Sept. 22, 1964 A. C. THORNE ETAL 3,150,226

ELECTRIC FURNACE

Filed March 21, 1961 2 Sheets-Sheet 1

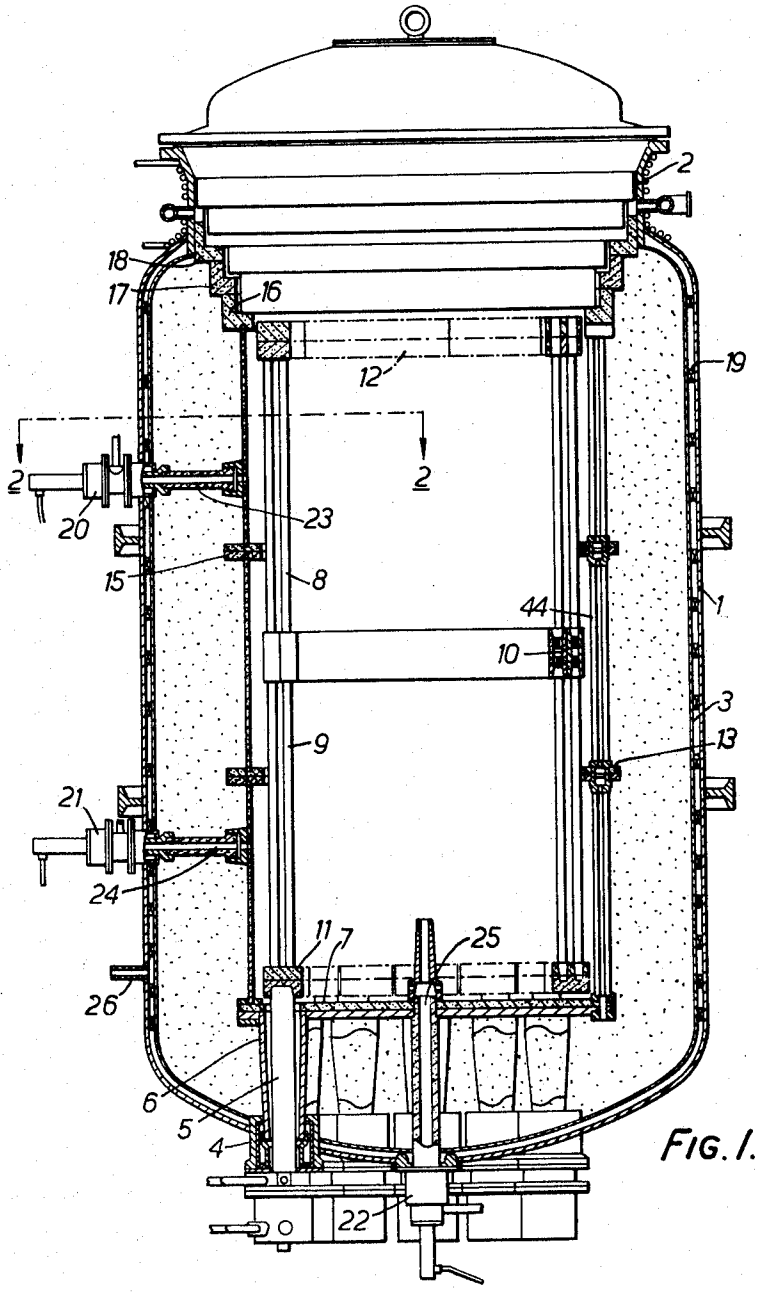


FIG. 1.

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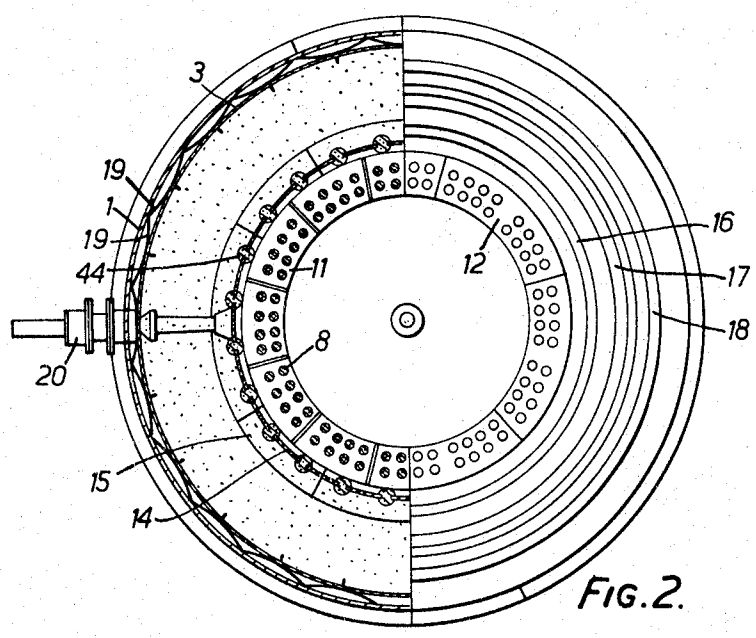


FIG. 2.

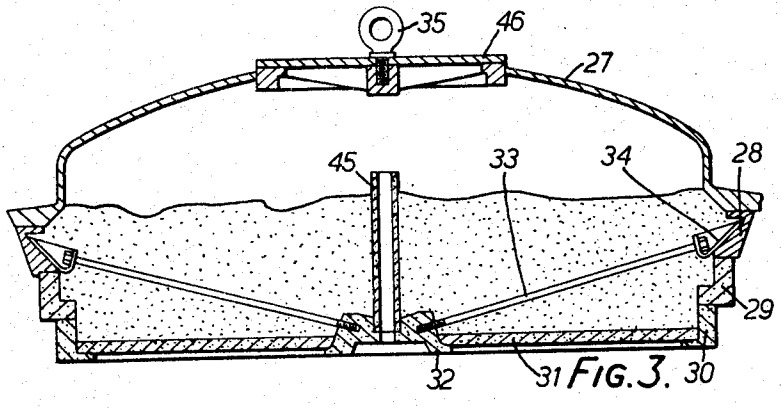


FIG. 3.

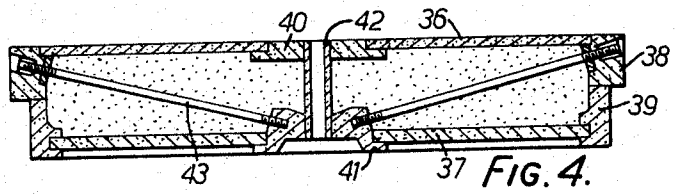


FIG. 4.

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United States Patent Office 3,150,226 Patented Sept. 22, 1964

3,150,226

ELECTRIC FURNACE

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Filed Mar. 21, 1961, Ser. No. 97,326
Claims priority, application Great Britain Mar. 24, 1960
13 Claims. (Cl. 13—25)

The present invention relates to an electric furnace, and seeks to provide an electric furnace capable of operating at temperatures in the region of 3000° C.

The invention provides an electric furnace comprising an outer wall provided with an opening for charging or discharging an article to be heated, an inner graphite wall encompassing the heating space of the furnace, the zone between the outer and the inner wall being adapted to provide heat insulation during furnace operation, a graphite resistance heating element within the heating zone disposed regularly about the heating space, and connection means through which the interior of the furnace may be evacuated or an inert gas introduced.

The resistance heating element may comprise a series of graphite rods arranged in circumferentially spaced relation on the surface of an imaginary cylinder to enclose the heating space, the rods being electrically interconnected at one end of the cylinder by a continuous graphite ring and the ends of the rods at the other end of the cylinder being fixed in a discontinuous graphite ring made in electrically separate segments to which current may be supplied.

The furnace may comprise an inner substantially cylindrical wall surrounding the heating space and the heating element, an outer substantially cylindrical wall spaced from the inner wall and closed at one end, a thin cylindrical metal shell arranged internally of the outer wall and adjacent thereto, a filling of lampblack or other refractory material arranged between the inner wall and the thin metal shell, and resilient means arranged between the thin metal shell and the outer wall to maintain a resilient pressure on the filling.

The opening for charging or discharging an article to be heated may comprise a flanged neck with a conical seating and there is provided a hollow cover filled with lampblack or other refractory material and comprising a dished and flanged metal closure plate secured to the upper side of a metal ring having a conical seat adapted to engage the conical seating in the neck of the furnace.

In order that the invention may be clearly understood, one embodiment thereof will now be described by way of example only, reference being made to the accompanying drawings in which:

FIGURE 1 is a vertical section through the furnace,

FIGURE 2 is in part a cross section on the line 2—2 of FIGURE 1, and in part a plan view with the furnace cover removed,

FIGURE 3 is a vertical cross section to a larger scale through the upper part of the furnace cover, and

FIGURE 4 is a vertical cross section to the same scale as FIGURE 3 through the lower portion of the furnace cover.

Referring to FIGURES 1 and 2, the furnace comprises an outer metal wall or shell **1** closed at the bottom and provided with a flanged water cooled neck **2** at the top to which is fitted the furnace cover shown in more detail in FIGURES 3 and 4.

Inside the outer wall or shell **1** there is arranged a thin metal shell **3** spaced therefrom. The cylindrical portion of this inner shell is spring loaded in a manner which will be subsequently described.

Arranged in the bottom of the outer wall or shell are a number of water jackets **4** in which are fixedly located vertical graphite feed rods **5**. These rods are surrounded by graphite tubes **6** fixed in the water jackets and carrying at their upper ends a graphite disc **7** which forms the hearth of the furnace and which is apertured to allow the feed rods to project therethrough. The furnace heating element comprises two part graphite rods **8, 9** arranged vertically and in a cylindrical fashion to enclose the heating space. Two series of rods are shown arranged on imaginary concentric cylinders. Each rod is made up of aligned rods **8, 9** interconnected by a graphite sleeve **10**, each of the adjacent ends of the rods **8, 9** being provided with a tapered portion followed by a threaded portion, and the sleeve being provided with complementary conical and threaded recesses into which the end of the rods are fitted. The lower ends of the rods **9**, make similar engagement with an annular graphite ring **11**, made in separate segments and provided on its underside with tapered recesses engaging the tapered upper ends of the graphite feed rods **5**. The upper ends of the graphite rods **8**, are located in apertures in a continuous annular graphite ring **12**. Three of these rods are anchored to the graphite ring **12**, and the others are mounted to allow relative axial movement, good electrical contact with the ring being maintained by internally tapered collets which may be expanded in the apertures by nuts on the rods. The diameter of the collets is adjusted so as to allow the rods to move axially.

The upper graphite ring **12** of the heating element is free to expand radially under the full heat of the furnace. Radial movement of the segments forming the lower graphite ring **11** is constrained by the graphite feed rods **5**. These rods are cooled at their lower ends by the water jackets **4** and their movement radially at this point is equal to the local expansion and contraction of the furnace casing which is considerably less than the radial movement of the upper graphite ring **12**. For this reason the upper ring is constructed so that when the furnace is cold the pitch circle diameter on which the upper ends of the heating rods lie is somewhat smaller than the pitch circle diameter on which the lower ends of the rods lie, and when the furnace reaches its maximum temperature it is somewhat greater so as to minimise bending stress on the rods due to expansion.

As can be seen from FIGURE 2, the annular graphite ring **11** comprises twelve separate segments. Each segment is associated with a graphite feed rod **5** and the feed rods are connected in groups of four to a delta connected three phase transformer so that the feed rods are star connected with the upper continuous graphite ring **12** forming the neutral point.

The graphite heating rods **8, 9** may be of tubular form if desired, and the two part construction of these rods involving interconnecting sleeves **10** may be replaced by rods made in a single piece if the depth of the furnace is such that a two part construction is unnecessary.

A cylindrical graphite wall or shell surrounding the heating element is built up on the hearth plate **7** in the following manner. A skeleton cylinder of graphite rods **44**, each of which is in three aligned sections inter-connected by sleeves **13**, is secured in the hearth plate **7**. These rods are axially slotted to receive the edges of graphite plates **14** arranged between adjacent rods to complete a cylindrical wall surrounding the heating element. There are three superimposed sets of plates **14** separated by graphite rings **15** apertured to receive the sleeves **13**. The upper and lower edges of the plates are also located in grooves provided for this purpose, in the furnace hearth, in the graphite rings **15** and in an upper annnular ring **16**, forming part of a closure of the space between the wall formed by the plates **14**, and the inner metal shell **3**. The upper ends of the rods **44** are also fixed into this annular ring **16**.

The cross section of the annular ring 16 is L-shaped and the ring is surmounted by two further L-section graphite rings 17, 18 of increasing diameters which complete a step form closure to the space just referred to. The abutting faces of the rings 16, 17, 18 are provided with dowel and slot connections to control relative radial movements under expansion.

The space between the thin metal shell 3 and the graphite plates 14 is filled with lampblack and the cylindrical portion of the shell 3 is loaded differentially from top to bottom by axially spaced rows of bowed springs 19, of different strength arranged between the shell 3 and the outer wall 1. The stiffness of the springs of a row increases gradually from top to bottom of the furnace so as to maintain a resilient pressure on the refractory filling. The differential loading is necessary to allow for variations in what may be called the "hydrostatic head" of the lampblack. The space between the hearth plate 7, which constitutes a bottom closure of the graphite wall mounted thereon, and the dished bottom wall of the furnace is also filled with lampblack. The graphite guide tubes 6 surrounding the graphite feed rods 5 will be embedded in this lampblack and to allow for the differences in expansion due to the temperature gradient the graphite tubes 6 are made in superimposed sections capable of relative movement radially of the furnace axis.

Metal water cooled radiamatic heads 20, 21, 22 are provided in the outer shell at the locations shown to enable the temperature of the upper and lower parts of the heating element and the temperature of the furnace charge to be determined and the current supply to be controlled automatically. Graphite tubes 23, 24, 25 span the space between the heads and apertures provided in the plates 14 and the furnace hearth 7. Tubes 23, 24 are arranged to pivot at their ends to cater for the difference in expansion between the outer wall of the furnace and the cylindrical graphite wall. A connection 26 is provided in the outer shell with the space between the shells 1, 3, whereby the furnace can be evacuated or argon introduced for cooling purposes. The housings for the radiamatic heads are water cooled and may be used to introduce an inert gas atmosphere, preferably argon, into the furnace. So as to reduce the cooling down time of the furnace after heating has been discontinued, arrangement is made whereby the argon supply to the furnace may be greatly increased, the supply being circulated through the furnace and an external cooler.

The closure forming the furnace cover will now be described in detail. Referring to FIGURE 3 the upper part of this closure comprises a metal cover 27 secured to a metal ring 28, beneath which are arranged annular graphite rings 29, 30 L-shaped in cross section and of decreasing diameter. The bottom of this portion is closed by a graphite disc 31 fitted with a central graphite block 32, which is coupled by graphite tie-rods 33 with brackets 34 fixed to the metal ring 28. This hollow cover is filled with lampblack and is provided with lifting lugs or with a central lifting eye 35. The rim of the metal ring 28 is tapered to engage a conical seating surface provided in the neck 2 of the furnace and the stepped portion 29, 30 is dimensioned to suit the internal diameter of the neck 2 and the annular graphite ring 18 respectively. The metal ring 28 forms a heat conductive path to the metal neck 2 which is water cooled at this point. By this means heat is conducted away from the cover. A graphite tube 45 is arranged vertically in the centre of the block 32.

The lower part of the cover, shown in FIGURE 4, forms a hollow graphite construction which is also filled with lampblack. It is built up from upper and lower plates 36, 37, annular rings 38, 39, of L-section, graphite members 40, 41 arranged at the centres of the plates 36, 37, and interconnected by a hollow tie-rod 42, and tie-rods 43 connecting the member 41 with the ring 38. The plates 36, 37 are supported by the rings and the members 40, 41. The step formation of the annular rings 38, 39 is dimensioned to suit the step formation of the rings 17, 16.

When assembled in the furnace there is a heat insulating space between the upper and lower parts of the closure.

The hollow tie-rod 42 and the vertical tube 45 enable the furnace closure to be completely evacuated via the interior of the furnace. It is visualised that volatile products of the charge and of the interior of the furnace which are vapourised by the heating will condense on block 32. To ensure this the tube 45 may extend into the part 46 of cover 27, which part may be air or water cooled to cool block 32 and tube 45.

The graphite plates or discs 7, 31, 36, 37 may be built up from laminations divided into sectors of petal fashion. The annular rings may be built up from laminations divided into segments.

The flange on the neck 2 of the outer shell 1 of the furnace is provided with a number of vertical guide rods engaging holes in the flange of the metal cover 27 to ensure axial alignment of the upper part of the furnace closure with the furnace when it is raised and lowered.

We claim:

1. An electric furnace comprising an outer substantially cylindrical wall having an opening for charging and discharging respectively the articles to be heated, an inner substantially cylindrical graphite wall radially spaced apart from said outer wall and defining a heating space in the furnace, the annular space between the outer and the inner wall providing heat insulation during operation of the furnace, a graphite resistance heating element disposed within said heating space, said heating element including a plurality of graphite rods arranged in circumferentially spaced relationship to define a cylindrical peripheral outline, a discontinuous graphite ring formed of electrically separated segments arranged to be connected to a source of current, a continuous apertured graphite ring, said rods engaging at one end said segments in electrical contact therewith, the other ends of some of said rods being fixedly secured to said continuous graphite ring, expandable collets at said other ends of the remainder of the rods, said collets extending into apertures of the continuous graphite ring, and adjustment means on said rods coacting with said collets for adjusting the internal diameter thereof to effect a high quality electric contact between the rods and the continuous graphite ring and to permit axial movement of said rods with reference to said rings.

2. An electric furnace according to claim 1 wherein the segments of the discontinuous graphite ring have frusto-conical recesses and wherein further rods are provided to supply current to said segments of the discontinuous graphite ring, said current supply rods having tapered ends engaging the frusto-conical recesses in the ring, and wherein water jackets in the outer wall of the furnace mount said current supply rods.

3. An electric furnace according to claim 1 wherein the outer substantially cylindrical wall is closed at one end, said furnace also comprising a thin cylindrical metal shell internally of said outer wall and adjacent thereto, a refractory material filling the space between the inner wall and said thin metal shell, and resilient means between the thin metal shell and the outer wall to maintain a resilient pressure on said refractory filling, said resilient means including a plurality of springs circumferentially spaced to surround the thin metal shell uniformly, the stiffness in the springs of a row increasing gradually from the top row to the bottom row.

4. An electric furnace according to claim 1 wherein a flanged neck is formed at the upper end of the outer wall, said neck defining the opening for charging and discharging respectively an article to be heated, said neck being separated by a gap from the upper end of the inner wall and having a conical seating, and wherein a series of superimposed graphite rings of gradually increasing diameter and L-section spans said gap so as to form a stepped closure at the upper end of the heating insulation zone between the outer and inner walls, and wherein a hollow cover is provided, said cover being filled with a

refractory material and including a dished and flanged metal closure plate and a metal ring, said plate being secured to the upper side of the metal ring and said ring having a conical peripheral wall engaging the conical seating of said neck.

5. An electric furnace according to claim 1, wherein the rods lie at the continuous graphite ring with a pitch circle diameter which is somewhat less than the corresponding pitch circle at the discontinuous graphite ring when the heating element is cold and somewhat greater when the heating element is at its maximum temperature, so as to minimise the bending stresses on the rods.

6. An electric furnace according to claim 5, wherein each rod is made in two or more aligned sections interconnected by a graphite sleeve.

7. An electric furnace according to claim 3 and designed for operation with the walls substantially vertical, wherein the closed end of the outer wall forms the base of the furnace, and wherein a graphite plate supports the inner wall, said graphite plate forming the hearth of the furnace.

8. An electric furnace according to claim 7, wherein further rods engage said segments of the discontinuous graphite ring to supply current thereto and water jackets encompass said current supply rods, and wherein the said hearth is separated from the water jackets by means of a series of vertical graphite tubes and the current supply rods pass through the graphite tubes and apertures in the hearth plate to the interior of the heating space.

9. An electric furnace according to claim 3, wherein the inner wall is built up from circumferentially spaced graphite rods arranged substantially vertically and provided with longitudinal slots to receive the edges of graphite plates arranged between adjacent rods to complete the wall, the lower ends of the rods being fixed in the hearth and their upper ends being fixed in an annular graphite ring, both hearth and ring being grooved to take the edges of the plates.

10. An electric furnace according to claim 9, wherein the graphite rods are made in axially aligned sections, the adjacent ends of each pair of aligned sections engaging graphite sleeves located in apertures in graphite rings arranged in horizontal planes and grooved to take the edges of the graphite plates, the graphite plates being arranged in superimposed sets.

11. An electric furnace according to claim 10, in which at least one radiamatic head is provided in the outer wall for supervising the temperature of the heating element, a graphite tube being arranged between the inner end of the head and a corresponding aperture in the inner graphite wall, the said tube being pivotally mounted at its ends to allow for differences in expansion of the inner and outer walls.

12. An electric furnace according to claim 4, wherein the cover includes a pair of superimposed graphite rings of decreasing diameter and of L-section arranged below the metal ring, a central graphite block, tie-bolts connecting the block to the metal ring, and a graphite disc secured to the central block and the lower of said graphite rings to form a closure at the under side of the cover.

13. An electric furnace according to claim 12, wherein the series of superimposed graphite rings of gradually increasing diameter supports, below and in spaced relation to the cover when seated in the neck of the furnace, a second hollow closure, said second closure comprising superimposed graphite rings of gradually increasing diameter, upper and lower graphite plates forming with the rings a hollow body filled with refractory material, and graphite members located at the centres of the discs, and interconnected by a hollow graphite tie-rod, the lower member being connected by tie-rods to the upper graphite ring.

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