

Nov. 17, 1959

P. BORGHULT ET AL

2,913,695

ELECTRIC RESISTANCE HEATING ELEMENTS

Filed July 5, 1956

5 Sheets-Sheet 1

Fig. 1

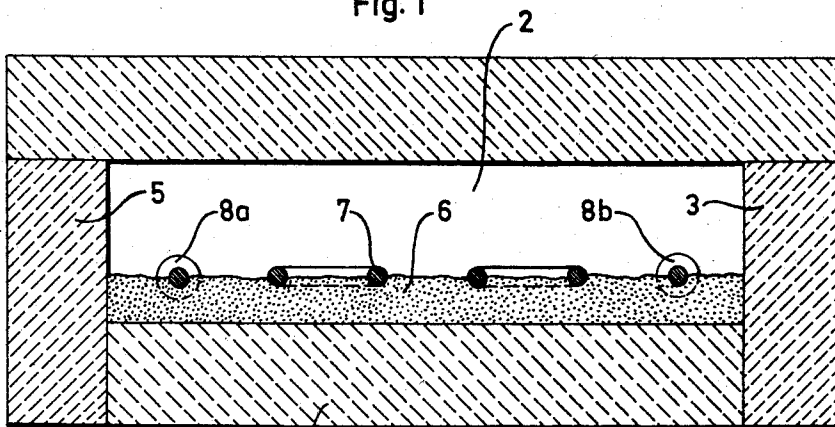
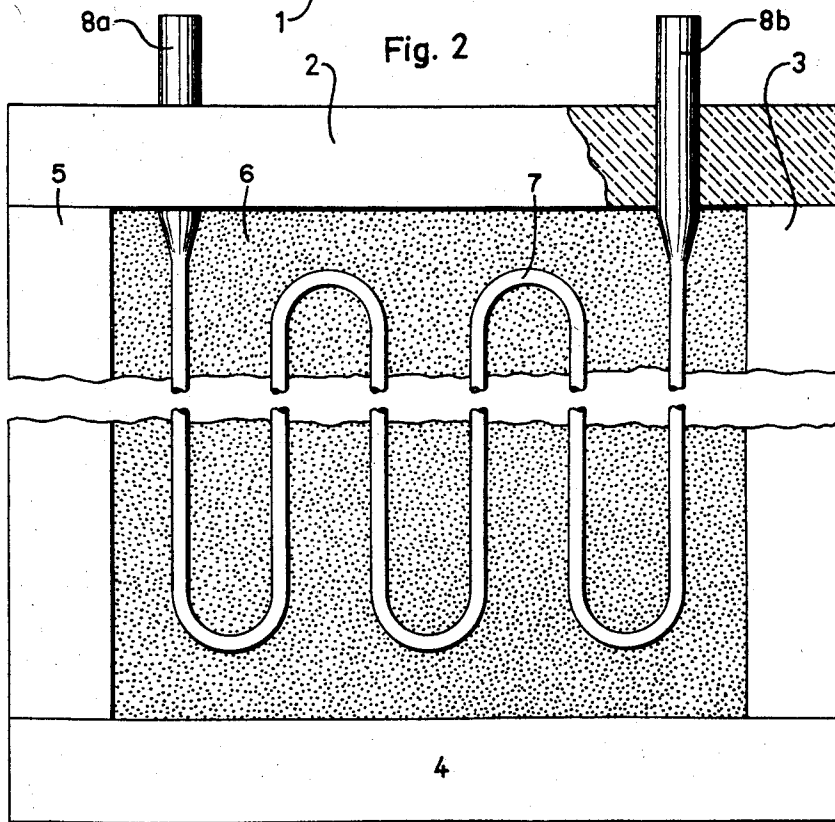


Fig. 2



INVENTORS
PER BORGHULT &
JOHN HELGE HAGLUND
BY
Braser, Smith & Hardy
ATTORNEYS

Nov. 17, 1959

P. BORGHULT ET AL

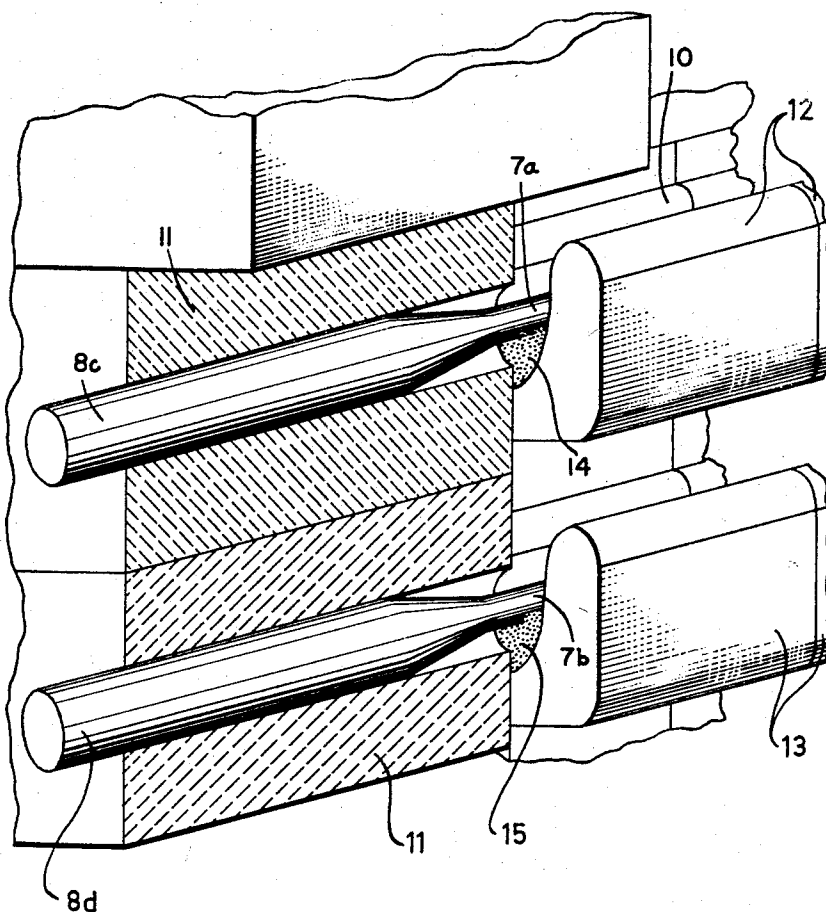
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Fig. 3



INVENTORS
PER BORGHULT &
BY JOHN HELGE HAGLUND
Buss, Smith & Hardy
ATTORNEYS

Nov. 17, 1959

P. BORGHULT ET AL

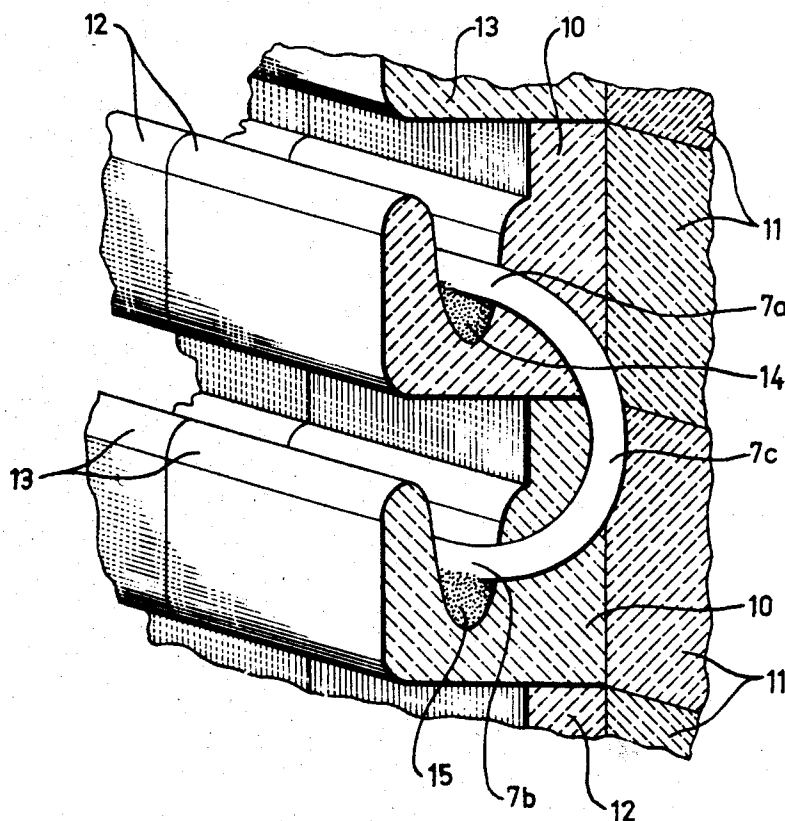
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Fig. 4



INVENTORS
PER BORGHULT &
JOHN HELGE HAGLUND
BY *Buss, Smith & Hardy*
ATTORNEYS

Nov. 17, 1959

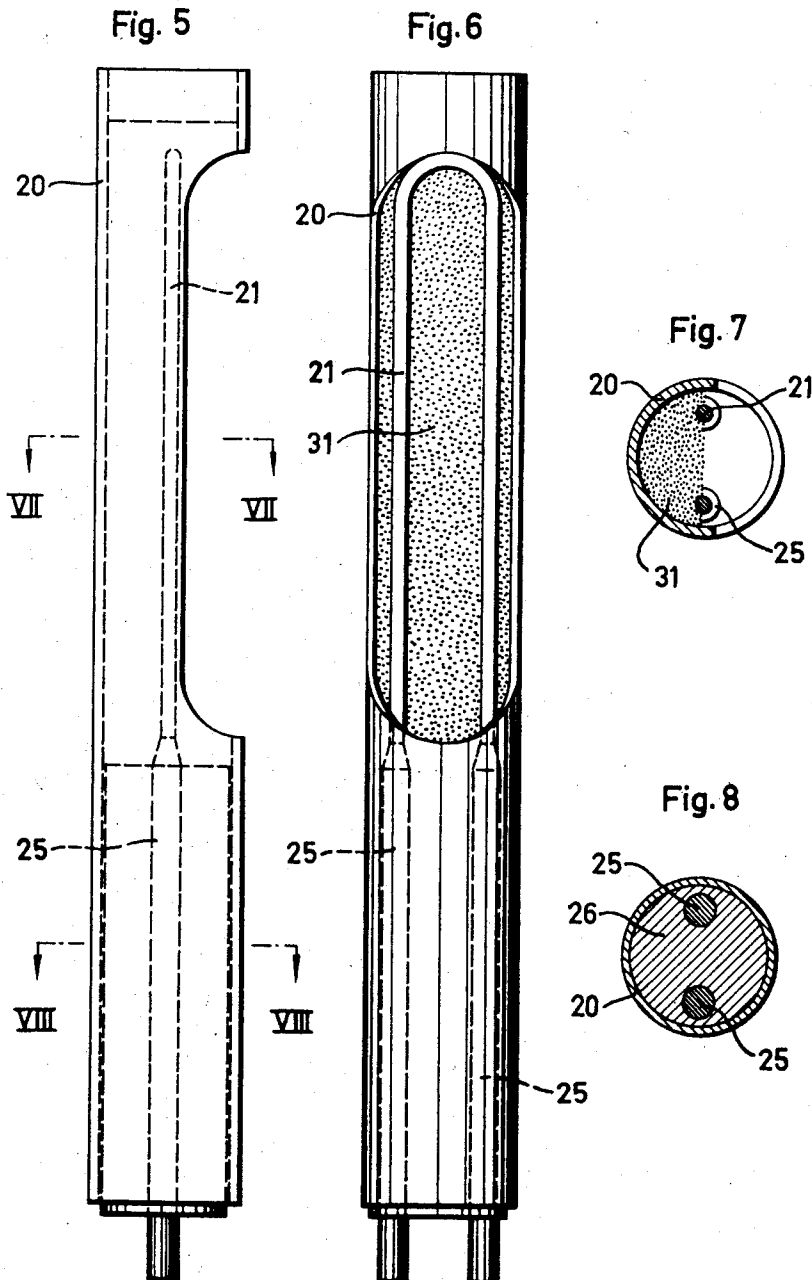
P. BORGHULT ET AL

2,913,695

ELECTRIC RESISTANCE HEATING ELEMENTS

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INVENTORS
PER BORGHULT &
BY JOHN HELGE HAGLUND
Bauer, Smith & Harding
ATTORNEYS

Nov. 17, 1959

P. BORGHULT ET AL

2,913,695

ELECTRIC RESISTANCE HEATING ELEMENTS

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Fig. 9

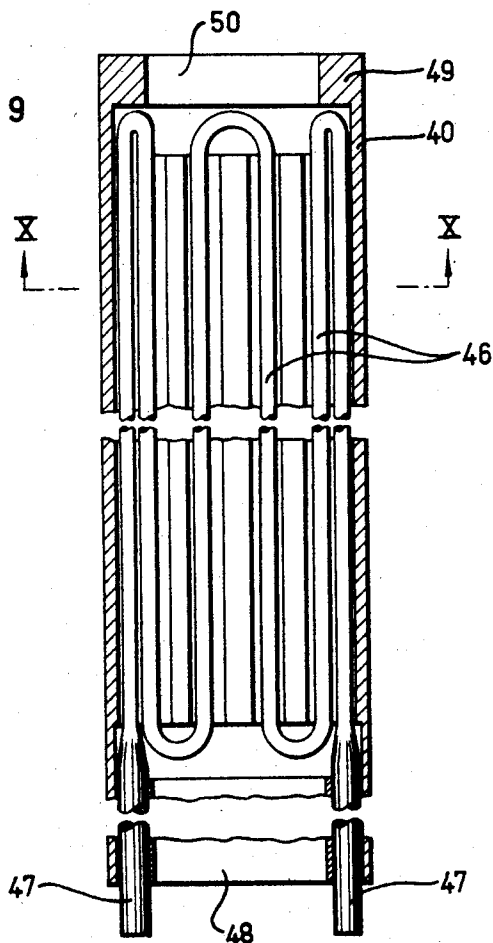
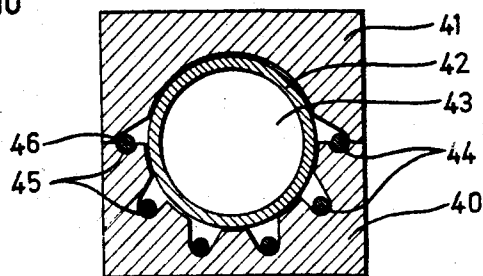


Fig. 10



INVENTORS
PER BORGHULT &
BY JOHN HELGE HAGLUND
Bruce, Smith & Harding
ATTORNEYS

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2,913,695

ELECTRIC RESISTANCE HEATING ELEMENTS

Per Borghult, Enskede, and John Helge Haglund, Hallstahammar, Sweden, assignors to Aktiebolaget Kanthal, Hallstahammar, Sweden

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13 Claims. (Cl. 338—317)

The present invention relates to mounting arrangements for electric resistance heating elements for electric resistance furnaces operating at temperatures above 1000° C., preferably however, up to at least 1400° C.

It has already been proposed to use, for operating temperature of this order of magnitude, resistance elements which have been produced in a powder metallurgical process, mainly from silicides, especially molybdenum silicide, possibly with a residue of oxides, carbides, such as silicon carbide, and borides, in which process there may be used as the metallic constituent, in addition to molybdenum, one or more of the elements Ti, Zr, V, Nb, Ta and Cr (titanium, zirconium, vanadium, niobium (columbium), tantalum and chromium). When heating such resistance elements to elevated temperatures, due to the action of the oxygen contained in the air, there will form on the same a superficial layer of silicon dioxide which is slightly plastic and sticky at elevated temperatures so as to sinter together into a gastight film which prevents further oxidation of the interior of the element.

Resistance elements made of such materials have fairly limited mechanical strength characteristics which have, in the past, placed the user before the alternative of either supporting the elements at a plurality of locations, or producing the same in lengths which are frequently too short as compared to the furnace dimensions concerned. If, in accordance with the common practice in the field of metallic resistance elements, an attempt is made to support elements of the type above referred to directly upon the refractory liner of the furnaces, this will result in that the elements stick to the liner and will be pulled apart on thermal expansions occurring since they are not freely movable. Such sticking, in addition to the action of the silicon dioxide film, may also be caused by the fact that the material of the elements have often a tendency to react chemically with the base material while forming reaction products having softening temperatures which are lower than the operating temperature of the elements. It should be noted in this connection that this sticking is not at all tied up with the degree of refractoriness of the liner material per se.

In order to avoid the drawback referred to, attempts have been made to mount the elements in cantilever-fashion so that there would be no direct contact between the elements and the refractory material within the heating zones of the elements. However, this necessitates that high demands must be placed on the mechanical strength characteristics of the elements which may lead to dimensions which are impractical from an electrical point of view.

The present invention has for its object to overcome the drawback referred to and mainly resides in that the resistance element, composed substantially of silicides, preferably molybdenum silicide, possibly with a residue of oxides, carbides and borides, is loosely sup-

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ported on a bed which is only in partial contact with the element and which consists of relatively movable grains of a refractory and electrically insulating material which is chemically resistant to the material of the resistance element, also at the operating temperatures concerned. This arrangement provides for a positive and satisfactory support for the elements, and the supporting bed acts to prevent the same from sticking to the furnace liner or refractory walls. The grains of the bed should be of a refractoriness sufficient to maintain the free mobility between the single grains up to a temperature of at least 1000° C., and in any case up to the operating temperature concerned. It is preferable that the grain quality should ensure the free mobility relative to each other up to a temperature of at least 1400° C. Owing to the fact that the material of the bed is chemically resistant to the material of the elements, the latter will be protected against chemical attacking at the points at which they contact the bed. Owing to the fact that the electrical resistance of the bed material is sufficiently high, no leakage currents in the bed will be capable of causing injury to the elements at their contact points with the bed. Due to the remaining requirements which are placed on the material of the bed as regards refractoriness and resistance to chemical attack, no difficulty will be encountered, as a rule, in satisfying also the demand for a high electrical resistance.

In operation some of the grains in the portion of the bed immediately adjacent the element will stick to the silicon dioxide film of the latter. When subsequently the length of the element changes due to temperature variations, the grains thus stuck to the element will move together with the element and will thus slide over the readily movable grains of the bed which do not stick to the element. In this way the element will be relieved of any destructive mechanical strains.

In accordance with the invention, the bed material may suitably consist of one or more of the following substances, viz. silicon dioxide, silicon carbide or aluminum silicate. Particularly satisfactory results have been obtained using a bed of mullite or sillimanite. It is to be understood, however, that the invention is not restricted to the employment of a bed material of this composition, since it is possible to use any desired heat-resistant material having a high electric resistance. However, the bed material must consist of substances which, even at the highest operating temperature concerned, remain chemically indifferent against the material of the resistance element so that no reaction products will form. The substances which, in the broadest aspect of the invention, may be comprised in the supporting bed for the resistance elements are: carbides, borides, silicides, silicates and oxides, either singly or in combination with each other.

The major part of the grains of the supporting bed should be spherical in shape, or should have beaded edges and corners, at least, so as to facilitate their relative mobility. The grains should be screened into definite granular fractions through different screens sized, for instance, according to the Tyler standard screen scale, it being preferable that the grains of each bed should be of one single granular fraction ranging, for instance, between two adjacent mesh numbers, or should be of two adjacent granular fractions, at least, for instance one fraction having grain sizes ranging from 6 to 8 mesh, and one adjacent fraction having grain sizes ranging from 4 to 6 mesh. It is understood, of course, that the average grain size should be so selected as to afford satisfactory support for the resistance element. It has been found that, in order to make the bed serve its intended purpose satisfactorily, its thickness should be at least,

twice the average diameter of the grains contained in the bed. As a general statement, the grain sizes of the bed particles should range between a minimum of 0.004" and a maximum of 0.4" (0.1 to 10 mm.).

It has been found that if the resistance elements are supported in accordance with the teachings of the present invention, the elements can be used also in conjunction with furnace liners which, when directly contacted by the elements, would subject the elements to destructive actions. Thus the present invention makes it possible to use refractory liner materials of a standard quality selected exclusively taking into account its refractoriness while disregarding any tendency of the material to react chemically with the element material at elevated temperatures.

Practical embodiments of the invention as applied to the manner of mounting resistance elements in furnaces, are illustrated in the accompanying drawings in which:

Fig. 1 is a vertical section through the bottom portion of a furnace whereas

Fig. 2 is a corresponding plan view shown partly broken away;

Figs. 3 and 4 are perspective scrap views showing a resistance element disposed on shelves formed on the internal wall surfaces of a furnace;

Fig. 5 is a side elevational view; and

Fig. 6 is a top end view of a supporting tube for a horizontally extending resistance element, while

Figs. 7 and 8 are cross-sections taken along the lines VII—VII and VIII—VIII, respectively, in Fig. 5;

Fig. 9 is a top plan view of the lower half of the refractory liner of a tube-type furnace; and

Fig. 10 is a cross-section through the refractory liner, taken along the line X—X in Fig. 9.

In the embodiment illustrated in Figs. 1 and 2, the bottom 1 and side walls 2 to 5 of the furnace are made of a refractory material. Disposed on the bottom 1 is a bed 6 of a granular material consisting of aluminum silicate of the approximative composition 65% Al_2O_3 and 35% SiO_2 . Supported half-way immersed into the bed 6 is a heating resistance element 7 consisting of 95% molybdenum silicide (MoSi_2), the balance to 100% consisting of oxides and silicates. The resistance element is formed at its ends with enlarged terminal portions 8a, 8b passed through holes made in the wall 2. The high-temperature heating zone proper of the element 7 is formed by the smaller-diameter part thereof whereas its terminal portions 8a, 8b will be at a considerably reduced temperature due to their larger cross-sectional area.

It would be possible, instead of using aluminum oxide and silicon dioxide in the form of aluminum silicate as referred to above, to use pure granular silicon carbide of grain sizes ranging between 0.08 and 0.2 inch (2 to 5 mm.). It is suitable to use the so-called light green silicon carbide since this is the purest form technically available.

As an alternative, a still further bed material may be employed, viz. powder metallurgically produced 0.16" (4 mm.) pellets containing 15% by weight of very finely divided MoSi_2 and 82% by weight of silicon carbide.

As a further example of carrying the invention into effect the case may be mentioned, in which the resistance element 7 is composed of 90% by weight of MoSi_2 , 5% by weight of chromium boride (CrB), the balance being a binder, and the bed 6 consists of pure crushed quartz in the form of screen separated grains ranging in size between 0.12" and 0.16" (3 to 4 mm.).

If, on the other hand, the bed material is pure aluminium dioxide (Al_2O_3) instead of aluminium silicate as referred to, then it has been found to react with the silicon contained in the resistance element material so as to form a silicate therewith which will gradually impoverish the element in silicon causing destruction of the resistance element. Such a selection of material for the bed, therefore, would not be compatible with the condi-

tion stipulated that the bed material must be chemically resistant to the material of the resistance element.

In the embodiment illustrated in Figs. 3 and 4, the refractory wall 10 is disposed as a liner on the internal surface of a supporting brick wall 11 and is formed on its surface facing the furnace chamber with shelves 12, 13, etc. Disposed on these shelves are granular beds 14, 15, etc., and resting on the latter are two branches 7a, 7b, respectively, of the resistance element. These branches are interconnected by a cantilevered intervening portion 7c. Fig. 3 illustrates the enlarged terminal portions 8c and 8d of the resistance element.

In the embodiment illustrated in Figs. 5 to 8 which is adapted for mounting horizontally extending resistance elements, the resistance element 21, being bent into a hairpin-like configuration, rests on a supporting bed of a granular, electrically insulating material disposed in the tube 20, this material being refractory and chemically resistant to the material of the resistance element, also at the operating temperature concerned. The electric resistance of the bed 31 should be sufficiently high to prevent the formation of any noticeable leakage currents. The material of the bed, as mentioned hereinbefore, has a refractoriness such as to allow the grains to conserve their relative mobility even at the highest temperatures concerned thereby providing for free thermal expansion and contraction lengthwise of the resistance element relative to the supporting tube.

The enlarged terminal portions 25 of the resistance element 21 are passed out through, and fill out, holes made in a plug 26 of ceramic material inserted in the corresponding end of the tube 20.

In Figs. 9 and 10 numeral 40 designates the upper and 41 the lower half of the ceramic liner. Designated by 42 is a ceramic tube which is inserted in the furnace liner and defines the furnace chamber 43. Formed in the lower half 40 of the furnace liner are a plurality—six in number in the embodiment illustrated—axially extending open channel-grooves 44 each of which forms a shelf. Disposed on the bottom portion of each such groove or shelf 44 is a supporting bed 45 consisting of a granular electrically insulating material which is refractory and chemically resistant to the material of the resistance element also at the operating temperature concerned, as stated hereinbefore. Rested on the respective supporting beds 45 are the straight-lined portions 46 of a looped resistance element which is bent longitudinally at intervals against a cylindrical surface. The uppermost two grooves or shelves 44 are formed in the parting interface between the upper and lower halves 40 and 41, respectively, of the liner. The terminal portions 47 of the resistance element—the cross-sectional area of which is larger than that of the resistance conductor proper, 46, are introduced through holes made in the rear wall 48 of the furnace. Disposed in the front wall 49 of the furnace is the furnace entrance opening. The latter may be closed, in the conventional manner, by a furnace door which is not shown in the figure. The looped resistance element should be placed in the grooves 44 before the ceramic tube 42 is moved longitudinally into its operative position. The resistance loop can conveniently be removed for replacement or repair after first withdrawing the tube 42 from the furnace.

What is claimed is:

1. Electrical heating apparatus comprising an electrical resistance heating element, and a bed of freely flowable refractory material grains having an electrical conductivity lower than that of the resistance element and chemically resistant to the material of said resistance element, said element resting uncovered upon the upper surface of said bed in contact with said refractory material grains, and said bed being operative to support said element throughout substantially the full length thereof, and to simultaneously accommodate movement thereof due to temperature-change induced expansion and contraction.

2. Apparatus as defined in claim 1 wherein the heating element consists essentially of heat resistant and oxidation proof silicides.

3. Apparatus as defined in claim 1 wherein the heating element consists essentially of molybdenum disilicide,

4. Apparatus as defined in claim 1 wherein the bed material consists essentially of one or more of the materials in the group consisting of heat-resistant carbides, borides, silicates, silicides and/or oxides.

5. Apparatus as defined in claim 1 wherein the bed material comprises one or more of the following substances: silicon dioxide, sillimanite and mullite.

6. Apparatus as defined in claim 1 wherein the heating element consists essentially of heat resistant and oxidation proof silicides, and the bed material consists essentially of one or more of the materials in the group consisting of heat-resistant carbides, borides, silicates, silicides and/or oxides, said bed material including one or more of the following substances: silicon dioxide, sillimanite and mullite.

7. Apparatus as defined in claim 1 wherein the heating element consists essentially of molybdenum disilicide, and the bed material consists essentially of sillimanite and mullite.

8. Apparatus as defined in claim 1 wherein the heating element is adapted for operating at temperatures above 1000° C., and the bed material consists essentially of one or more of the materials in the group consisting of carbides, borides, silicates, silicides and/or oxides and having a sintering temperature higher than the operating temperature of the resistance element.

9. Apparatus as defined in claim 1 wherein the grain size of the grains of the bed is comprised between 0.004 and 0.4 inch (0.1 to 10 mm.).

10. Apparatus as defined in claim 1 wherein the bed is of a depth at least equal to twice the average size of the grains of the bed.

11. Apparatus as defined in claim 1 wherein the

maximum bed grain size is substantially equal to 2 to 3 times the minimum bed grain size.

12. Apparatus as defined in claim 1 wherein the grains of the bed are approximately spherical in shape having edges and corners facilitating movement thereof relative to one another.

13. Apparatus as defined in claim 1 wherein the heating element consists essentially of a heat resistant and oxidation proof intermetallic compound mainly containing molybdenum and silicon.

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