A high intensity electrical heater for industrial heating, drying or curing applications. The heater comprises a container within which is disposed a heating element and a silicon carbide face sheet having its one side provided with an electrically non-conductive and chemically non-reactive refractory coating or refractory cement, which is adjacent to said heating element.

9 Claims, 1 Drawing Figure

Primary Examiner—Volodymyr Y. Mayewsky
Attorney, Agent, or Firm—Leo C. Krazinski
ELECTRICAL INFRARED HEATER WITH A COATED SILICON CARBIDE EMITTER

DETAILED DISCLOSURE

This invention relates to improved electrical heating units or modules suitable for industrial heating, drying or curing applications and, more particularly, to high intensity electrical heat radiation units comprising, inter alia, infra red radiant heating elements and silicon carbide face sheets or emitters coated on the side which is adjacent to the heating elements, with an electrically non-conductive and chemically non-reactive refractory coating or cement.

Prior to the subject invention silicon carbide had not been used as face sheet or emitter material in electrical heaters in conjunction with non-integral heating elements. Instead, quartz or ceramic materials have been so employed. Silicon carbide is, of course, not unknown as building material for the construction of heaters. However, silicon carbide found application as an ingredient in electrical heating or resistance element compositions, as disclosed in, e.g., U.S. Pat. Nos. 3,518,351 and 3,009,886, etc., as an emissive coating applied to refractory materials, as shown in, e.g., U.S. Pat. No. 3,404,031, and conventionally as face material in gas-fired radiant infra red heaters due to its uniform porosity which facilitates the metering and burning of the gas on the surface.

However, as stated above, quartz and ceramic materials rather than silicon carbide have been employed in electrical heaters as face sheets or emitters adjacent to conventional nickel/chromium and/or iron/chromium/aluminum wire elements. The reasons for this, in spite of the fact that silicon carbide would be an extremely efficient and suitable face sheet because of its properties as an excellent emitter in the infra red spectrum, are as follows:

Commercial grade silicon carbide is a relatively poor electrical insulator, that is, it conducts electricity both along its surface and through its thickness and it is thus a good enough conductor to cause the wire element to arc against the silicon carbide face sheet, thereby shorting out the element. In addition, the impurities found in silicon carbide plates may also tend to cause dead shorts to ground through the plate at normal operating voltages.

Chemically, silicon carbide reacts at high temperatures with both nickel/chromium and iron/chromium/aluminum, the main alloys used in electrical wire element manufacture. While this chemical reaction does not pose an electrical problem, the accelerated deterioration and corrosion of the wire element results in a drastically limited life culminating in an open element.

Accordingly, it is the primary object of this invention to provide an improved silicon carbide face sheet or emitter which can be used in conjunction with electrical wire elements in heaters without the drawbacks and liabilities pointed out above.

Other objects and advantages accruing from the present invention will become apparent as the description proceeds.

The objects of this invention are accomplished by providing silicon carbide face sheets or emitters with certain refractory coatings or cements on the side which is adjacent or in intimate contact with the wire element. Such coatings or cements which have to be electrically non-conductive and chemically non-reactive, render the silicon carbide face electrically neutral and prevent chemical interaction between the live wire elements and the silicon carbide face. The potential advantages of silicon carbide as a face material in an electrical heater adjacent or in contact with the wire elements, and in particular, its high emissivity in the infra red spectrum, can then be fully realized with such a coating.

A heating unit containing such a coated silicon carbide emitter is extremely durable and efficient. It is less susceptible to breakage because of impact than, for instance, conventional heaters with quartz or ceramic emitters. Heaters equipped with coated silicon carbide emitters also have the capability of operating at a very high watt density, e.g., 4,000 w/sq.ft. (which is equivalent to 13,648 B.T.U./ sq. ft./hr.) and higher.

The material for coating the underside of the silicon carbide emitter, that is, the side which is adjacent to or in contact with the wire element, can be chosen from among any of the commercially available or otherwise well-known refractory coatings or cements which will constitute a barrier and isolate, both electrically and chemically, the live wire element from the silicon carbide emitter.

In order to provide an effective electrical and chemical barrier and prevent substantially all electrical and chemical interaction, the refractory coatings or cements chosen must possess certain indispensable properties and characteristics and maintain them under the conditions of use and operation, in particular, at high temperatures of, e.g., about 2,000°F.

First of all, these refractory materials must have a melting point of at least about 2,500°F. Secondly, they must exhibit excellent hardness and abrasion resistance characteristics and possess a hardness of at least about 1,000 Knoop. (That of silicon carbide is 2,130–2,140 Knoop.)

Thirdly, as regards dielectric properties, they should preferably be non-conductive but in any event satisfy the minimal requirement of dielectric strength of at least about 400 v/mil. Next, there is a requirement in terms of coefficient of expansion which should not exceed the range of about 4.0 × 10⁻⁶ to 5.8 × 10⁻⁶. (The silicon carbide herein must have a coefficient of expansion within the same range.) Lastly, the thermal conductivity of these refractory materials is important: it should be as high as possible but not less than about 10 B.T.U./hr./sq. ft./°F/fin.

Illustrative of refractory coatings which exhibit these requisite characteristics are calcium zirconate, zirconium silicate, and magnesium zirconate and chromium oxide; with magnesium zirconate and chromium oxide (in both chromic and chromous form) being particularly preferred.

Other examples of suitable refractory coatings can readily be selected by men skilled in the art from e.g., the listing of "Refractory Coatings" which appears on p. 113 of the "Flame Spray Handbook," Vol. III, published by Metco Inc., 1965 and from the "Materials Selector," p. 467, 1972.

The above-mentioned refractory coatings are in the form of dry powdery materials. It is also possible to employ liquid based refractory cements, such as bonded mixtures comprising Al₂O₃ and SiO₂, exemplified by Mullite (3 Al₂O₃ · 2 SiO₂); Fiberfrax coating cement QF 180, sold by the Carborundum Co., of the following...
chemical composition: Al₂O₃—41 percent, SiO₂—57 percent, Na₂O—0.8 percent, B₂O₃—0.6 percent, MgO—0.4 percent, Fe₂O₃—0.04 percent, and traces 0.2 percent; Fiberfrax coating cement QF 180 Blue, sold by the Carborundum Co., of the chemical composition: Al₂O₃—38 percent, SiO₂—60 percent, Na₂O—0.8 percent, B₂O₃—0.6 percent, MgO—0.4 percent, Fe₂O₃—0.04 percent, and traces 0.2 percent; Fiberfrax coating element QF 150, sold by the above company, of the following chemical composition: Al₂O₃—44 percent, SiO₂—54 percent, Na₂O—0.8 percent, B₂O₃—0.6 percent, MgO—0.4 percent, Fe₂O₃—0.04 percent and traces 0.2 percent.

Alfrax coating cement No. 3449, likewise sold by the Carborundum Company of the following chemical analysis: Al₂O₃—92.1 percent, SiO₂—6.4 percent, Fe₂O₃—0.1 percent, TiO₂—0.2 percent, CaO—0.2 percent, K₂O—0.1 percent, Na₂O—0.9 percent; and Kao-wool cement, sold by Babcock & Wilcox Corp. of the following chemical constitution: Al₂O₃—41 percent, SiO₂—57 percent, Na₂O—0.8 percent, B₂O₃—0.6 percent, MgO—0.4 percent and traces 0.2 percent.

In the following table, several of the above mentioned refractory coatings and cements are exemplified in terms of the critical characteristics according to the concept of this invention.

<table>
<thead>
<tr>
<th>Material</th>
<th>Melting point (°F)</th>
<th>Hardness (Knoop)</th>
<th>Dielectric strength (x/mil)</th>
<th>Thermal conductivity (Bt.u./hr./ft.°F/F/in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium oxide</td>
<td>3,000</td>
<td>1,900</td>
<td>1</td>
<td>0.5 x 10⁻⁴</td>
</tr>
<tr>
<td>Zirconium silicate</td>
<td>3,000</td>
<td>1,000</td>
<td>1</td>
<td>4.2 x 10⁻⁴</td>
</tr>
<tr>
<td>Mullite</td>
<td>3,000</td>
<td>1,000</td>
<td>1</td>
<td>6.5 x 10⁻⁴</td>
</tr>
<tr>
<td>QF180 (kiln-fired)</td>
<td>3,900</td>
<td>1,400</td>
<td>400</td>
<td>6.3 x 10⁻⁴</td>
</tr>
<tr>
<td>Alfrax 3449 (kiln-fired)</td>
<td>3,600</td>
<td>1,000</td>
<td>400</td>
<td>0.1 x 10⁻⁴</td>
</tr>
</tbody>
</table>

1. Non-conductive.

Depending upon the type of material employed, the barrier coating can be applied by several methods, e.g., flame spraying, plasma flame spraying or ordinary brush, airspray or roller coating, as well as silk screening. For instance, when using a dry powdered refractory coating material, such as zirconium silicate or chromium oxide, a flame spray or plasma spray technique is more suitable; with a liquid-based refractory cement, however, brushing, airspray or roller coating or silk-screening will be utilized with the handling characteristics of the solution or slurry determining the most appropriate application technique.

Furthermore, it is important to keep in mind that barriers made of liquid-based refractory cements have to be kiln-fired to achieve the required degree of hardness, i.e., a hardness of at least 1,000 Knoop. Kiln-firing at about 1,900°F for about 4 hours or equivalent time/temperature conditions will accomplish this hardness objective.

The coating of the underside of the silicon carbide emitter should be of a thickness of about 1 to 5 mils to preferably about 3 mils. A chromium oxide coating of a 3 mil thickness withstands, for example, a potential of 2,000 volts on a Beckman 2A insulation tester.

The silicon carbide face sheet or emitter is manufactured by molding and can therefore be formed into almost any desired surface configuration. For example, both sides can have a smooth or straight face or the inside face can be molded to form a raceway or path into which the elements are recessed. Yet another form would be a pattern of stand-offs which function as pins around which the wire is guided and held in a particular element configuration. As will be obvious to men skilled in the art, many other configurations are possible, depending on the over-all design and function of the heating unit. This face sheet is typically one-half inch thick but may of course be thinner or thicker. In all instances, however, the coating of that side of the silicon carbide emitter which is to be adjacent or in close contact with the wire heating element, is accomplished prior to assembly of the heating unit.

The subject invention will be better understood from the following non-limitative examples and the appended drawing of improved heating units containing according to the concept of this invention novel coated silicon carbide emitters in combination with other conventional constituents of the electrical heaters.

In the appended drawing, the single FIGURE illustrates a heating unit according to this invention.

**EXAMPLE 1**

A high intensity electrical heating unit, 230V, 8KW, 35A 10, was constructed consisting of the following parts: a metal case 1; a first molded insulation block 2 consisting of hardened Kaowool insulation supplied by Babcock and Wilcox, its chemical constitution being the following: alumina 47 percent, silica 52.9 percent, iron oxide 0.05 percent and titania magnesia calcia, alcalis and boric anhydride 0.07 to 0.15 percent with recesses 3 for the wire heating elements 4 made of No. 15 Kanthal A-1 wire supplied by the Kanthal Corp. consisting of iron 72 percent, chromium 22 percent, aluminum 5.5 percent and cobalt 0.5 percent, eight passes, a second molded insulation block 5, consisting of soft Fiberfrax insulation supplied by the Carborundum Co. and consisting of alumina 51.7 percent, silica 47.6 percent, sodium oxide 0.3 percent, barium oxide 0.15 percent and iron oxide 0.02 percent, traces 0.2 percent, and a back-up insulation block 6, being 20 K insulation material supplied by C. E. Refractories and consisting of alumina 45.1 percent, silica 51.9 percent, iron oxide 1.3 percent, titania 1.7 percent; magnesia trace, calcium 0.1 percent, alcalis 0.2 percent, boric anhydride 0.08 percent; and a one-half inch silicon carbide face sheet 7 provided with a chromium oxide coating 8 on the underside in contact with the first insulation block 2 and the wire elements 4; insulators 9 between the wall of the metal case 1 and the silicon carbide face sheet consisting of Fiberfrax paper, one-sixteenth inch thick, supplied by the Carborundum Co. of the same chemical constitution as the above-mentioned soft Fiberfrax insulation; and Lips 10 integral with the top of the case walls to hold down the silicon carbide face sheet 7.

The chromium oxide coating was applied on the silicon carbide face sheet by flame coating to a thickness of 3 mils.
During a 1-month test period with a 1-hour-on, 1-hour-off cycle, this unit performed very well with the following results: measured Voltage = 235V, measured Current = 36.6A, measured wattage = 8.6 KW or 4.3KW/sq ft; thermocouple temperature range from 260° to 1,710° F; maximum face temperature 1,200° F; no apparent leakage to the ground; no element overheat; no peeling or spalling and no rusting.

EXAMPLES 2 and 3

Two heater units were constructed similar to the unit described in Example 1, the differences being the following: it had 5 passes of Kanthal A-1 wire and operated with 5.5 KW and the refractory coating material was Carborundum's QF 180, in one unit, and Carborundum's Alfrax No. 3449, in the other, both having been applied to the underside of the silicon carbide face sheet in liquid form with a brush. These coatings were then air dried and then fired in a kiln at approximately 2,100° F for about 4 hours. These units were operated with good results for a 30 day test period with a cycle of 1 ½ hours on and 1 ½ hours off.

It is to be understood that the above examples and the appended drawing are only illustrative of the invention and many variations and modifications may be effected without departing from the scope thereof.

What is claimed is:

1. A high intensity electrical infra red heater comprising, in combination, a silicon carbide sheet, an electrically non-conductive and chemically non-reactive barrier sheet bonded to one side of said silicon carbide sheet, an electric heating element adjacent to said barrier sheet for heating said silicon carbide sheet, a thermally and electrically insulating sheet supporting said heating element, and an open ended container enclosing and carrying said insulating sheet, heating element, barrier sheet and silicon carbide sheet.

2. A high intensity electrical infra red heater according to claim 1, wherein said heating element is in contact with said barrier sheet.

3. A high intensity electrical infra red heater according to claim 2, wherein said barrier sheet consists of a refractory cement.

4. A high intensity electrical infra red heater according to claim 3, wherein said refractory cement has a melting point of at least about 2,500° F, a hardness of at least about 1,000 Knoop, a dielectric strength of at least about 400 v/mil, a coefficient of expansion ranging from about 4.0 x 10⁻⁴ to 5.8 x 10⁻⁴, and a thermal conductivity of not less than about 10 B.T.U./hr/sq ft./° F/in.

5. A high intensity electrical infra red heater according to claim 4, wherein said refractory cement is selected from among calcium zirconate, zirconium silicate, magnesia zirconate and chromium oxide.

6. A high intensity electrical infra red heater according to claim 5, wherein said refractory cement is chromium oxide.

7. A high intensity electrical infra red heater according to claim 3, wherein the refractory cement is a bonded mixture comprising Al₂O₃ and SiO₂.

8. A high intensity electrical infra red heater according to claim 7, wherein said refractory cement is kiln-fired after being coated and dried on the silicon carbide.

9. A high intensity electrical infra red heater according to claim 1, wherein said barrier sheet has a thickness of about one to five mils.

* * * * *