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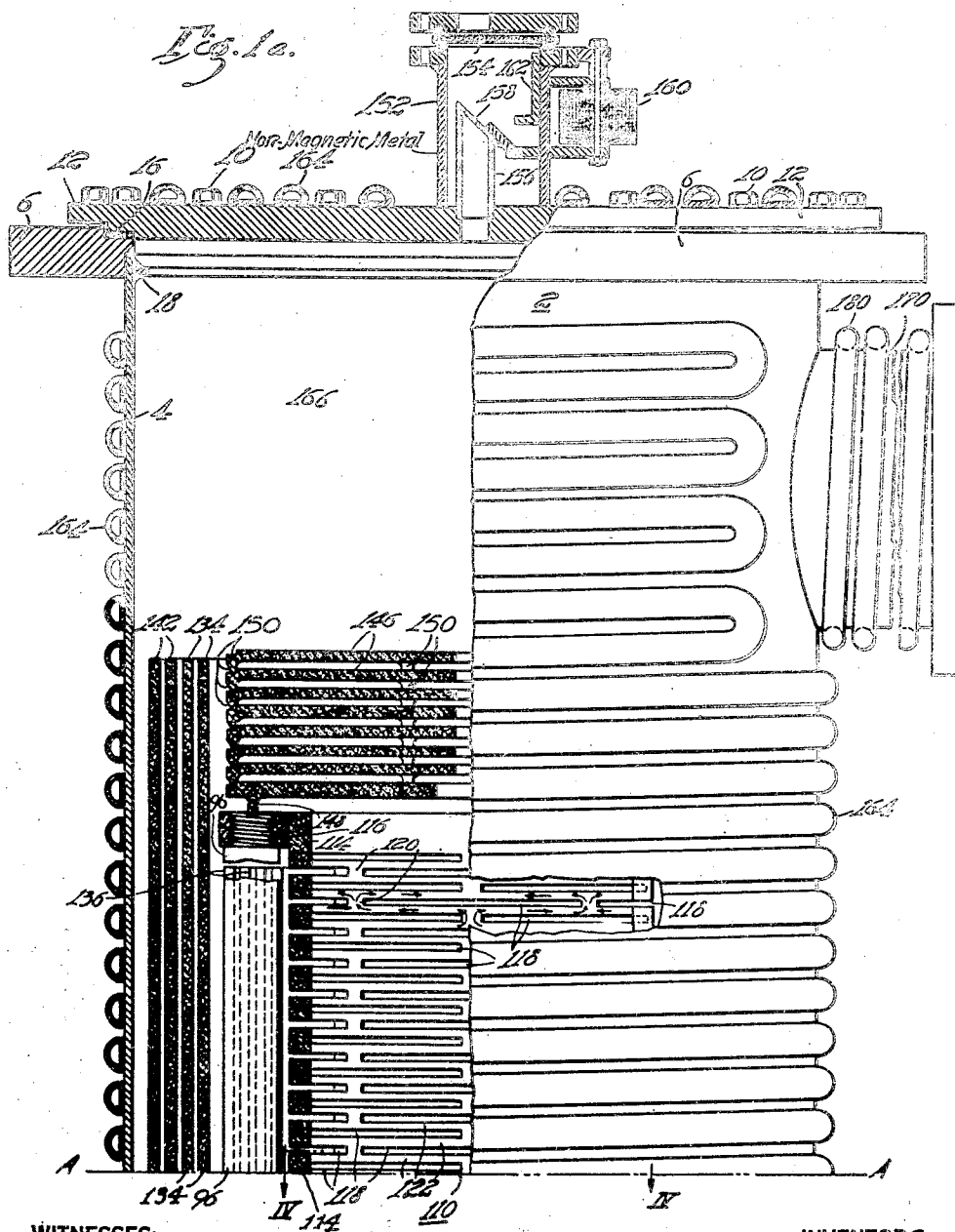
H. A. ROSE ET AL

2,476,916

ELECTRIC RESISTANCE VACUUM FURNACE

Filed Sept. 8, 1945

4 Sheets-Sheet 1



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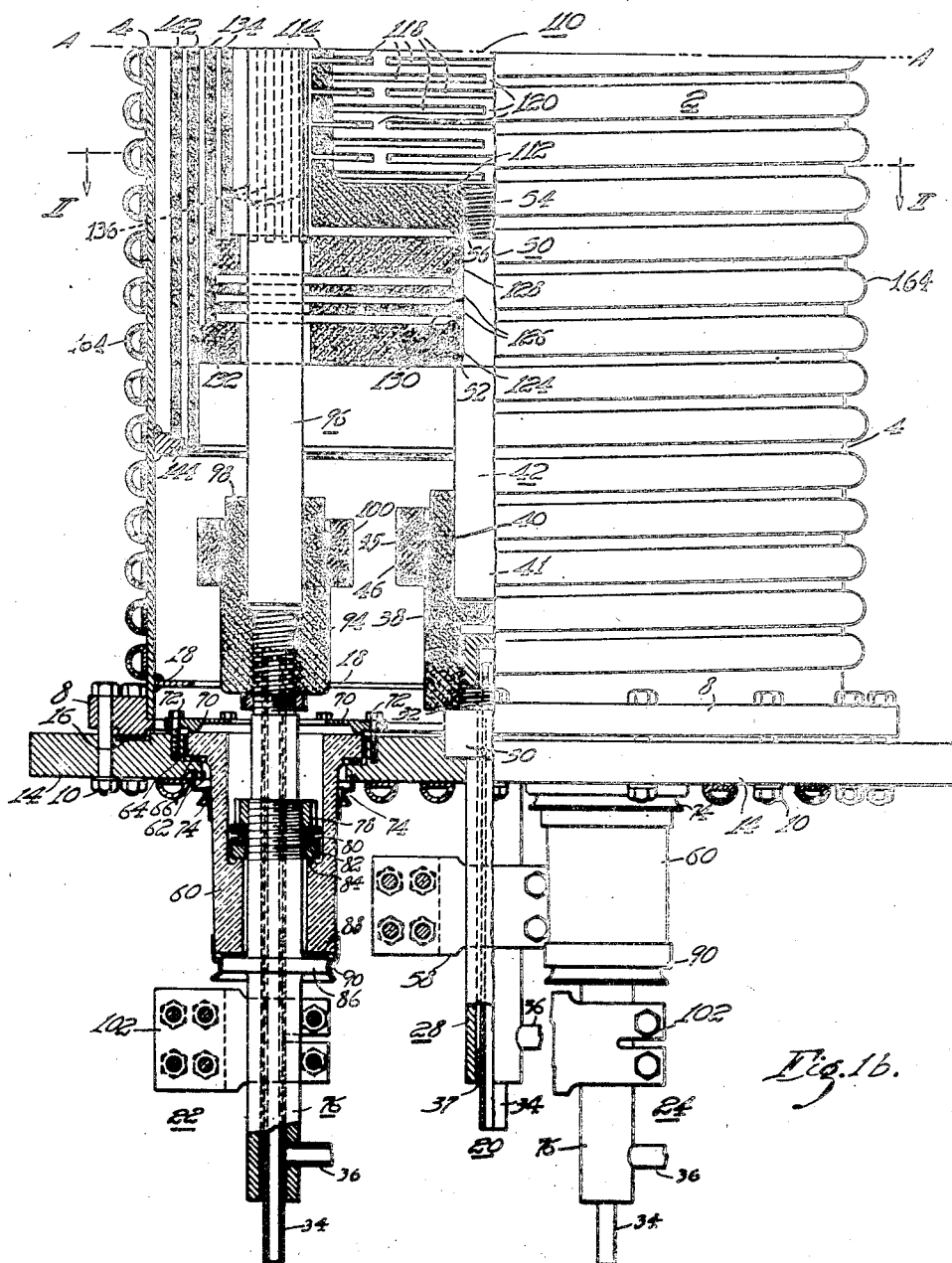
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ELECTRIC RESISTANCE VACUUM FURNACE

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4 Sheets-Sheet 2



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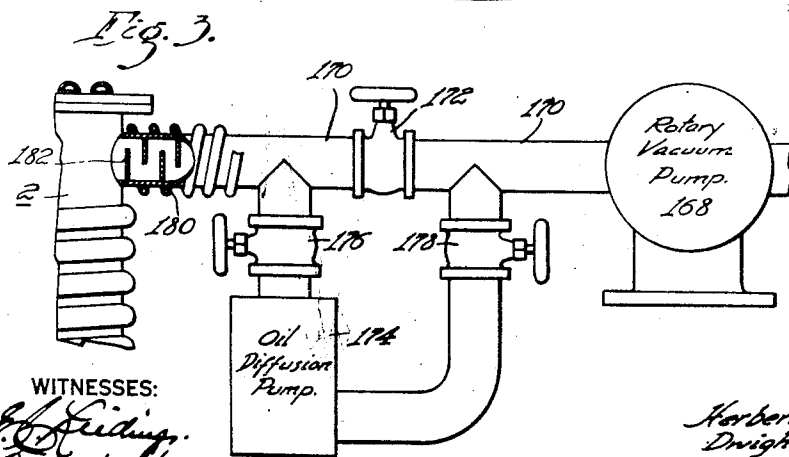
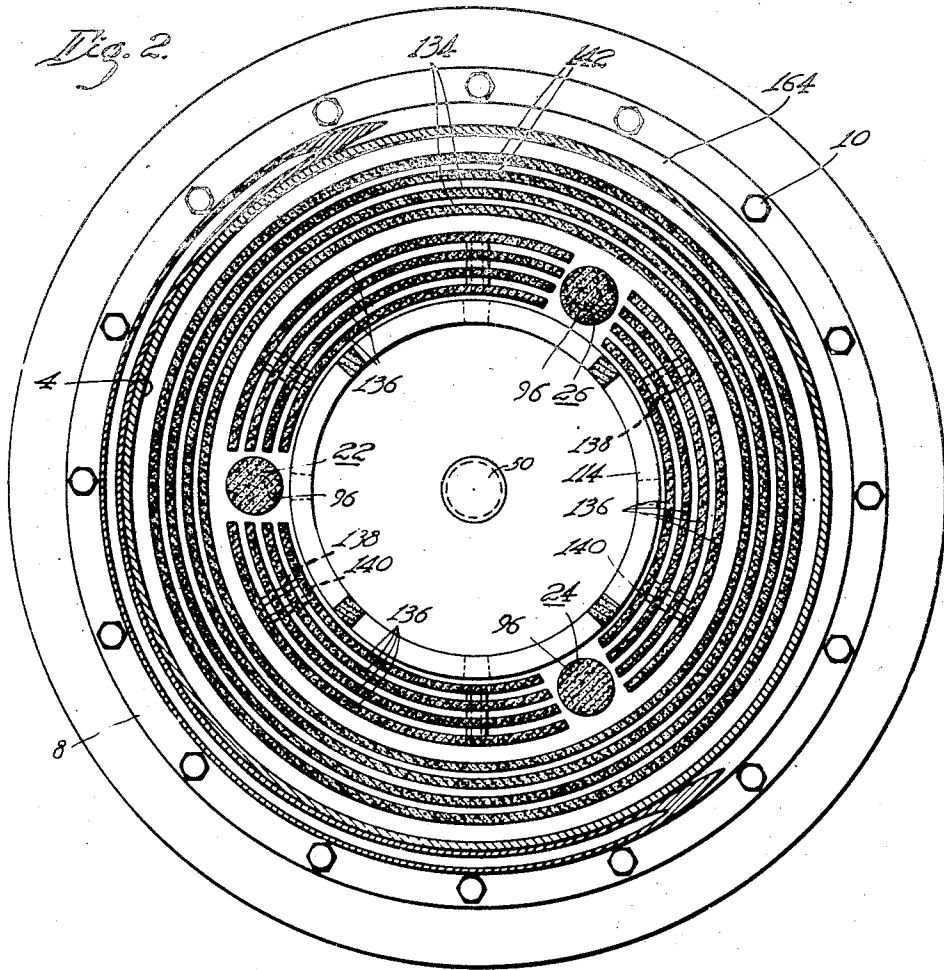
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ELECTRIC RESISTANCE VACUUM FURNACE

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4 Sheets-Sheet 3



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ELECTRIC RESISTANCE VACUUM FURNACE

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4 Sheets-Sheet 4

Fig. 4.

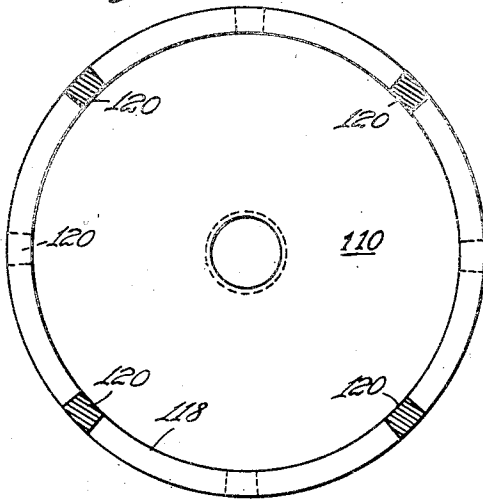


Fig. 5.

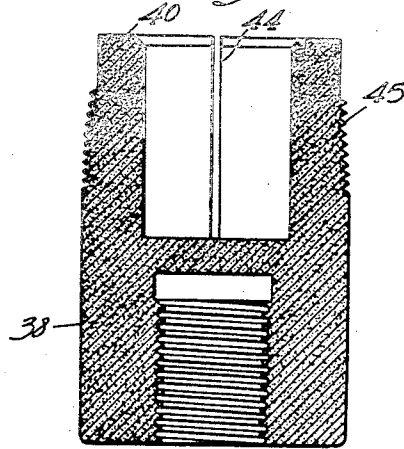


Fig. 6.

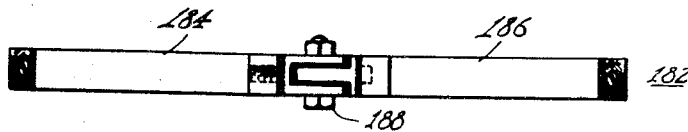
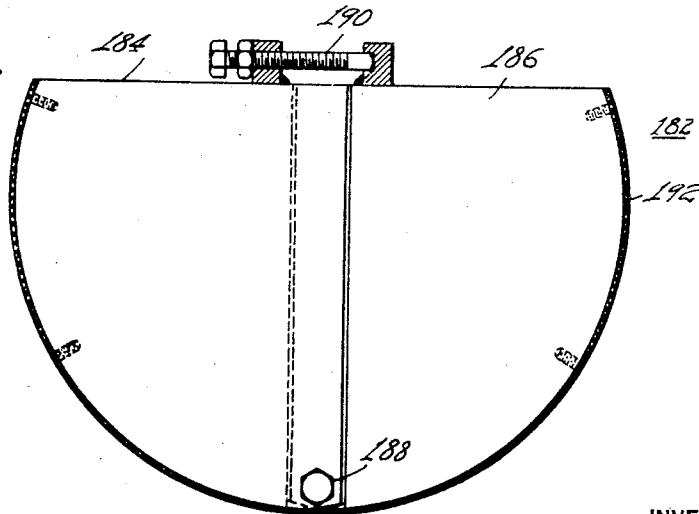


Fig. 7.



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2,476,916

ELECTRIC RESISTANCE VACUUM FURNACE

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Application September 8, 1945, Serial No. 615,172

19 Claims. (Cl. 13—31)

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Our invention is directed to improvements in high temperature furnaces, and in furnace systems adapted to heat material to temperatures in the order of 2000° C. and higher while in a rarified atmosphere having a pressure of as low as fractions of a micron of mercury.

A primary object of our invention is to provide means for rapidly removing occluded gases from a material. Graphite anodes for use in high-power mercury tube-rectifiers are examples of materials which can be degassed in apparatus following the teachings of our invention, the degassing being to an extent and at such speeds as all rarely attained with apparatus used in prior practice.

An object of our invention is to provide a heating chamber in which all portions are at essentially the same high operating temperature.

An ancillary object of our invention is to provide a high temperature furnace which is free from refractory and insulating ceramics so that the furnace can be satisfactorily used for degassing without being burdened with gases from materials ordinarily used in furnace construction.

Another ancillary object of our invention is to provide heating element supports which constitute part of the heating system and so arranged as to minimize heat losses from the furnace.

Another ancillary object of our invention is to provide a heating resistor element which can encompass a charge, the resistor element being adapted to be heated to extremely high temperatures, but having such a construction that it readily adapts itself to changes in dimensions arising out of heating and cooling.

Another ancillary object of our invention is to provide a furnace adapted to receive a vacuum pumping system, using an oil-diffusion pump and means, specifically in the form of cooled baffles, for preventing back diffusion or migration of oil vapor into the furnace.

Another ancillary object of our invention is to provide a furnace in which the radiation shields are used to surround the charge-heating space in such a manner as to minimize heat losses and to make the use of refractory-tile insulating material unnecessary.

A preferred form of our invention comprises a lower region, which receives the charge to be treated, and a smaller upper region, which comprises a gas chamber. The lower region includes electric heating means surrounded by open radiation-shields which confine the heat so that the size of the furnace can be kept down. A vacuum

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or pumping system is connected to the exhaust gas from the furnace, the connection being made at the gas chamber. The pumping system includes an arrangement of different pumps for quickly exhausting the inside of the furnace and quickly removing any gases which may be driven from the furnace parts and from the charge when the furnace temperature rises rapidly.

Other objects, innovations, features, combinations and methods of our invention, in addition to the foregoing, will be discernible from the following description of a preferred form thereof, which is to be taken in connection with the accompanying drawings on different scales unless otherwise specified.

In the drawings:

Figures 1a and 1b, when placed with the former directly above the latter and their lines A—A fitting, constitute, to scale, a vertical view, partly in section and partly in elevation with parts broken for clarity, of a furnace embodying the principles of our invention;

Fig. 2 is a sectional view on the line II—II of Fig. 1b and is drawn to the same scale;

Fig. 3 is a diagrammatic view showing a vacuum pumping system attached to the furnace shown in Figs. 1a and 1b;

Fig. 4 is a sectional view of a heating resistor element, as seen substantially on the line IV—IV of Fig. 1a;

Fig. 5 is a sectional view of a part of a conductor-means through which electricity passes into the furnace for energizing its heating resistor element; and

Figs. 6 and 7 are edgewise and broadside views, respectively, of a baffle means used in the pipe connection between the furnace and the vacuum pumping system.

The furnace shown in the drawings comprises an upright vacuum-tight metallic furnace casing indicated in its entirety by the reference numeral 2. The casing has an outer wall 4 comprising a hollow steel cylinder. Welded to the top and bottom portions of the cylinder are steel annular members or rings 6 and 8, respectively, through which pass spaced bolts 10 for receiving steel closures of the casing, comprising a steel top plate 12 and a steel bottom plate 14. Vacuum-tight joints are provided between the rings and the closures by means including metal-encased gaskets 16 protected from radiant heat by narrow rings 18 secured to the inside of the cylindrical wall 4 near its edges.

Passing through the bottom plate 14 are a plurality of water-cooled conductor-means, or con-

ductor-assemblies, through which electrical power passes into the furnace. These comprise a conductor-means, indicated in its entirety by the reference numeral 20, which passes through the center of the bottom plate; and three insulated conductor-means, 22, 24 and 26, equally spaced from the central conductor-means 20 and from each other.

The conductor-means 20 is generally long and round and is vacuum-tightly secured to the bottom plate 14. It comprises a hollow metal conducting rod 28 which is liquid-tightly closed at its upper end. The rod includes an intermediate protuberance 30 seating in a seat in the bottom plate, and an upper outwardly-threaded stem 32. An inner pipe 34 is received inside the conducting rod 28 and terminates just short of the closed end of the rod. An outlet pipe 36 and a seal 37 are provided near the bottom of the conducting rod 28. Cooling water delivered into the pipe 34 flows upwardly through it, around its top open end and downwardly between the pipe and the inside wall of the conducting rod 28, and out through pipe 36.

The conductor-means 20 further comprises a graphite member 38 screwed on the stem 32 of the conducting rod 28. This graphite member is also shown in Fig. 5. It has an upper hollow cylindrical portion 40 which snugly receives in it a similarly shaped lower portion 41 of a round graphite rod 42 of the conductor-means 20. The rod 42 extends upwardly considerably beyond the graphite member 38. The cylindrical portion 40 has a longitudinal cut or slit 44 and a tapered outside thread 45 which receives a suitable graphite nut 46 so that the graphite member 38 and the graphite rod 42 can be tightly clamped together to provide good electrical contact therebetween. The rod 42 comprises an upper portion 50 of less diameter than the lower portion 41, so as to provide a circular supporting shoulder 52. The top of the upper portion 50 is provided with a threaded part 54 which extends upwardly from an upper shoulder 56. A terminal 58 is clamped around the conducting rod 28 below the bottom plate 14 of the casing 2.

Each of the conductor-means 22, 24 and 26 passes vacuum-tightly through but insulated from the bottom plate 14. They are substantially alike so that the following description of one should suffice for the three. Each comprises a round ceramic sleeve 60 of porcelain passing through a hole 62 in the bottom plate 14. The sleeve has a top flange 64 supported, through a gasket 66, on a circular seat in the bottom plate 14. An annular metal plate 70, with an enlarged hole, bears on the top of the flange and compresses the gasket 66 by means of bolts 72 which are threaded into holes in the bottom plate 14, spaced around the hole 62 through which the sleeve 60 passes. A metal-to-porcelain seal 74 is provided between the sleeve 60 and the bottom of the bottom plate 14 for a further sealing of the hole 62. The sleeve 60 carries a metal conductor rod 76 by means of a nut 78 threaded on the rod, and pressing on a spring 80 which bears on a washer 82 on an inside shoulder 84 of the sleeve 60. The nut forces a lower flange 86 of the conductor rod 76 against a gasket 88 which bears against the bottom of the sleeve 60. A metal-to-porcelain seal 90 further seals the space between the sleeve 60 and the conductor rod 76. The conductor rod 76 is water-cooled through an internal construction such as that provided for the conductor-means 20.

Each insulated conductor-means also includes a graphite member 94 threaded on the top of the conductor rod 76, and a graphite rod 96 which is received in a split hollow upper cylindrical portion 98 of the graphite member 94. A nut 100 on a tapered thread of the member 94 tightly clamps the graphite member 94 around the lower end of the graphite rod 96. Each conductor-means is further provided with a terminal 102 clamped around its conductor rod 76, below the sleeve 60. The graphite rod 96 of each insulated conductor-means 22, 24 and 26 extends considerably above the top of the graphite rod 42 of the conductor-means 20.

In the particular embodiment of our invention which is herein shown and described, the central conductor-means 20 is connected to one side or terminal of a power supply, and the insulated conductor-means, 22, 24 and 26 are connected in parallel to the other side or terminal of the power supply. Consequently, the insulated conductor-means are substantially at the same potential, and each carries about one-third of the current carried by the conductor-means 20, thereby limiting the heating of the metal-to-porcelain seals between the conductor-means and the casing.

Connected between the central conductor-means 20 and the outer insulated conductor-means 22, 24 and 26 is an electrical heating means which can be heated to temperatures as high as 2000° C. and above. This heating means consists of a resistor element which is so shaped that it can also function to receive within it a charge to be heat-treated. A plurality of spaced radiation-shields surrounds the resistor element for confining the heat. The resistor element and the shields are all of graphite and are free to expand and contract. These and the other graphite parts for the furnace are preferably of that grade which can be machined and is strong mechanically. Graphite known in the electrical art as rectifier or anode graphite is highly satisfactory.

The resistor heating element is in the form of a cup-shaped member indicated in its entirety by the reference numeral 110. It comprises a substantially solid relatively thick bottom wall 112 and an upwardly extending thinner cylindrical wall 114 to the outer upper end of which is threaded a substantially solid thick annular graphite member or ring 116, extending outwardly. The bottom 112 and the ring 116 comprise support members or means by which the resistor element is supported. The bottom wall 112 is provided at its center with a threaded hole which receives the threaded top part 54 of the conductor-means 20; and the ring 116 has three equally spaced threaded holes which receive the tops of the insulated conductor-means 22, 24 and 26, so that the resistor element is carried and positioned by the different conductor-means. The ends of the conductor-means are flush with or below the surface of the members in which they are screwed.

The cylindrical wall 114 of the heating resistor element 110 is provided with a plurality of narrow horizontal perforated rows having relatively long and narrow openings or grooves 118, each row comprising four equal openings of slightly less than 90° span, transverse to the axis of the wall 114. The adjacent rows have their openings symmetrically staggered, with the ends of each opening of any one row being in line with the centers of openings in the next or immediately adjacent row. The solid structure of the wall 114 comprises narrow wall portions 120 separating the openings in each wall row, and narrow cylindrical

rows 122 between the perforated rows. Because of the openwork construction of the resistor element, current flowing between the central conductor-means 20, on the one hand, and the conductor-means 22, 24 and 26, on the other hand, must zigzag through the cylindrical wall 114. Assuming that the current flows from the central conductor-means 20, it divides into paths as more or less illustrated by the arrows shown in Fig. 1a, on the resistor element. The current-flow paths are considerably elongated and may be said to comprise four parallel paths through the resistor element 110, because of the four narrow separating walls 120 between each narrow solid cylindrical portion 122 of the cylindrical wall 114. However, at the top of the resistor element, the solid ring 116 collects the current flowing from the wall 114, and the current divides so as to flow to the graphite rods 96 of the insulated conductor-means 22, 24 and 26.

The resistor element can be electrically heated to incandescence so that it radiates energy to any charge which is placed inside the resistor element, the charge preferably resting on the bottom wall 112 and clearing the cylindrical side wall 114.

In order to attain the desired high temperatures at satisfactory efficiency, heat losses from the resistor element must be minimized. To this end, the graphite rod 42, which carries the resistor element 110, also supports on its shoulder 52, a plurality of disc-type horizontal radiation-shields 124, 126 and 128 held spaced by graphite spacers 130. Each of these disc-type radiation-shields has three outer holes through which passes, with adequate clearance, the graphite rods 96 of the insulated conductor-means 22, 24 and 26. The lower radiation-shield 124 has a larger outer diameter than the others. Each of the top and bottom radiation shields 124 and 128, respectively, is thicker than either of the intermediate radiation-shields 126, for strength, and is provided with an annular outside seat 132. The seats 132 receive and carry concentric tubular radiation-shields 134. The top disc-type radiation-shield 128 is also provided with a plurality of outer concentric grooves between its rod-receiving holes. As shown in Fig. 2 and by the dash lines at the upper left of Fig. 1b, these grooves receive groups of spaced arcuate partly-cylindrical upright radiation-shields 136, a group being provided between each pair of rods 96 but adequately spaced therefrom for electrical insulation. As shown in Fig. 2, the partly-cylindrical radiation-shields 136 are spaced and locked together by a plurality of spacers 138 and pins 140 at a plurality of places in each group.

A plurality of additional upright outer cylindrical radiation-shields 142 are carried concentrically beyond the radiation-shields 134 by a step ring 144 secured to the inside of the casing 4, as shown in Fig. 1b.

A plurality of stacked spaced horizontal disc-like radiation-shields 146 are provided above the resistor element 110 and correspond in diameter to the outer diameter of the ring 116. The lowermost of these upper radiation-shields has a depending portion 148 loosely resting in a groove of the ring 116 and the others have spaced depending lugs 150 loosely resting on shoulders in the immediately lower radiation shield. These upper disc-like radiation-shields are obviously carried by the resistor element 110.

Central openings are provided in the upper radiation-shields 146 for free gas passage and for observing the charge through a non-magnetic

peep tube 152 in the top plate 12 of the casing. This peep tube is gas-tightly covered with a replaceable glass plate 154, and has an inner metal sighting tube 156 closable by a pivoted iron cover 158 biased to closing position, but movable to opening position by energization of an electromagnet 160, which magnetizes a closure-attracting iron pole 162.

The metal furnace casing 2 is water-cooled wherever possible; and to this end water-cooling coils 164 are wrapped around the cylindrical casing wall 4, and on the top and the bottom casing plates 12 and 14 in any convenient manner, the tubing of the coils being flattened against the members they are to cool for better thermal relation therewith.

It may be observed from Figs. 1a and 1b that a comparatively large gas chamber 166 is provided between the removable top plate 12 of the metal furnace casing 2 and the uppermost part of the radiation shields. A vacuum pumping system is connected to this gas chamber for maintaining a high vacuum in the furnace. The vacuum pumping system is shown schematically in Fig. 3 as comprising a mechanical rotary vacuum pump 168 having an intake comprising a pipe 170 secured to the furnace casing 2, and opening at the gas chamber 166. A valve 172 is provided in this pipe and a by-pass system, including an oil diffusion pump 174 and valves 176 and 178, branches around the valve 172. The portion of the pipe 170 near the furnace 2 is water-cooled by a coil 180 wrapped around it. Within the pipe 170, near the gas chamber 166 of the furnace, are a plurality of spaced staggered baffles 182 of copper upon which any oil vapor diffusing backwardly from the vacuum pumping system condenses and thereby is prevented from contaminating the furnace graphite or charge inside the furnace casing 2. Any convenient means may be provided for draining the oil, if this is found to be necessary. Figs. 6 and 7 illustrate a baffle. The baffle is built of two sections 184 and 186 having partly-circular peripheries and pivoted at 188 so that they can be spread tightly against the inside of the pipe 170 by means of a spreading mechanism 190. The peripheries of the baffle sections are provided with metal braid 192 to assure adequate thermal contact between the baffle and the pipe.

In operation the furnace is loaded by first removing the top plate 12 and the upper radiation-shields 146. The charge is placed inside the resistor element 110. The radiation-shields 146 then can be replaced and the top plate 12 securely bolted back on.

Electric power supplied to the resistor element 110 heats it to extremely high temperatures, driving out gas from the furnace parts and from the charge inside the resistor element. The gases are drawn into the gas chamber 166 by the vacuum pumping system, readily passing through the various openings in the resistor element and radiation-shields, and through the spaces between the radiation-shields. In operating the vacuum pumping system, the valves 176 and 178 are first closed and the valve 172 opened so that the rotary vacuum pump will operate to quickly reduce the pressure in the furnace to a pressure of 150 to 200 microns. The valve 172 is then closed and the valves 176 and 178 opened so that the oil diffusion pump 174 is added to bring the pressure down to fractions of a micron. In a specific embodiment, a rotary vacuum pump with a speed of 300 c. f. m. and an eight-inch oil diffusion

pump with a speed of the 600 c. f. m. brought the furnace pressure down to ten microns in less than a minute.

It should be noted that all the radiation-shields are comparatively loosely supported. The conductor-means are secured only at the points where they pass through the bottom plate 14. The top of the conductor-means 20 and the tops of the conductor-means 22, 24 and 26 are associated with the resistor element 110 which has considerable give because of its numerous long openings or slots 118. It acts in the nature of a bellows and readily accommodates itself to changes in dimensions and locations arising out of high temperature variations during operation of the furnace. It easily follows changes in the lengths of the conductor-means and its own dimensional changes without introducing shearing forces or other forces tending to disrupt the arrangement of the parts inside the furnace, or to break them. By having the various conductor-means pass through the same end of the casing, the distance between their ends tends to remain more nearly the same with changes in their lengths caused by heat.

An indication of the size of furnace of a specific embodiment such as herein described may be gathered from the fact that in this particular embodiment, the outside diameter of the steel cylindrical wall 4 of the metal casing 2 was 21¾ inches. The length between the facing surfaces of the top and bottom plates 6 and 8 was 51½ inches. The resistor element had an outer diameter of close to 11½ inches at its cylindrical wall 114 and an inner diameter of close to 10 inches.

While we have described our invention in a particular form now preferred, it is evident that many features of it are distinctly novel and subject to wide modification, and that other forms embodying our invention will be apparent from the teachings herein described.

We claim as our invention:

1. A furnace of a type described comprising an outer metallic casing having a removable end, a heating resistor element of graphite inside said casing, said resistor element having an end and a tubular portion adapted to encompass a charge, said tubular portion having an open end, and having a plurality of relatively narrow and elongated staggered transverse openings throughout, a plurality of spaced radiation-shields around said tubular portion, and a plurality of spaced disc-like radiation-shields between said tubular portion and said removable end of said casing, loosely fitted so as to be readily removable from and insertable into radiation-shielding position.

2. A furnace of a type described comprising an outer metallic casing having an end, a heating resistor element of graphite inside said casing, said resistor element having a charge-receiving end and a tubular portion adapted to encompass a charge, said tubular portion having an open end, and having a plurality of relatively narrow and elongated staggered openings throughout, a first conductor-means comprising a graphite rod connected centrally to said charge-supporting end of said resistor element, and a plurality of spaced conductor-means comprising graphite rods connected to the opposite end of said resistor element.

3. The invention of claim 2 characterized by said graphite rods extending away from said resistor element, in the same direction, and said openings being transverse to the axis of said tubular portion.

4. A furnace of a type described comprising an outer metallic casing having an end, a heating resistor element of graphite inside said casing, said resistor element having a first end and a tubular portion adapted to encompass a charge, said tubular portion having an open end, and having a plurality of relatively narrow and elongated staggered transverse openings, a first conductor connected centrally to said first end of said resistor element, said resistor element having an outwardly-extending ring spaced from first end, and conductor-means secured to spaced points of said ring.

5. The invention of claim 4 characterized by said conductor-means comprising graphite bars associated with said resistor element, said graphite bars having end-portions carrying said resistor element, and additional portions extending in the same direction from said end portions.

6. A furnace adapted for degassing comprising an outer metallic casing having a removable end, a cup-shaped heating resistor of graphite inside said casing, said cup-shaped resistor having an end and an upwardly-extending tubular portion adapted to encompass a charge, said tubular portion having an open end, and having a plurality of relatively narrow and elongated staggered openings throughout, a plurality of spaced curved radiation-shields around said tubular portion, and a plurality of spaced disc-like radiation-shields at both ends of said cup-shaped resistor element, the end radiation-shields toward said removable end of said casing being loosely fitted so as to readily be removable from and insertable into radiation-shielding position, a first downwardly-directed conductor-means connected centrally to said bottom of said resistor element, an outwardly-extending ring at the upper end of said tubular portion, and downwardly-directed conductor-means secured to spaced points of said annular ring, said conductor-means passing through and clearing said radiation-shields.

7. A degassing furnace system comprising an outer upright vacuum tight metallic casing having a removable top, a cup-shaped heating resistor of graphite having a bottom and an upwardly extending tubular portion for receiving a charge, said tubular portion having a plurality of relatively narrow and elongated staggered openings throughout, a central conductor-means vacuum-tightly passing through the bottom of said casing, a plurality of spaced disc-like radiation-shields of graphite carried by said conductor-means below said resistor-bottom, a plurality of radiation-shields comprising upright curved sections of graphite loosely carried about said tubular portion of said resistor, and a plurality of spaced upper disc-like radiation-shields of graphite loosely carried above said resistor element by said upright radiation-shields.

8. The invention of claim 7 characterized by said casing extending above said upper disc-like radiation-shields to provide a gas chamber thereabove, and a vacuum pumping system connected to said gas chamber.

9. A high-temperature furnace of a type described adapted for degassing operation, comprising an outer metallic casing, an expansible carbonaceous heating resistor element comprising a tubular portion providing a charge-receiving space, said resistor element having an open upper end, outwardly directed support means at said upper end, and a support member across its bottom end, a plurality of conductor means including relatively insulated conductors vacuum-

tightly passing through said casing, a first of said conductors being under said support member and comprising a carbonaceous portion extending to said support member, said carbonaceous portion being electrically connected to said support member centrally thereof, a plurality of spaced disc-like carbonaceous radiation-shields under said support member, said radiation-shields being carried by said first conductor.

10. A high-temperature furnace of a type described adapted for degassing operation, comprising an outer metallic casing, an expansible carbonaceous heating resistor element comprising a tubular portion providing a charge-receiving space, said resistor element having an open upper end, outwardly directed support means at said upper end, and a support member across the bottom end of the resistor element, and a plurality of conductor means including relatively insulated conductors vacuum-tightly passing through said casing, a first of said conductors being under said support member and comprising a carbonaceous portion extending to said support member, said carbonaceous portion being electrically connected to said support member centrally thereof, said conductor means comprising a plurality of other conductors comprising carbonaceous portions electrically connected to said support means, the last said carbonaceous portions being spaced from each other and parallel to the axis of said tubular portion.

11. An invention in accordance with claim 10 but characterized further by a plurality of carbonaceous spaced disc-like radiation-shields horizontally under said support member, having aligned holes therein, certain of said conductors passing through said holes.

12. An invention comprising that of claim 10 but further characterized by upright radiation-shields comprising curved portions circumferentially between said other conductors.

13. An invention including that of claim 12 but further characterized by having a plurality of spaced removable superimposed radiation-shields horizontally above said heating resistor element, and a plurality of radiation-shields horizontally below said heating resistor element, said radiation shields being carbonaceous.

14. A high-temperature furnace of a type described adapted for degassing operation, comprising an outer metallic casing having a removable upper portion, a hollow graphite resistor inside said casing having an open upper end toward said removable casing-portion, said resistor comprising a bottom member for supporting a charge inside said resistor, said resistor being slotted, a plurality of spaced upright radiation-shields around said resistor, a plurality of spaced disc-like radiation-shields at both ends of said resistor, the radiation-shields toward said removable casing-portion being loosely superimposed so as to be readily removable from and insertable into radiation-shielding position, and conductor means connected to said resistor for supplying said resistor with electrical energy, said conductor means passing through said casing at places outwardly of the space between said removable casing-portion and said removable radiation-shields.

15. A high-temperature furnace of a type described adapted for degassing operation, comprising an outer metallic casing having a removable upper portion, a hollow graphite resistor inside said casing having an open upper end toward said removable casing-portion, a graphite member at the bottom of said resistor for supporting a charge

inside said resistor, said resistor being slotted, a plurality of spaced upright radiation-shields around said resistor, a plurality of spaced disc-like radiation-shields at both ends of said resistor, the radiation-shields toward said removable casing-portion being loosely superimposed so as to be readily removable from and insertable into radiation-shielding position, a central conductor means vacuum-tightly passing through the bottom of said casing, and electrically connected to said resistor, a plurality of spaced outer conductor means vacuum-tightly passing through the bottom of said casing and electrically connected to the top of said resistor, said conductor-means being constructed and arranged for supporting said resistor, said central conductor means and said outer conductor means being relatively insulated.

16. A high-temperature furnace of a type described comprising, an outer metal casing, a carbonaceous heating element inside said casing adapted to receive a charge to be heated therein, said heating element having a plurality of openings therethrough for increasing the path of current-flow therethrough and for the passage of gas, said heating element being electrically insulated from said casing, and a plurality of spaced carbonaceous radiation-shields substantially completely about all sides of said heating element, said radiation-shields being arranged and spaced in said casing so as to permit gas to pass freely to and out of the spaces between them, and conductor means gas-tightly passing through said casing and connected to said heating element at spaced places thereon, said conductor means supporting said heating element inside said radiation-shields, said radiation-shields being so arranged as to be electrically insulated from said heating element and said conductor means so that the radiation-shields do not carry current.

17. A high-temperature furnace of a type described comprising, an outer metal casing, a carbonaceous heating element inside said casing adapted to receive a charge to be heated therein, said heating element having a plurality of openings therethrough for increasing the path of current-flow therethrough and for the passage of gas, said heating element being electrically insulated from said casing, and a plurality of spaced carbonaceous radiation-shields substantially completely about all sides of said heating element, said radiation-shields being arranged and spaced in said casing so as to permit gas to pass freely to and out of the spaces between them, a first carbonaceous conductor passing through a hole in a side of said casing and connected to an end of said heating element, a second carbonaceous conductor passing through a hole in said side of said casing and connected to the opposite end of said heating element, insulating vacuum-tight sealing means at said holes between said conductors and said casing, said conductors supporting said heating element and passing through spaces provided by a plurality of said radiation-shields, out of electrical contact therewith.

18. A high-temperature furnace of a type described adapted for degassing operation, comprising an outer vacuum-tight metallic casing, a carbonaceous heating resistor element comprising a tubular portion providing a heat-treating space, means connected to separated places on said tubular portion for passing electric current through it, said tubular portion having elongated narrow passages therein, a plurality of spaced carbonaceous radiation-shields at all sides of said

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resistor element in non-current-carrying relation thereto, said plurality of radiation-shields being constructed and arranged to permit gas to pass freely from the spaces therebetween and from the space inside of the resistor element into the rest of the casing, relatively insulated carbonaceous conductors passing through said radiation-shields for supplying said resistor element with electrical energy, said conductors being space-insulated from said radiation-shields, said casing being sufficiently longer than said resistor element to provide an exhaust gas-chamber beyond the resistor element and said radiation-shields, and means for pumping gas from said metallic casing, said pumping means comprising an intake pipe connection to said gas-chamber.

19. An invention including that of claim 18 but further characterized by a plurality of said radiation-shields comprising removable substantially horizontal discs above said resistor element, said gas-chamber being above said discs.

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12

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