

Aug. 2, 1938.

R. R. RIDGWAY

2,125,588

ELECTRIC FURNACE

Filed June 6, 1935

4 Sheets-Sheet 1

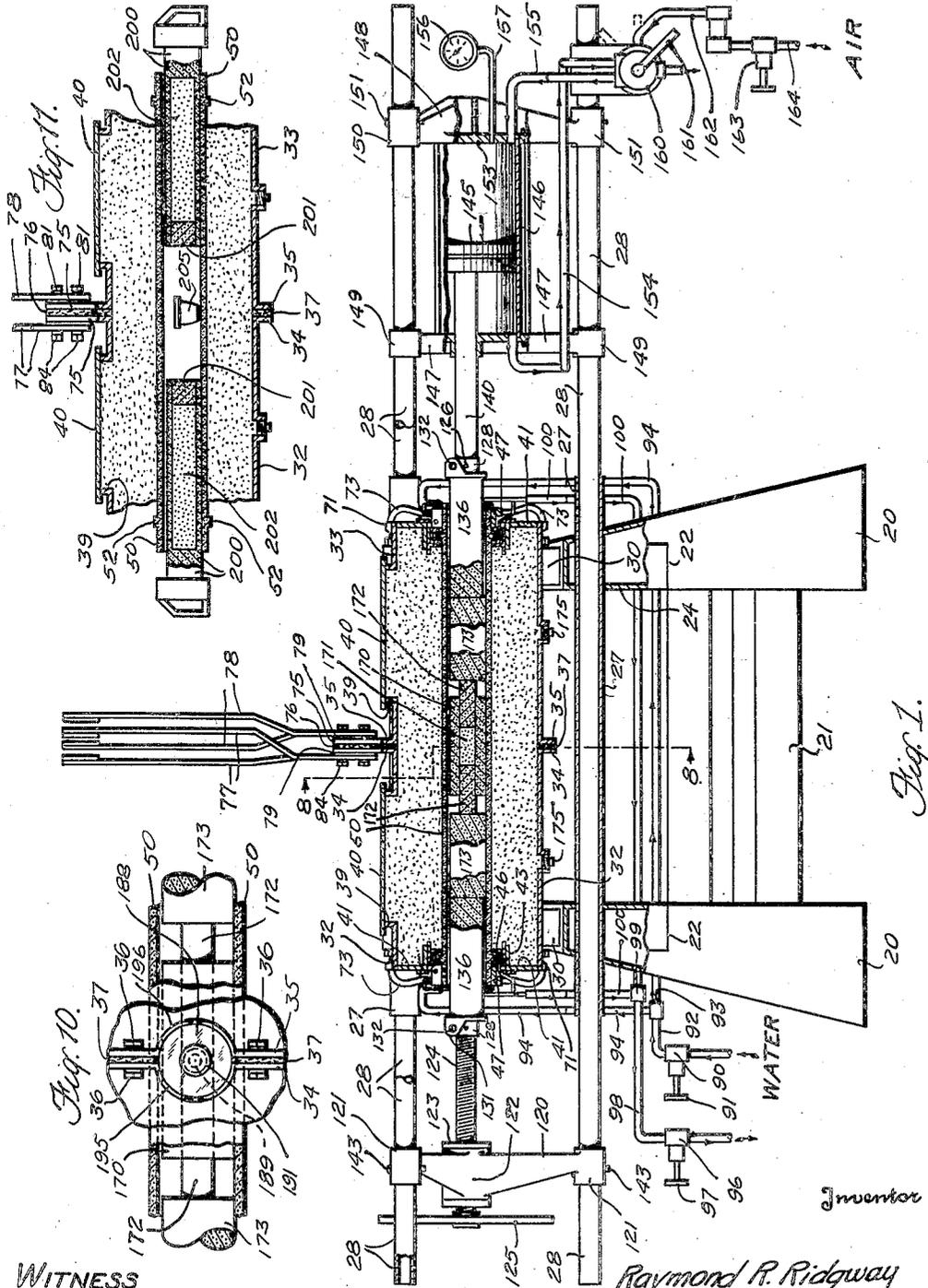


Fig. 1.

Fig. 10.

WITNESS

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4 Sheets-Sheet 2

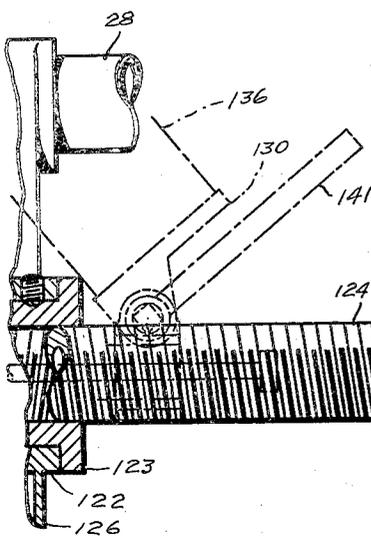


Fig. 1.

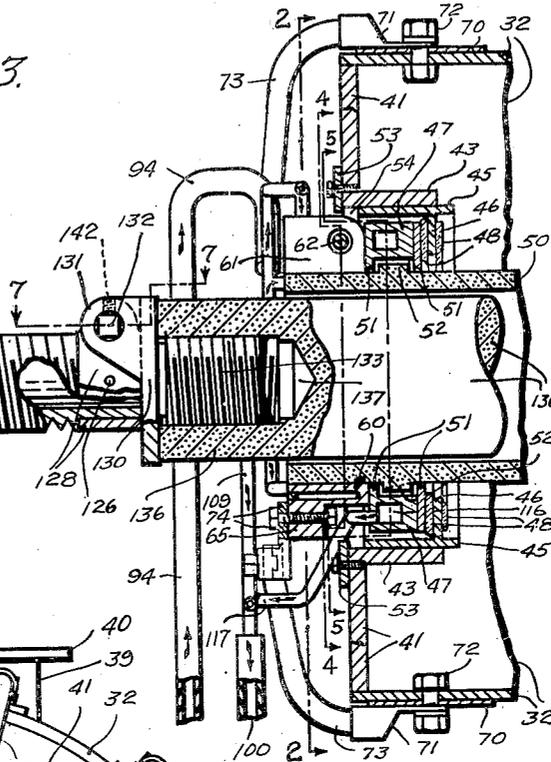


Fig. 2.

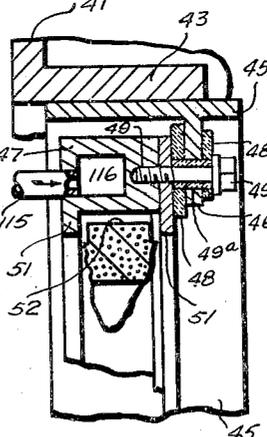
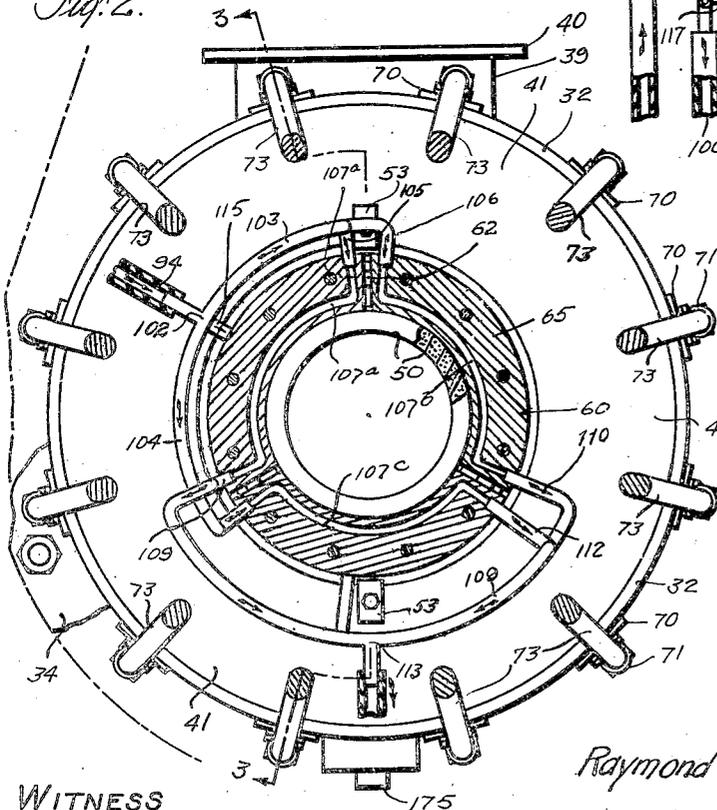


Fig. 4.

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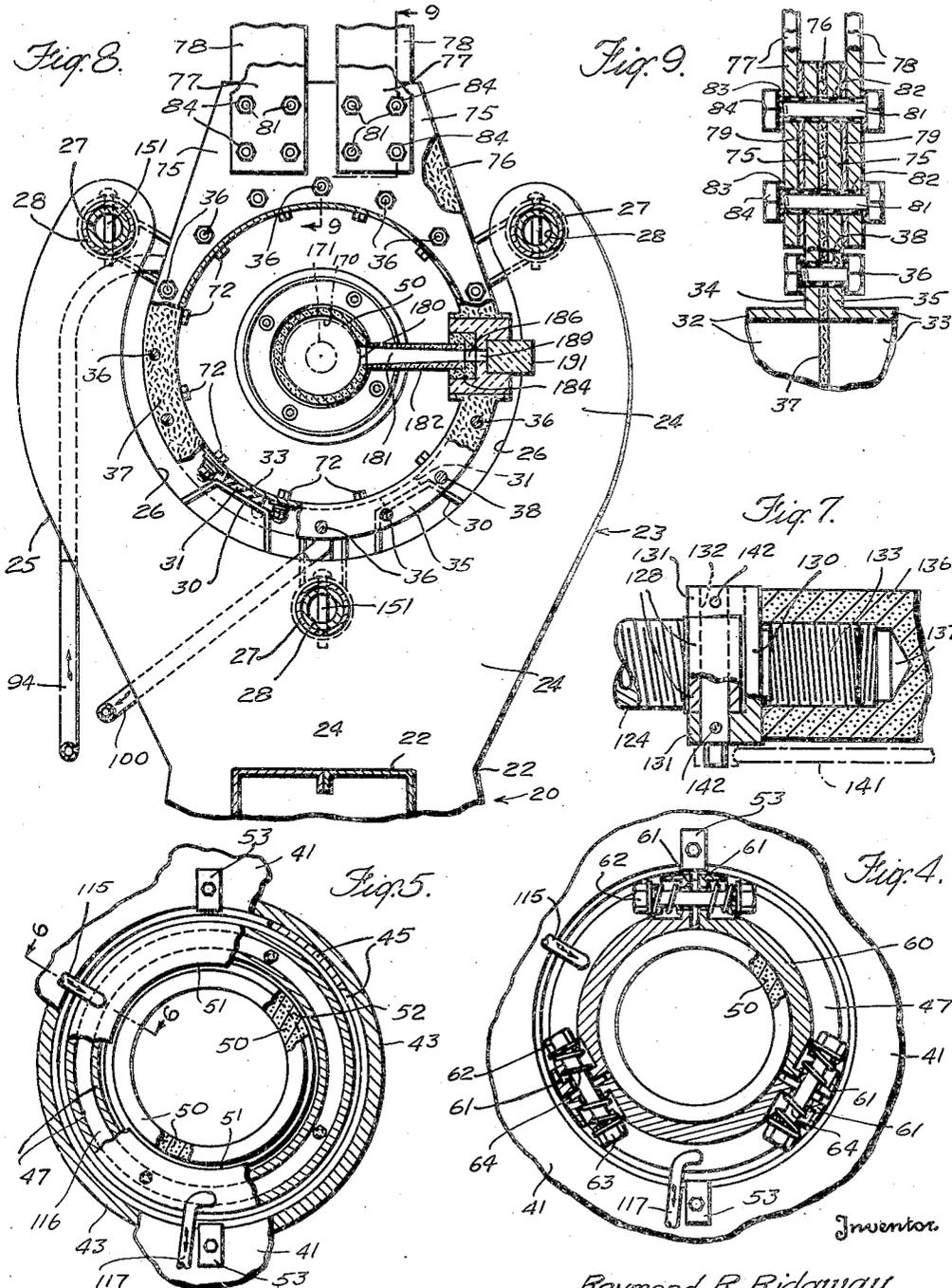
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Filed June 6, 1935

4 Sheets-Sheet 4

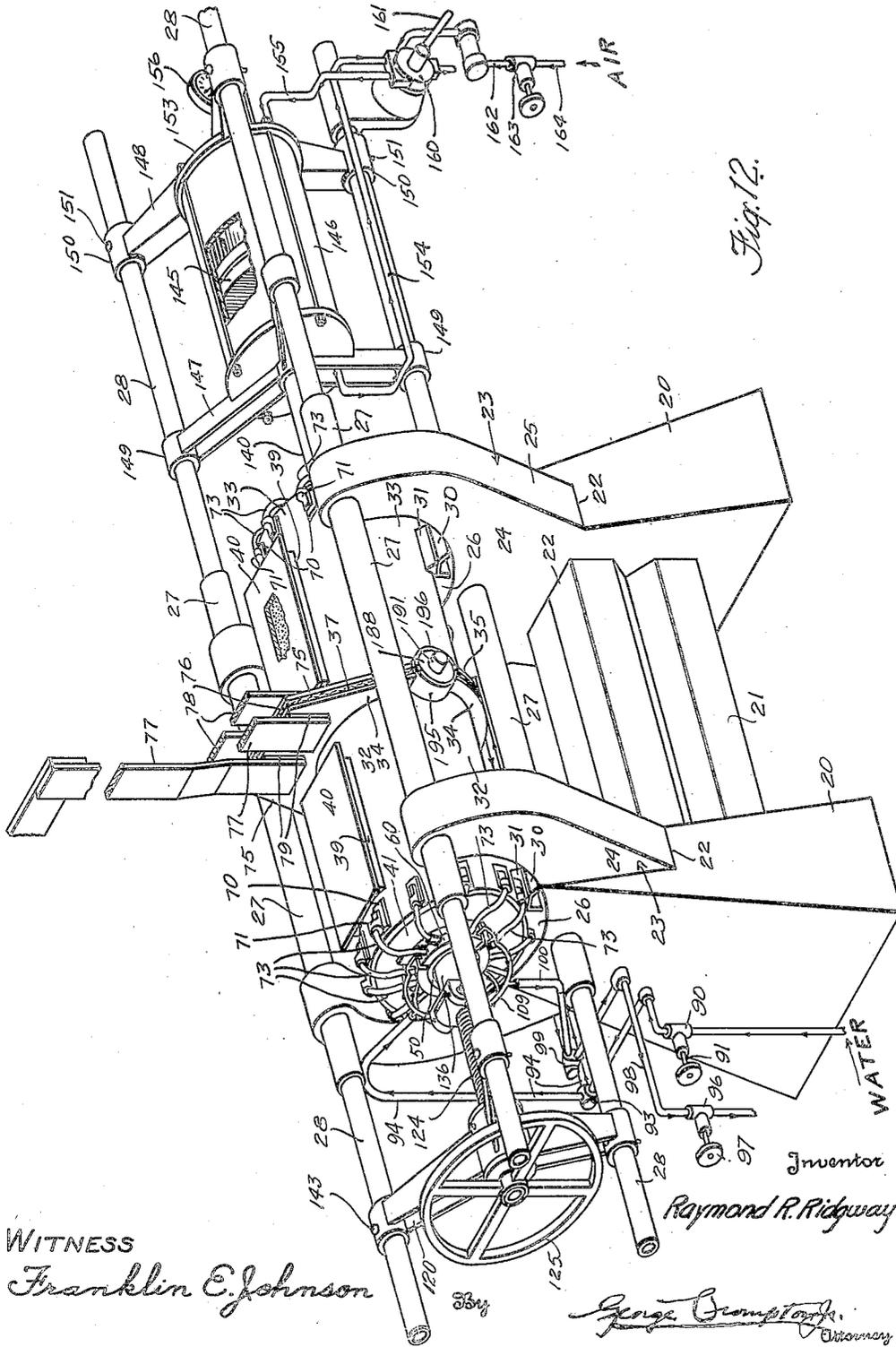


Fig. 12.

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UNITED STATES PATENT OFFICE

2,125,588

ELECTRIC FURNACE

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Application June 6, 1935, Serial No. 25,244

8 Claims. (Cl. 13—25)

The invention relates to electric furnaces, particularly of the resistance type and, with regard to its more specific features, to an electric furnace having pressure molding apparatus.

5 One object of the invention is to provide a furnace which will operate continuously at temperatures up to 2500 deg. C. Another object of the invention is to provide a low voltage carbon resistor furnace which will operate at a high power
10 factor so that an electrical control of temperature can be maintained where the wattage absorption of the furnace is proportionate to the change of voltage and where the wattless component of the current is kept at a minimum. Another
15 object of the invention is to provide a carbon resistor tube furnace adapted for large power inputs manufactured of metallic parts yet having no appreciable power losses from magnetic hysteresis and eddy currents. Another object of
20 the invention is to provide a furnace construction to receive an easily replaceable tube resistor. Another object of the invention is to provide a furnace construction adapted to insure long life to a tube resistor. Another object of the inven-
25 tion is to provide a gas-tight container for an oxidizable tube arranged so as to prevent destruction of the tube by reaction with air and at the same time providing for expansion and contraction of the tube which occurs during heating and cooling of the furnace. Another object
30 of the invention is to provide for the maintenance of continuous electrical contact and constant contact resistance with the resistor and at the same time permitting expansion and contraction of the tube freely in the container shell. Another
35 object of the invention is to provide a high temperature furnace adapted for the maintenance of a long uniform temperature zone which is at the same time adapted to the application of mechanical pressure on the furnace contents and the simultaneous exact measurement of the
40 temperature. Another object of the invention is to provide a furnace which will operate at a high degree of thermal efficiency while conforming to the requirements of the other objects listed above. Another object of the invention is to provide an improved furnace for carrying out the process disclosed in the copending application of Ridgway and Bailey, Serial No. 694,502 filed October
45 20, 1933. Another object of the invention is to provide combined pressure apparatus and furnace apparatus which may be easily and quickly manipulated for loading and unloading. Another
50 object of the invention is to provide an electric furnace having a sufficient seal. Another object

of the invention is to provide a resistance type furnace in which adequate provision is made for cooling the members that support the resistance element. Another object of the invention is to provide a furnace construction of extremely low
5 inductance as well as of low ohmic resistance. Another object of the invention is to distribute the current evenly around the electrodes in order to attain uniform temperatures. Other objects will be in part obvious or in part pointed out
10 hereinafter.

The invention accordingly consists in the features of construction, combinations of elements and arrangements of parts, as will be exemplified in the structure to be hereinafter described and
15 the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which is shown a preferred embodiment of my invention,

Figure 1 is a view partly in axial section and
20 partly in elevation of the furnace and pressure apparatus;

Figure 2 is a view partly in end elevation and partly in cross-section along the lines 2—2 of
25 Figure 3;

Figure 3 is an axial sectional view on an enlarged scale of one end of the furnace;

Figure 4 is a cross-sectional view taken on the line 4—4 of Figure 3;

Figure 5 is a cross-sectional view taken on the
30 line 5—5 of Figure 3;

Figure 6 is a fragmentary enlarged sectional view on an axial plane of a gland ring and associated parts;

Figure 7 is a plan view of a pressure plunger
35 showing its articulation to a screw shaft;

Figure 8 is a cross-sectional view taken on the line 8—8 of Figure 1;

Figure 9 is a detailed sectional view of the bus bars and their connection to the furnace;

Figure 10 is an enlarged front elevation of the central portion of the furnace showing the sighting tube for an optical pyrometer and associated structure;

Figure 11 is a fragmentary axial sectional view
45 illustrating a manner of using the furnace apart from the pressure apparatus;

Figure 12 is an isometric view of the entire apparatus.

Similar reference characters refer to similar
50 parts throughout the several views of the drawings.

Referring first to Figures 1 and 12, I provide a pair of standards 20, 20, as shown in Figure 1, which may be similar but oppositely oriented and
55

which, as disclosed, may be hollow frustums of pyramids formed out of sheet steel or the like. Referring also to Figure 8, the standards 20, 20 are connected by a longitudinal frame member 21 which may be of hollow construction and which, as shown, connects two vertical plane surfaces of the standards 20, 20, thus to give rigidity to the entire supporting frame structure. I may join the several sheets of steel by welding. Intersecting the standards 20, 20 at the plane marked by the lines 22, 22 on Figure 12 are generally U-shaped supports 23 comprising plane sheet metal ends 24, outside sheet metal plates 25, and inside sheet metal plates 26, the latter being bent into circular cylindrical segments, and either the plates 25 or 26 being bent around the tops of the U, and the entire structure constituting a support for a cylindrical furnace from which it cannot accidentally roll off. This structure described is strong and rigid and of very low specific heat. The inside pair of sheet metal ends 24 may be integral with the corresponding sides of the pyramidal standards 20 if desired, and the various parts may be welded together, the entire frame structure being more clearly understandable from inspection of Figure 12 than is possible by way of verbal description.

Extending through the upper ends of the U-shaped supports 23 and also through the lower portion of the supports are three supporting tubes 27. These tubes 27 lend further strength and rigidity to the supporting structure; they also constitute a mounting for thrust members for the pressure apparatus to be described. These thrust members preferably take the form of three tubes 28 which are slidable in the supporting tubes 27.

Referring now to Figure 8, resting on the inside cylindrical plates 26 are chairs 30, 30 in the form of inverted U's. There are a pair of these chairs 30 in each support 23, thus making four in all, and upon the inclined tops thereof I affix insulating and heat-resistant pads 31.

Resting on top of the pads 31 are a pair of aluminum cylinders 32 and 33 connected together by flanges 34 and 35 and bolts 36. An insulating ring 37 is interposed between the flanges 34 and 35, and as better shown in Figure 9 insulating sleeves 38 are provided surrounding the bolts 36. As shown in Figures 1 and 12 a rectangular portion 39 is formed in the otherwise cylindrical wall of each cylinder 32 and 33, and through the openings formed thereby access may be had to the interior of the cylinders as for the introduction of heat insulating material the nature of which will be presently described. Covers 40 normally cover these openings.

Referring now particularly to Figure 3, closing the otherwise open end of each cylinder are annular end plates 41. These annular plates 41 may be made of aluminum or other suitable material and may be welded to the cylinders 32 and 33 respectively. By the provision of aluminum cylinders partly closed by aluminum end plates, I have provided a non-magnetic material surrounding the central heating chamber of my furnace, and at the same time the material is electrically conductive and I use the cylinders 32 and 33 for passing a heavy heating current into the furnace by a cylindrical path, the advantages of which will presently be pointed out.

Referring now also to Figure 6, the annular plates 41 have integral cylindrical portions 42 geometrically projected from the inside bounding circles of the plates. The portions 42 con-

stitute supports for the heating resistance element and the electrodes. Slidably mounted in the cylindrical extensions 43 are cylindrical rings 45 having radial inward extensions 46. One of the features of the invention is the provision of means permitting the expansion and contraction of the heating tube hereinafter described without fracture thereof. Another feature of the invention is the accomplishment of the foregoing with a gas-tight seal. I provide gland rings 47 which support the tube hereinafter referred to and also constitute the seal, expansion and contraction being taken care of by sliding of the rings 45 in the extensions 43. I have found, however, that in order to prevent seizing of the rings 45 in the cylindrical extensions 43 it is desirable to water-cool the gland rings 47. Accordingly these rings are water-cooled in a manner which will be more fully pointed out hereinafter.

Referring now particularly to Figure 6, the construction of a gland ring 47 and its connection to a cylindrical ring 45 is therein disclosed. I provide a pair of insulating rings 48 which, because of the high temperatures encountered due to direct radiation from the heating tube, I prefer to make of mica, Transite or the like. The rings 48 are located on opposite sides of the radial inward extension 46 and bolts 49 extend through both rings 48, through the extension 46, and into the gland ring 47 securing these parts together, but the gland ring 47 being insulated from its support the cylindrical ring 45. I may also provide insulating tubes 49a of mica or the like surrounding the bolts 49. Thus each gland ring 47 is insulated from the aluminum shells 32 and 33 respectively. Excepting as hereinafter noted the furnace is symmetrical and every part on the left is duplicated by a part on the right and this holds true up to the bus bars and to the thrusting elements of the pressure apparatus, so I shall now continue to describe the left-hand end of the furnace using the singular excepting where there are a number of identical parts at each end.

Referring now to Figures 1 and 3, the furnace is a resistance type of furnace and the principal heating element thereof is a graphite tube 50 (there is only one such tube) which extends the length of the combined cylinders 32 and 33 and projects slightly therebeyond at each end thereof. The graphite tube 50 is supported by the gland ring 47 which has radial inward extensions 51 defining an annular space in which is located an annular ridge 52 integral with the graphite tube 50, the fit being a loose one and this construction constituting a labyrinth seal, which is filled with the material which fills the cylinders 32 and 33. Thus this gland prevents entry of air into the furnace and at the same time supports the tube 50 by loose connection in order to avoid breakage due to the high heat employed and consequent expansion and warping of some of the parts.

The entire assembly constituting the tube 50, the water-cooled gland ring 47, and the cylindrical member 45 with its extension 46 is free to move inside of the cylinder 43 as the graphite tube 50 expands under the influence of the heat generated therein, until the end of the ring 45 contacts with limiting stops 53 bolted to the annular plate 41, as shown in Figure 3; the gap 54 is large enough to take care of all the expansion of the one-half of the tube 50 that takes place in practice, while progressive creeping of the tube 50

in one direction only is eliminated by the provision of these stops 53.

Referring now to Figures 2, 3 and 4, I secure electrodes 60, 60, 60 to each end of the graphite tube 50. The electrodes 60 are segmental and of identical shape. Each one subtends an arc of approximately 120 deg., and as better shown in Figure 4, each is provided at its two ends with abutting flanges 61, there being six such flanges for the three segments collectively, and each set of three segments being flexibly connected together by bolts 62 passing through the flanges 61 and nuts 63 which engage springs 64; thus the segmental electrodes 60 are maintained in firm contact with the tube 50 but when the diameter of the tube 50 increases on account of thermal expansion, the electrodes expand with it despite the fact that they are water-cooled. The electrodes 60 are likewise formed with radial flanges 65, each one connecting a pair of flanges 61 and displacing nearly one hundred and twenty degrees, and the flanges 65 receive electric current from the cylinders 32 and 33, as will now be described.

Referring now to Figure 3, circumferentially around and upon the outside of each of the cylinders 32 and 33, I solder copper plates 70, and to these plates 70 I bolt cable terminals 71, preferably of copper, by means of bolts 72. The terminals 71 are mounted on the ends of cables 73, the other ends of which extend into clamps 74 bolted to the flanges 65. The cables 73 are preferably of copper stranded cable, which provides a path of extremely low resistance for the current, also being mechanically flexible, and the arrangement of these cables can be understood from reference to Figure 2 which shows twelve of them, four extending to each electrode 60.

Referring now to Figures 1, 8 and 9, I provide upwardly extending wings 75, integral with the flanges 34 and 35 respectively and the insulating ring 37 has a similar upward extension 76, and to these wings 75 I fasten bus bars 77 and 78. The bus bars 77 and 78 are each of them branching bus bars, and of slightly different shape and interlaced construction, as shown in Figure 1, and the form adopted insures that they and connecting leads or bars shall have low inductive reactance. As illustrated in Figure 9 in detail, copper plates 79 are soldered to the aluminum wings 75 and the bus bars 77 and 78 are held to these copper plates 79 by means of four bolts 81 surrounded by insulating tubes 82 so that the bus bars 77 and 78 are insulated from each other. Each bolt 81 is further provided with insulating washers 83 and a nut 84 to complete the insulation and to hold the parts together, this entire construction being clearly shown in Figures 8 and 9. The bus bars 77 and 78 preferably are made of copper, and I note that by providing copper plates soldered to the aluminum cylinders 32 and 33 and extensions thereof, a very excellent conducting path for the electric current is provided, much superior to a direct contact between aluminum and copper without the soldering, as aluminum quickly oxidizes and the film of aluminum oxide found on the surfaces of exposed aluminum parts is not an extremely good conductor of electricity.

For molding boron carbide, in order to make articles thereof, I found that a temperature of around 2200 deg. C. had to be attained and therefore a reasonable requirement of the furnace was that it should be able to operate continuously at temperatures up to 2500 deg. C. So far as I am at present aware, there are few materials which

will withstand such high temperatures and the outstanding class of substances is carbonaceous substances. I have found that electric furnace graphite of the brand known as "Acheson's" graphite is the material which is most reliable and constant in its properties within the temperature range desired for the resistance tube. Graphite, however, is not strong, relatively speaking, and therefore I make the tube of substantial cross-section, particularly as it is subject to mechanical strains in the furnace. Graphite, however, has low electrical resistance when compacted into a tube or the like and therefore a mechanically strong resistor tube will have low electrical resistance if the furnace is of reasonable size. Therefore, in the case of a furnace large enough to mold fair sized articles, inasmuch as there is a limit to the length of the furnace for mechanical reasons, the heating tube is of low resistance, and in order to attain high temperatures and reach them in a practical length of time, a high power (energy input rate) on the resistor is required. Because of the high power and the low resistance of a practicable resistor tube, high currents at low voltages are encountered. Since the R is so low the inductance L must be kept at a minimum value if high power factors are to result in the furnace.

This and allied objects of the invention are attained in the construction already described because the current paths in the aluminum shells 32 and 33 are not localized and the current path may be thought of as a series of elements along the cylindrical shell, the current direction being instantaneously always opposite to that in the carbon resistor tube. It will be observed that this feature would be attained even though the bus bars were not located at a mid point of the furnace as disclosed. Inasmuch as the heating tube 50 is as close to the aluminum shell as it may be consistent with heat insulation requirements, the magnetic flux induced by the current in one of these parts does not give reactance to the flow of the current in the other part. Furthermore it will be seen that no continuous metallic current paths link the magnetic flux induced by the flow of the heavy currents.

Because of the radial distribution of the cables 73 around the circumference of the furnace, only a fractional part of the current links the flux induced in the space inside the cylindrical shells. Thus substantially the minimum inductance is attained which is theoretically possible. Although the cables 73 form a slight loop in extending to the water-cooled electrodes 60, they are quite short and I have found by experimentation that the slight increased voltage required for end connections such as described is less than the losses incurred in having an actual sliding electrical contact in the position of the gland ring 47.

Although I prefer to make the cylinders 32 and 33 of aluminum because it provides good electrical conductivity and mechanical strength with low weight and low specific heat and absence of magnetic effects, nevertheless it should be noted that because the geometry of the furnace is practically noninductive these cylinders might be made even of steel or iron without large losses. However, as stated, aluminum shells are preferred.

Besides providing a current path of low inductance, it will be seen that the construction provides a current path also of low ohmic resistance and thus the furnace utilizes a very high per-

centage of the kva. input in heating the resistance element 50. So far as operation of the furnace is concerned, the current might be direct current, but in commercial practice alternating current is the one chiefly met with, and for high power installations at the low voltages it is the only one commercially practical, and therefore the elimination of inductive effects is of great importance from a commercial standpoint as even in the case of frequencies as low as 25 cycles per second, with the amount of current which I found it desirable to use, inductive reactance is a factor of prime importance and the avoidance thereof measurably increases the efficiency of the furnace, and the accuracy of temperature control.

Considering now the cooling of the electrodes and the gland rings, and referring first to Figure 1, I provide a water connection 90 in the form of a union having a valve 91 which is connected by piping 92 to a T-union 93 where the water branches, by way of feed pipes 94 extending to each end of the furnace. At the exhaust end, I provide a union 96 having a valve 97 which receives water from a pipe 98 extending from a T-union 99 that receives water from pipes 100 extending to each end of the furnace. By means of the valves 91 and 97, the flow of water may be controlled, and by restricting the flow by the valve 97, the cooling chambers may be maintained full of water. Distribution and return of cooling water is the same at each end of the furnace.

Referring now to Figure 3, it will be seen that the pipe 94 extends upwardly beyond the axis of the tube 50 and there has a U-bend. Referring now to Figure 2, the delivery end of the pipe 94 is therein shown and it is connected to a T-union 102 with branching extensions 103 and 104, the former leading up and the latter leading down. The piping is distributed around a circle which includes the electrodes described, and still referring to Figure 2, at the top of the circle the extension 103 extends away from the plane of this view along a line parallel to the axis of the furnace and branches into feed pipes 105 and 106. This connection is fragmentally shown in Figure 3, and as therein shown, the feed pipe 105 extends downwardly and into one of the three electrodes 60, being the left-hand upper electrode as they are viewed in Figure 2. Referring now to Figure 2, the feed pipe 106 extends downwardly into the right-hand upper electrode 60. Water passages are formed in all three electrodes, a passage 107a in the left-hand upper electrode extending downwardly through the radial flange 65 and into the base of the electrode 60, then along its entire length and outwardly. This passage 107a may be formed by milling radial slots in the electrode at opposite ends of its 120 deg. contour, then milling an arcuate slot connecting these radial slots near the inner periphery of the segmental electrode, then closing the slots at the outside with welded segmental rings and bars.

The feed pipe 105 leads to a similar passage 107b similarly formed in the right-hand upper electrode 60. Passage 107a delivers water to a delivery pipe 109, and passage 107b delivers water to a delivery pipe 110.

The downwardly extending feed pipe 104 extends backwardly and then inwardly to deliver water to a passage 107c the delivery end of which is connected to a return pipe 112, thus cooling the lower electrode 60. The pipe 109 extends radially, then axially, then radially again, and finally

into a segment coaxial with the furnace, and pipes 110 and 112 are joined by a union to this segment 109, and thus water flows both ways in the segment 109 to a T-union 113 which connects to the exhaust pipe 100.

At the T-union 102 is a third pipe 115 extending in the third dimension from pipes 94, 103 and 104, and this leads water to the gland ring 47 in a manner that can be better appreciated by reference to Figures 3, 5 and 6. Figure 5 shows the pipe 115, and Figure 6 illustrates one end of it which extends through to the annular space 116 in the ring 47. An exhaust pipe 117, as shown in Figure 4, and also in Figure 3, leads water to the union 113, and thus to the exhaust pipe 100. This gland ring 47 is preferably a brass casting, and the passage 116 may be made with a core.

Referring now to Figure 1, I provide at one end of the furnace movable pressure apparatus and at the other end thereof adjustable apparatus to take the thrust. Referring to the left-hand side of Figure 1, the tubes 28 support a spider 120 having parallel bores through three bosses 121 on the ends of the three arms thereof, and having a central hub 122 in which is a nut 123 secured thereto. Extending through the nut 123 is a screw shaft 124 on the left-hand end of which is fastened a hand wheel 125.

Referring now to Figure 3, the right-hand end of the screw shaft 124 is turned down, and fastened thereon by means of a pin 126 is a collar 127 having a boss 128 as better shown in Figure 7, through which is a bore extending at right angles to the axis of the shaft 124. A plate 130 has a pair of ears 131 with holes aligning with the hole in the boss 128, and plate 130 is pivotally mounted on the collar 127 by means of a pin 132 extending through ears 131 and box 128. Extending forwardly from the plate 130 is a threaded support 133. The screw shaft 124 may be hollow, as shown, in order that it may be of large diameter without being too heavy.

Upon the threaded support 133 I mount a graphite pressure plunger 136, which has an internally threaded bore 137 for this purpose. The parts shown in Figure 7, with the exception of the screw shaft 124, are duplicated at the right-hand end of the furnace, there being a second graphite pressure plunger 136 at the right-hand end of the furnace connected, however, to a piston rod 140. By reason of the articulation of the graphite plungers 136 as described, they may be swung through approximately 180 deg. when the plungers are withdrawn from the furnace, and in order to facilitate this, desirably I provide a handle 141 fastened to the pin 132 at each end, each pin 132 being secured to the ears 131 as by means of cross-pins 142. To take the thrust on the screw shaft 124 I provide transverse pins 143 extending through the bosses 121 and the shafts 28. It will be seen that when the parts are in the position shown in Figure 7, the thrust upon the plungers 136 is taken by the plate 130 and transmitted to the collar 127 and thence to the screw shaft 124 at one end of the furnace, or to the piston rod 140 at the other end of the furnace. For loading the furnace, the plunger 136 may be rapidly withdrawn by means of the hand wheel 125 at the left-hand end of the machine, or by the pneumatically actuated apparatus at the right-hand end of the machine, and by the provision for swinging the plungers 136 through 180 deg. I am enabled to make the entire apparatus more compact yet allowing ready access to the inside of the resistance tube 50.

Considering now the pneumatic pressure apparatus by which high pressures may be exerted upon a substance to be molded under heat and pressure in the resistance tube 50, this apparatus may be supported upon the tubular shafts 28 at the right-hand side of the furnace as shown in Figure 1.

Referring to that figure the piston rod 140 is connected to a piston 145 in a cylinder 146 which is supported by spiders 147 and 148 having bosses 149 and 150 through which the tubes 28 pass. Longitudinal thrust is transmitted from the piston 145 and cylinder 146 to the rods 28 through pins 151 similar to the pins 143 and having the same function. The cylinder 146 has cylinder heads 152 and 153, and a pipe 154 connects to the left-hand end of the cylinder 146 through the cylinder head 152, while a pipe 155 connects to the right-hand end of the cylinder 146 through the head 153. If desired a gauge 156 may be provided connected to the right-hand end of the cylinder 146 by means of a pipe 157. Each of the pipes 154 and 155 leads to a triple valve 160 having an operating handle 161, and a pipe 162 connects by way of a valve 163 to piping 164 leading to a source of air under pressure, steam under pressure or the like. Triple valves being known, no cross-section thereof is shown, but in one position of the handle 161 air is admitted to the right-hand side of the piston 145 while the left-hand end of the cylinder 146 is connected to an exhaust pipe 165 which simply exhausts into the air. In an opposite position of the valve handle 161 air or steam is directed to the left-hand side of the piston 145, and the right-hand side of the cylinder 146 is connected to the exhaust 165. In a third, which is a mid or neutral position of the handle 161, the flow of air or steam is shut off altogether by the valve 160, and both sides of the cylinder 146 are connected to exhaust 165, or the parts connecting to the pipes 154 and 155 may be blocked. Various modifications of this and various types of valves may be used, but by means of the handle 161 the piston 145 may be moved to the right or left, and when moved to the left it may be thrust in that direction with great force, which is transmitted to the graphite plunger 136.

As in the copending application previously referred to, an important use for the furnace is to mold powdered boron carbide (B₂C) under heat and pressure thereby forming a boron carbide article of great density, strength, and uniformity of crystalline structure. In the table below I give a typical example of instantaneous values of electrical quantities for a furnace constructed in accordance with the invention.

Instantaneous values of electrical quantities

	Power input k. w.	Am- peres	Volts	Mi- crohms	25 cycles			60 cycles		
					Z	X	P. F.	Z	X	P. F.
Start of run.....	61.2	5,880	10.6	1.77	1.8	.332	.983	1.94	.798	.912
At molding temperature.....	8.28	1,600	5.2	3.235	3.25	.332	.995	3.33	.798	.971

In the above table Z and X are given in microhms while P. F. represents power factor.

The remarkable thing about the electrical data is the high power factor achieved in this furnace using such large currents at very low voltage. This is achieved by the features herein before described.

Considering now Figure 1, I have shown a graphite mold 170 in the center of the furnace, and therein is the article 171 being molded under heat and pressure. Graphite plungers 172 are shown extending into the bore of the mold 170 and graphite spacers 173 connect the plungers 172 to the movable plungers 136.

In order to conserve the heat generated in the furnace and in order to prevent the apparatus from becoming overheated, I fill the cylinders 32 and 33 with an inert material, and in order to avoid oxidation or other chemical activity this inert material should be, as nearly as possible, of the same substance as the resistance element 50. Graphite being the substance which I prefer to use for the resistance element, I have found that powdered carbon, such as lamp black or the like is the substance which I prefer to use to confine the heat in the resistance element 50. Therefore I fill the cylinders 32 and 33 with powdered carbon, and this seeps into the space between the resistance element 50 and the ridges 52 thereof and the gland ring 47, and whatever oxidation takes place, takes place only at the opening of this gland. Any slight amount of air in the powdered carbon is converted into carbon monoxide or carbon dioxide and the reaction goes no further. I may charge the cylinders with carbon through the covers 40, and in order to facilitate removal of all carbon therefrom I have provided screw threaded plugs 175 in the bottom of the cylinders 32 and 33.

It is one of the features of this invention that carbon black may be used without electrical leakage at the low voltage practically attained through the specific non-inductive features, as the sole insulating material loosely packed inside of the cylinders. This carbon black provides heat insulation of great efficiency which is non-conducting at the voltages used. It is well known that at temperatures as high as the operating temperature of this furnace, heat losses by radiation are enormous. Carbon black acts as a radiation screen and at the same time prevents conduction and convection. Any gas leaks in the joints of the furnace permitting oxygen in the air to enter the compartment will be reacted upon by the finely divided carbonaceous filling material to absorb the oxygen by combining with it. Furthermore, in case carbon monoxide is formed and explodes, the covers 40 provide what is in the nature of a safety valve as they simply lift with the explosion which thus does no damage to the apparatus.

In the operation of this furnace it is desirable that a check be made upon the heat developed

in the graphite tube 50. To this end, and referring now to Figures 8, 10 and 12, I provide an orifice 180 in the tube 50 which is in line with the tapered bore 181 in a graphite tube 182 whose axis is perpendicular to that of the tube 50 and which is supported, as better shown in Figure 8, at the inside end by a countersunk

portion in the side of the tube 50 and at the outside end by means of a graphite plug 184 which is also countersunk to receive the end of the tube 182 as shown in Figure 8. The plug 184 has a bore 186 and is in turn supported by a countersunk portion in a cylindrical block 188 having a bore 189 which is in alignment with the bores 181 and 186. The block 188 may be made of suitable electrical and heat insulating material. In Figure 8 I show the three bores 181, 186 and 189 blocked by a plug 191 which is inserted into a countersunk portion of the outside of the cylindrical block 188. This plug 191 may be made of the same substance as the block 188 and may be readily removed. When it is removed an optical pyrometer may be used to determine the heat of the mold 170.

Referring now to Figures 10 and 12, it will be observed that the flanges 34 and 35 merge into semi-cylindrical portions 195 and 196 which support the block 188 as shown. The semi-cylindrical portions 195 and 196 do not contact each other but are separated by the insulating ring 37.

Referring now to Figure 11, I show a modification of my furnace in which any article may be fused or otherwise heat treated but not under pressure. In this embodiment of the invention the furnace is of the same construction as that already described, and the piston and cylinder unit as well as the screw shaft 124 and operating mechanism may be used for the purpose of readily opening and closing the furnace, or simplified mechanism may be substituted therefor. In place of the graphite plungers 136 I provide graphite plugs 200 which are hollow the greater part of their length as shown in Figure 11, and have the inner ends of their bores blocked by plugs 201. The remainder of the interior of the plugs 200 may be filled with lamp black 202 or other form of carbon or the like. By this construction I provide effective heat insulation for the furnace at low expense. In the center of this furnace I have shown a crucible 205 representative of a container for an article or substance being fused under heat but not under pressure.

It is a feature of the invention that the total water-cooled area in contact with the graphite tube is maintained at a minimum. This is attained by the combination of the narrow sliding gland 47 and the narrow electrodes 60. If the electrical contacts were allowed to slide to take care of expansion and contraction, much larger areas would have to be provided and greater heat losses incurred.

There are definite practical limitations in the manufacture of graphite resistors of great length in proportion to their cross-sectional area. Since it is desirable in a furnace of the type described to have the temperature gradient fall continuously from the point of highest temperature, which is in the center of the furnace, to the ends where the water-cooled electrodes are attached, a long zone of constant temperature in the center of the furnace requires a tube which is relatively long in proportion to its cross-sectional area. The amount of the tube wasted on the ends for the electrodes and for the glands should therefore be kept to the minimum, and by the provision of narrow glands and electrodes a substantial saving and improvement have been effected.

Considering now the operation of my furnace, having selected a suitable graphite mold 170, and plugged up one end thereof with a graphite plunger 172, I fill the mold from the other end

with a measured quantity of grain prepared and then insert the other plunger 172. At this time the plunger 136 is withdrawn from the furnace and is away from the opening of the graphite resistance tube 50, being swung back on its fulcrum 132. The piston 145 is to the right so that the other plunger 136 is out of the tube 50 and it may also be swung out of the way. It may be desirable to cold-press the plungers 172 against the boron carbide in the mold 170 with a slight pressure to facilitate handling. Whether this is done or not, the entire unit may be readily introduced into the graphite tube 50 and placed approximately in the middle thereof, as by means of any long rod. Graphite blocks 173 are then inserted in the furnace and moved up against the plungers 172. The plunger 136 is now lowered and by spinning the hand wheel 125 it is caused to enter the furnace.

By careful control of the handle 161, after lowering the other plunger 136 to horizontal position, this plunger may be now introduced into the furnace. At this time the parts may be carefully watched so that the plunger 136 is moved just far enough to eliminate open spaces between the various elements in the tube 50 without undue shock to the moving plunger. At this time it should be ascertained that the position of the two plungers 136 is approximately the same at both ends of the furnace, or if the positions of these plungers respectively are different, adjustment may be made by turning the hand wheel 125. The valves 91 and 97 should be now opened to insure the flow of cooling water, and after the valve 91 is opened wide the valve 97 should be closed slightly to squeeze out air blocks.

The current may be now applied and the air should be now turned on by means of the valves 161 and 163 until the reading on the gauge 156 is such as to give the desired pressure per square inch against the boron carbide 171 being molded. As heretofore stated, all the factors of heat, pressure, time, and the like may be varied, and there will be a corresponding variation in the final article. However, results can be duplicated and the furnace is quite universal for the production of many different types of articles. I contemplate that in many cases it will be desirable to attach a pointer to the piston rod 140 which may extend to a scale marked on one of the rods 28, for example. Any suitable type of pointer or indicator may be used and it may be removable or adjustable or both.

An optical pyrometer may be used through the medium of the pyrometer tube described, in order that the operator may control the temperature as desired. In order to hasten the cooling, a stream of water may be turned upon the outside of the cylinders 32 and 33. The pressure may be reduced at an instant's notice by manipulation of the valve 161.

The furnace described may be easily operated and controlled on account of the means described for moving the plungers 136 and swinging them out of the way. Furthermore, a very high heat may be generated as already indicated, and despite the high heat and pressure the graphite tube 50 is not destroyed for its expansion is taken care of at the gaps 54 and the pressure is confined to a single axis. In fact, it will be noted that no couple whatsoever is generated by the pressure means employed, there being no component of force in any direction other than a horizontal direction and the pressure as well as

the thrust being along a single axis. Furthermore, by reason of the distribution of the rods 28 at equal distances from the axis of the tube 50, all strains and forces are balanced and there is no pressure against the cylinders 32 or 33 or any of the parts connected to the electrodes. Radial expansion of the graphite tube can take place without fracturing any part due to the expansibility of the electrode structure. Furthermore, the flow of current is cylindrical and radial thus substantially avoiding inductance effects. The insides of the cylinders 32 and 33 may be readily reached at any time and it will be noted that the resistance tube, the heat insulating structure and the electric current carrying structure, as well as the water coolant connections, are freely suspended so as to be virtually independent, in a structural sense, from the pressure apparatus. This further reduces undesired strains and stresses and also facilitates the dismantling of the furnace or the replacement of parts whenever desired.

It will thus be seen that there has been provided by this invention an apparatus in which the various objects hereinbefore mentioned are successfully achieved. As various possible embodiments may be made of the above invention and as many changes may be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:—

1. In an electric furnace, a casing, a tubular resistance element, a support for the resistance element permitting slight axial movement thereof relative to the casing, a multi-segment electrode, radial flanges projecting from the opposite ends of each of the segments, and spring means holding said flanges together whereby to hold the segments firmly against the tubular resistance element yet allowing the resistance element to expand when heated.

2. In apparatus as claimed in claim 1, the combination with parts therein specified of pipes to convey cooling medium to each of said segments.

3. In an electric furnace, a graphite tube, a pair of cylinders surrounding said graphite tube, an insulating annulus separating said cylinders, conductors to convey current separately to said cylinders, annular discs closing the ends of said cylinders, supporting sealing glands around said graphite tube in the form of hollow annuli supported by said annular discs, separate annular electrodes clamped to said tube, and connections to lead current to the electrodes from said cylinders.

4. In an electric furnace, a graphite tube, a pair of cylinders surrounding said graphite tube, an insulating annulus separating said cylinders, conductors to convey current separately to said cylinders, annular discs closing the ends of said cylinders, supporting sealing glands around said

graphite tube in the form of hollow annuli supported by said annular discs, hollow annular electrodes, means to convey cooling medium to each of the four hollow annuli, and means to convey current from the cylinders to the electrodes.

5. In an electric furnace, a furnace casing, a support for said casing, pressure apparatus comprising a piston and cylinder unit and a thrust taking unit, and connecting means between said piston and cylinder unit and said thrust taking unit supported by said support but free to move horizontally independently thereof, whereby the casing is free from any of the pressure forces.

6. In an electric furnace, a symmetrical, approximately cylindrical metallic casing divided into two parts along a median line, a pair of interlaced parallel bus bars, one connected to each of said parts, annular insulation separating said parts, a central axial tube of resistance material in said casing, radial electric connecting means conveying current from the ends of the respective parts of said casing, an electrode structure rigidly clamped to said tube and connected to said radial electric connecting means, and separate supporting means for said tube allowing sliding motion for expansion and contraction of said tube, the construction constituting a substantially non-inductive furnace having a high power factor by reason of non-inductiveness and rigidly clamped electrodes avoiding fracture of the tube by reason of the sliding action.

7. In an electric furnace, a tube of fragile resistance material, a furnace casing surrounding the tube, supporting means for the tube connected to the casing and supporting the tube rigidly in a radial direction but permitting movement in an axial direction, a sealing gland around said tube, a multi-section electrode clamped to said tube including resilient means permitting the expansion thereof, and conductors connected to the electrode to convey current thereto, the resiliently pressed multi-section electrode constituting a good electrical contact without danger of fracturing the tube and a sliding support permitting expansion and contraction without fracturing the tube yet sealing the inside of the furnace to prevent the escape of heat.

8. In apparatus of the class described, a cylinder and piston unit, a plurality of parallel rods, a spider connecting the cylinder to the plurality of parallel rods, a thrust taking member including a nut and a screw, a second spider connecting the nut to the plurality of parallel rods, a furnace casing located between the rods and a support for the casing supporting also the parallel rods, the rods being free to move in the direction of their axes independently of the casing and the support, whereby the rods take the pressure of the piston and the strain is not exerted on the casing.

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