platinum black in the conventional manner. This may be accomplished by mixing together 3 grams of platinic chloride, .02 gram of lead acetate, and 100 cc. of water. The piece to be plated and a strip of platinum are disposed in this solution, and a voltage between six and twelve volts at .15 to .20 ampere is applied to the piece as cathode and to the platinum strip as anode until a black plating of the desired depth is obtained on the piece. By using twelve volts at .20 ampere a relatively coarse-grained plating is obtained, which is preferred. This provides, after rinsing with distilled water and air drying, a surface coating which gives the disk an emissivity of about 1. This plating is not as permanent as the surface obtained on the stainless steel with the molten sodium dichromate treatment; and, in use of the device where the platinum black plated surface is employed, care must be exercised to avoid damage to the surface plating.

A platinum disk may be employed and it may be plated with platinum black, generally in the manner described above for the silver disk.

For uses where a mismatch in emissivity characteristic may be tolerated, plain uncoated heat-conducting metal disks such as silver, copper, platinum, brass, stainless steel, or the like may be employed, so long as they are not deleteriously affected by the temperatures encountered in use. For instance, a copper disk cannot be successfully used with temperatures in the order of 500° F. to 750° F., for the copper tends to oxidize and the oxide flakes under service conditions.

Figure 3 illustrates a method of temperature sensing employing the sensing device of Figures 1 and 2. In Figure 3 a radiant heater has been

shown in schematic cross section and includes heater wires 10 which are disposed within sleeves of glass fabric insulation 11. A facing 12 of glass cloth is stretched below the heater wires 10 and may lie in engagement with the insulating sleeves 11. The glass cloth facing 12 is a radiating surface which has a black body emissivity characteristic of approximately 1. This emissivity is approximately equal to the emissivity of the stainless steel disk with the surface oxide obtained by treatment in molten sodium dichromate, as described above.

The disk is placed with its upper flat surface 13 in thermally conductive contact with the glass fiber radiating surface 12 of the heater (by light pressure application), and the lower surface 14 of the disk is exposed to air at appreciably lower equilibrium temperature than the radiating surface. By having the disk of the sensing unit provided with an emissivity substantially equal to that of the radiating surface 12, the thermocouple which is attached to the disk responds substantially directly to the temperature of the radiating surface; and such response does not change during service, for the emissivity of the disk is substantially constant at any given temperature and does not change as would a silver or stainless steel disk upon progressive chemical change of its surface.

It will be noted that the disk 2 extends over a plurality of turns of the heater wires 10, and thus the junction 3 which is disposed in the center of the disk is not materially affected by the position it assumes with respect to any individual heater wire, the disk being a good conductor of heat.

In order to secure a substantially uniform application of light pressure to the surface of the glass cloth 12 by the disk 2, preferred practice is to pivot the holder 4 and apply a predetermined pressure by counter-weighting or otherwise.

While in the embodiment chosen for illustration there is shown a single thermal junction which may be effective for indicating or initiating a suitable control, where both indication and control are desired, it is possible to provide a multiple junction in the conventional manner. While the disk has been shown as circular, it may be made of other shape. Also, it is not necessary that the disk be mounted upon a holder, for in some uses the disk may be actually sewn or otherwise fastened to the glass cloth radiating surface. Preferred practice is to coat the disk on all of its surfaces either by electroplating or oxidizing in the manner referred to above, but it will be obvious that the essential requirement is that the radiating surface, that is the surface which is not in contact with the radiating surface of the heater unit, should have the coating or plating to preferably provide an emissivity substantially equivalent to the emissivity of the radiating surface of the heater unit, such as the glass cloth facing shown in Figure 3. Where platinum is used as the disk, the problem of change in emissivity due to oxidation is not a factor, but, of course, the emissivity of the disk will not be substantially equivalent to that of a glass cloth radiator; and if matching emissivities are desired, then the platinum may be plated with platinum black as mentioned above.

The method of the invention is particularly applicable to the sensing of the temperature of a radiating surface which is heated by spaced turns of heater wire, such as the radiant heater unit

of Figure 3 for example. The heat-conductive sensing device which has an emissivity which matches that of the radiating surface is pressed into engagement with the radiating surface under predetermined pressure, and there is thus obtained a response by the temperature sensing which is reproducible and is directly related to the average temperature of the radiating surface, requiring no compensation at the unit responsive to the sensing device for differences in emissivity between the sensing unit and the radiating surface.

I claim:

1. A thermo-responsive device comprising a disk of heat-conducting metal having an emissivity substantially less than 1, said metal disk having a flat surface for contact with a heated surface the temperature of which is to be sensed and an opposite flat surface constituting a heat-radiating surface subject to radiation losses, a substantially stable surface layer on said heat-radiating surface of said disk having an emissivity of about 1, and a thermo-responsive element attached to said disk and responsive to the temperature thereof.

2. A thermo-responsive device comprising a thin disk of stainless steel having an emissivity substantially less than 1, said stainless steel disk having a flat surface for contact with a heated surface the temperature of which is to be sensed and an opposite flat surface constituting a heat-radiating surface subject to radiation losses, an oxide coating layer on said heat-radiating surface of said disk having an emissivity of about 1, and a thermo-responsive element attached to said disk and responsive to the temperature thereof.

3. A thermo-responsive device comprising a thin disk of silver having an emissivity substantially less than 1, said silver disk having a flat surface for contact with a heated surface the temperature of which is to be sensed and an opposite flat surface constituting a heat-radiating surface subject to radiation losses, a platinum black coating layer on at least the surface of said heat-radiating surface of said silver disk and providing an emissivity of about 1, and a thermo-responsive element attached to said disk and responsive to the temperature thereof.

4. In a method of determining the average temperature of a radiant heater unit having a radiating surface, the steps comprising placing in direct contact with said radiating surface a temperature-sensing element including a heat-conducting metal member possessing an emissivity substantially less than that of said radiating surface, said metal member having a substantially stable coating on at least the surface thereof subject to radiation losses, which coating possesses an emissivity substantially matching that of said radiating surface, and sensing the average temperature of said radiating surface directly from the temperature of said sensing element.

5. In a method of determining the average temperature of a radiant heater unit having spaced turns of heater wire and a glass cloth radiating surface with an emissivity of about 1 heated thereby, the steps comprising placing in direct contact with said glass cloth radiating surface and spanning a plurality of turns of said heater wire a temperature-sensing element including a heat-conducting metal disk possessing an emissivity of substantially less than 1, said disk having a substantially stable coating on at least the surface thereof subject to radiation losses, which coating possesses an emissivity of about 1, substantially matching the emissivity

of said glass cloth radiating surface, and sensing the average temperature of said glass cloth radiating surface directly from the temperature of said sensing element.

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