Feb. 11, 1941. H. JUNG ET AL 2,231,723

ELECTRIC FURNACE

Filed Jan. 25, 1939 2 Sheets-Sheet 1

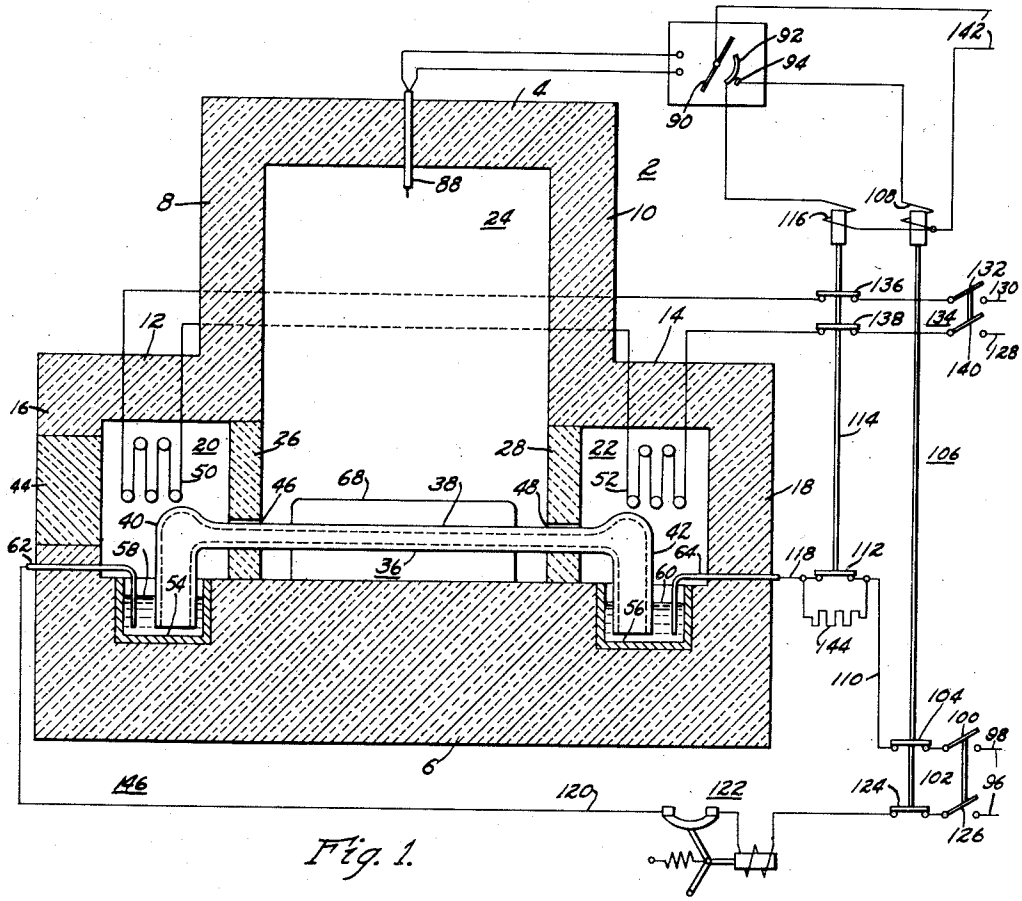


Fig. 1.

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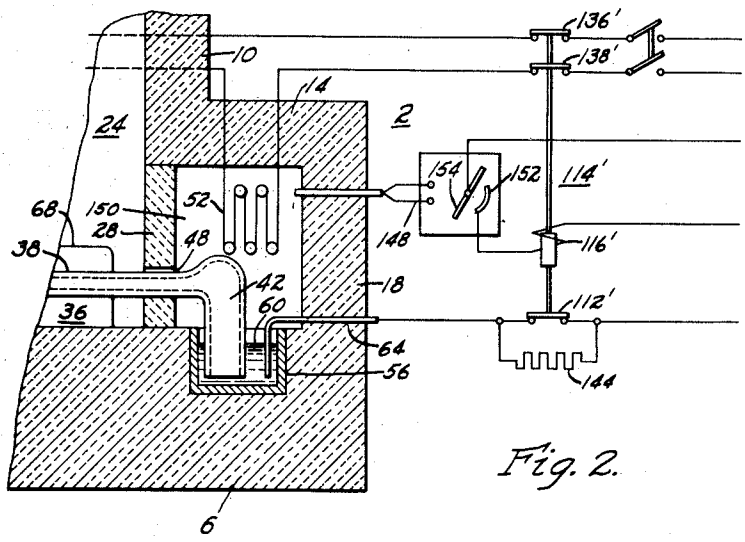


Fig. 2.

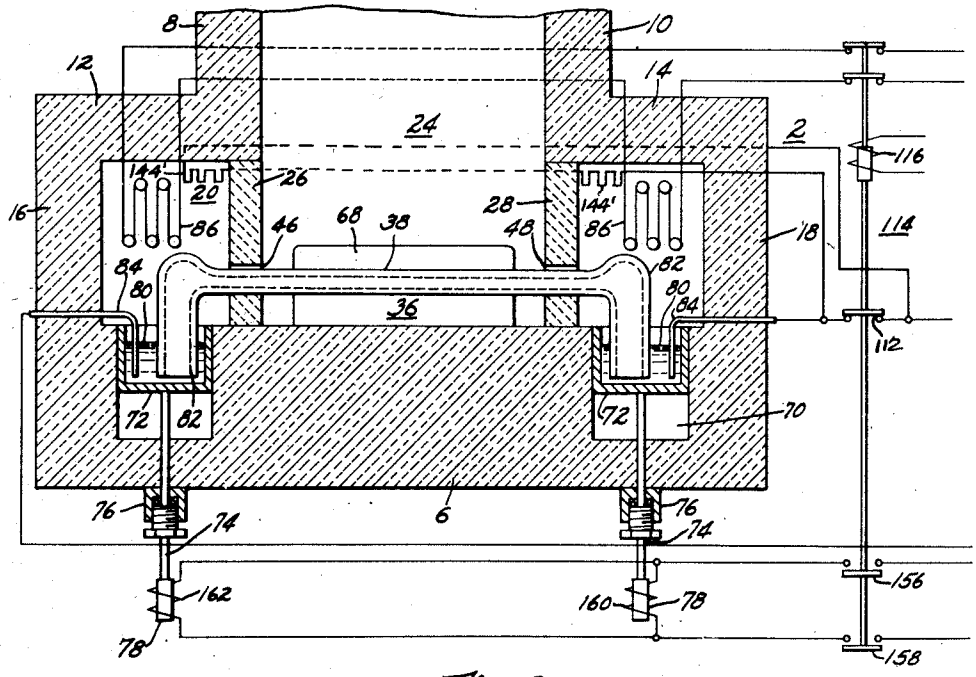


Fig. 3.

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UNITED STATES PATENT OFFICE

2,231,723

ELECTRIC FURNACE

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Application January 25, 1939, Serial No. 252,778
In Germany January 25, 1938

14 Claims. (Cl. 13—20)

This invention pertains to an electric furnace adapted to be electrically heated through the medium of heating elements or conductors of the rare-metal oxide type such as, for example, the oxides of the zirconium earths, ytterbium earths, and similar substances capable of resisting high temperatures. Heating elements of the type referred to are usually non-conducting at ordinary temperatures, or even somewhat above, but have negative temperature coefficients so that at the higher temperatures they are satisfactory conductors, especially for furnace-heating elements, and because of their heat resisting characteristics are particularly adaptable for high temperature furnaces.

Heretofore, in the use of such elements in furnaces, it has been the practice to manually insert auxiliary heaters in the furnace for the purpose of raising the temperatures of the main heating elements of the rare-earth oxide type until the last becomes sufficiently conducting to maintain by the heat generated therein their low conductivity, after which the auxiliary heaters could be removed and the heat for the furnace obtained from the main heating elements.

It is an important object of our invention to provide a construction for an electric furnace heated by rare-earth oxide heating elements which avoids the necessity of insertion and removal of the auxiliary heaters of the prior practice.

In accordance with our invention, we provide separate secondary chambers contiguous to the main heating chamber of the furnace but which are insulated to some degree therefrom. The terminal ends of the main heating elements are disposed in the secondary chambers together with auxiliary heaters which may be permanently fixed in these chambers. In starting the furnace, the auxiliary heaters heat the secondary chambers, thereby raising the temperature of the terminal ends of the main heating elements to render them sufficiently conducting to start their heating function, whereupon the auxiliary heaters can be cut off, that is, the energy to the auxiliary heaters is removed at or about this point, and we prefer to do this by automatic temperature responsive means.

The use of the main heating elements of the type to which this invention is directed requires that suitable provisions be made to convey electrical energy thereto. In accordance with our invention, we provide crucibles adapted to contain a metal which will melt at temperatures approximating those at which the main heating elements become sufficiently conducting to pass heating current. The terminal ends of the main heating elements are turned downward into these crucibles and power leads also extend into the crucibles so that the metal in the crucibles acts as conductors connecting the power leads to the main heating elements. As a precaution against damage to the terminal ends when the metal in the crucibles solidifies as, for example, when the furnace is shut down, we prefer to provide a raising and lowering means for the crucibles so that they can be lowered out of contact with the terminal ends when it is expected that the furnace will be shut down, and in starting the furnace they can be raised after the metal in them has become molten.

This can be accomplished manually or automatically, but we prefer to use an automatic temperature responsive means.

It is a further object of our invention to provide protective means for limiting the current to the main heating elements so that they will not draw excessive current by virtue of their rise in temperature and consequent lowering of resistance. This protective means takes the form of a resistance with a high positive temperature coefficient, as, for example, an iron wire, which is connected in series with the main heating element, this iron wire being shunted at the lower temperatures at which the main heating element is non-conducting or only slightly conducting. If desired, the protective resistances may be disposed in a secondary chamber whereby the heat generated in them is utilized.

As before said, the terminal ends of the main heating elements are preferably in the secondary chamber, as are the crucibles and the auxiliary heating elements, this construction tending to provide the necessary preheating for, and conduction of current to, the main heating elements. To facilitate the transfer of heat along the main heating elements from its terminal ends, we prefer to make these elements tubular and hollow so that the hollow therein can act as a path for convection gas-currents whereby the lengths of the elements in the main heating chamber are somewhat indirectly heated.

Other novel features, objects and elements of our invention will be apparent from the following description thereof taken in connection with the drawings, in which like reference numerals apply to like parts, and in which:

Figure 1 is a cross sectional view of a furnace embodying our invention, shown diagrammatically, with electrical controls therefor,

Fig. 2 is a fragmentary sectional view, mainly of a secondary chamber of the furnace and showing a modification of the control,

Fig. 3 is a fragmentary sectional view of the bottom of the furnace showing still another modification with automatic means for raising and lowering the crucibles of the secondary chambers.

Referring more particularly to Fig. 1, a furnace is indicated in its entirety by the reference numeral 2, and includes a top wall 4, a bottom wall 6, side walls 8 and 10 and the usual end walls, one or both of which may have openings for the insertion and removal of the charges to be heated in the furnace. As shown in the drawings, the side walls 8 and 10 are irregular and include outwardly projecting sections 12 and 14, respectively, and downwardly projecting portions 16 and 18, respectively, and which form, in conjunction with the bottom wall 6, a secondary chamber 20 at the left and a second secondary chamber 22 at the right of the furnace. The walls and portions thereof are constructed in any usual manner, as, for example, of non-metallic refractory material defining a main heating chamber 24 and an outer layer of insulating fire brick or the like.

In order to separate the secondary chambers 20 and 22 from the main heating chamber partitions of semi-insulating material, as, for example, refractory-tile walls of relatively small thickness, are built flush with the inner faces of the side walls 8 and 10. Thus the refractory wall 26 completes the enclosure of the secondary chamber 20, and the refractory wall 28 completes the enclosure of the secondary chamber 22, these walls 26 and 28 forming part of the enclosing walls defining the heating chamber 24, as more particularly shown in Fig. 1.

The main heating elements, indicated in their entirety by the reference numeral 36, are tubular and each comprises a horizontal portion 38, extending through the heating chamber, and has downwardly-turned, terminal ends 40 in the secondary chamber 20, and 42 in the secondary chamber 22. These terminal ends are somewhat enlarged with respect to the portion 38, that is, the cross-sectional area of the terminals is greater than that of the horizontal portions so that the resistance of the terminals is always less than that of the main heating portion 38 whereby the heating will be concentrated in the main heating chamber. In order to facilitate the removal and insertion of the heating elements, we prefer to form the walls 26 and 28 with removable tiles that are directly above the heating element which can be removed, if necessary, so that the heating elements can be taken out of the furnace through an additional removable section 44 in the wall portion 16. The manner in which such removable sections are formed and supported is not an important feature of our invention, since such expedients are common in the art. Manifestly, the walls 26 and 28 are of simple form, with suitable apertures 46 and 48, respectively, through which the ends of the horizontal portion 38 of the heating element extend.

On one or more walls of the end walls of the secondary chamber 20 is mounted, in any common manner, a metallic heating unit 50, and a like heating unit 52 is similarly mounted in the secondary chamber 22, these heating units being the auxiliary heating means for heating the secondary chambers to raise or maintain the temperature of the terminal ends 40 and 42.

The bases of the secondary chambers are formed with cavities in which are disposed crucibles 54 and 56 adapted to contain a metal 58 and 60, respectively, and into which the terminal ends of the main heating element 36 dip. The crucibles are sufficiently large so that current-conveying leads 62 for the crucibles 54, and 64 for the crucible 56 can also dip into the metal; these leads extending out of the furnace so that the electric power supply can be connected to them.

In the operation of the structure thus far described, it is manifest that at the start of a heat run, current can be conveyed to the auxiliary heating units 50 and 52 to heat up the secondary chambers 20 and 22 to, say, a temperature of about 1000° C. which is above the melting point of silver which may be contained in the crucibles 54 and 56. When the silver melts, exceptionally satisfactory contact is established between each of the current-conveying leads and their associated terminal ends of the heating element.

The heat in the secondary chambers due to the auxiliary elements, accordingly, raises the temperature of the terminal ends to a point whereby the element 36 becomes somewhat conducting, this decrease in resistance being facilitated by convection gas-currents passing within the hollow of the heating element 36. Once the furnace is started, the semi-insulating, and therefore somewhat heat conducting, walls 26 and 28 pass sufficient heat from the main heating chamber to maintain the secondary chambers 20 and 22 at their proper temperature. In one specific embodiment of our invention, the secondary chambers as aforesaid may be kept at a temperature of approximately 1000° C. while the main heating chamber may be at a temperature of 1800° C., or 2000° C., or even higher.

Each heating unit element 36 may be formed of zirconium oxide tubes which have been impregnated with an aqueous solution of ytterbium nitrate and then fired, during which process the nitrate is converted to ytterbium oxide. This impregnation and firing is repeated until the tube attains the desired amount of both oxides. We can employ a tube which is circular in cross section having an internal diameter of 6 millimeters and an external diameter of 12 millimeters, approximately, and a length between wall sections 26 and 28 from about 100 to 150 millimeters, or even more and obviously considerably less. The manner in which the tubes are disposed in the heating chamber is primarily one of design, and for practical application the tubes may be spaced between intervening piers 68 upon which a charge plate or a charge may be supported.

In Fig. 3, we show wherein the base of the secondary chamber is formed with an extended cavity 70 whose depth is about twice the height of the crucible 72. The crucible has secured thereto a downwardly projecting rod 74 which extends through the bottom wall 6 and out of the furnace through a packing gland 76, and terminates in a core 78. Within the crucible is a metal 80, preferably silver, into which a terminal end 82 and a current lead 84 are adapted to dip.

In the operation of the modification shown in Fig. 3, the crucible 72 can be assumed in its lowermost position with the silver 80 below the bottom ends of the terminal end 82 of the main heating element and the downwardly-turned end of the lead 84. When the temperature of the secondary chamber is raised sufficiently by the auxiliary heating means, such as a heating ele-

ment 86, the metal in the crucible melts. The crucible can now be raised to complete the circuit between the lead 84 and terminal 82. When the furnace is expected to be shut down, the crucible can be lowered while the silver is still in molten condition so that when the latter hardens or solidifies, it cannot damage either the terminal end 82 or the lead 84.

In accordance with our invention, we prefer to control the furnace automatically, and to this end, with reference more particularly to Fig. 1, we provide temperature responsive means in the form of a thermocouple 88 or the like extending into the heating chamber 24 and controlling a contactor 90 provided with two cooperating contacts 92 and 94. The contact 92 is of an extended length so that a circuit will be completed between it and the contactor 90 at, say, a temperature of the main heating chamber which assures that the temperature of the secondary chamber is about 1000° C. for this particular embodiment, the circuit being maintained thereafter because of the extended length of the contact 92. At a higher temperature of the main chamber 24, the contactor 90 engages the contact 94 to complete a second control circuit.

The heat responsive means just described comprises the controlling means for the energizing circuits of the main heating elements 36 and the auxiliary heating units 20 and 22. The main heating elements may be energized from a power source 96, one conductor 98 of which passes through a pole 100 of the switch 102, through a normally closed contactor 104 of a relay 106 having an operating coil 108, through a conductor 110, and through a normally closed contactor 112 of a relay 114 having an operating coil 116, from whence the current passes through a conductor 118 to the supply lead 64. The current then passes through the molten metal 60, to the terminal end 42 of the heating element, and then through the heating element to its other terminal 40, from whence it continues through the molten metal 58 to the other supply lead 62. The current continues by way of the conductor 120, through an overload protective device 122, to a normally closed contactor 124, of the relay 106, through the other pole 126 of the switch 102, and back to the other side of the power source 96.

The auxiliary heating units may be connected, as shown, in series and derive their power from a source of electrical energy 128, the current passing through a conductor 130, through a pole 132 of a double pole switch 134, through a normally closed contactor 136 of the relay 114, through the heating elements 50 and 52 in series, and back to the source of power 128 through normally closed contacts 138 of the relay 114, and the other pole 140 of the switch 134.

The relays 114 and 106 are controlled by the temperature responsve means, one side of each being connected to one side of a power source 142 and the other side of each being connected to the contacts 92 and 94, respectively; the other end of the power source 142 obviously being connected to the contactor 90. The control and energizing circuits are completed by a positive temperature coefficient resistor 144 connected across the conductors 110 and 118 whereby it is shunted in a normally closed position of the contactor 112, and is inserted in series with the energizing circuit for the main heating element whenever the contactor 112 is raised, or operated, to circuit-opening position.

In starting the furnace, the switches 102 and 134 are closed completing their respective circuits, but inasmuch as the resistance of the heating elements 36 is exceptionally high practically no current will pass through the energizing circuit which may be indicated in its entirety by the reference numeral 146. However, the auxiliary heating elements 50 and 52 are preferably of the metallic resistor type such as, for example, an alloy containing nickel and chromium, so that upon closing of the switch 134, these heating units will be energized and thereby raise the temperature of the secondary chambers 20 and 22. As these secondary chambers become heated, the main heating elements 36 become more and more conducting until finally they become sufficiently conducting to raise the temperature of the heating chamber 24. When the heating chamber 24 reaches the proper temperature, the contact 90 engages the contactor 92 to energize the relay 114 whereupon the circuit to the auxiliary heating units 50 and 52 is opened at the contactors 136 and 138 and the protective resistance 144 is inserted in series in the energizing circuit 146 by virtue of the raising of the contactor 112. This does not, however, interrupt the flow of heating current to the elements 36 which continue to convert the electrical energy into heat until the temperature of the heating chamber 24 has risen to a value sufficient to cause the contactor 90 to engage the contact 94, thereby completing the circuit to the relay 106 which operates its contactors 104 and 124 to circuit-opening position.

The operation of the contactors 104 and 124 obviously interrupts the circuit to the main heating elements, and this indicates that the heating chamber 24 has reached the desired temperature at which the heat-treating process in the furnace is to be carried out, it being understood that the contacts 92 and 94 are suitably adjusted to be engaged by the contactor 90 upon the proper values of temperatures.

Manifestly, the furnace will be maintained at its operating temperature by the temperature responsive means 88 since when the temperature lowers to the point at which the contactor 90 and contact 94 disengage, the relay 106 will be deenergized and the energizing circuit 146 reestablished at the contactors 104 and 124.

It should be observed, however, that the extended length of the contact 92 assures that the relay 114 will not be deenergized during the control temperature range of the contact 94, since during this range the secondary chambers 20 and 22 are maintained at proper temperature by heat from the main heating chamber 24 passing through the walls 26 and 28.

In the shut-down of the furnace, the reverse process of control obviously takes place. The control switches 102 and 134 are opened, thereby cutting off all energy both to the main heating elements and the auxiliary heating units, and as the temperature drops in the heating chamber 24, the relay 106 will first be deenergized, and then the relay 114, whereupon starting conditions are reestablished awaiting only closing of the control switches 102 and 134.

In the modification of Fig. 1, the energizing circuits for the heating elements and units are all under the control of the temperature within the main heating chamber 24 but it is obvious that separate temperature responsive devices may be employed to control the heating units 50 and 52, and in Fig. 2 we show the modification where-

in a temperature responsive device 148 is employed responsive to the temperature in a secondary chamber 150. In this case the contact 92, of Fig. 1, is omitted and instead the temperature responsive means 148 controls the equivalent of the relay 114. The relay 114 of Fig. 1 has its counterpart in Fig. 2 in the form of a relay 114' connected to a contact 152 adapted to be engaged by a contactor 154 of the heat responsive means 148. The relay 114' has an operating coil 116' and normally closed contactors 136', 138' and 112' equivalent, respectively, to the contactors 136, 138 and 112 of Fig. 1 and in the same circuits.

It is manifest then that the control circuit of Fig. 2 differs from that of Fig. 1, only in that the circuit for the auxiliary heating units in the secondary chambers is controlled by the temperature of the secondary chambers rather than by the temperature in the main heating chamber 24. The temperature responsive device 148 is necessarily operable to energize the relay 114' at temperatures approximately about 1000° C. for the specific embodiment described. It is not believed necessary to go into further detail in the operation of the modification of Fig. 2, since the operation of the control circuits and its correlation to the system of Fig. 1 is obvious to any one skilled in the art.

The lowering or raising of the crucibles shown in Fig. 3 can obviously be manually executed. However, we can also accomplish the same automatically by providing the relay 114 or 114' of the systems of Fig. 1 and Fig. 2, respectively, with additional normally-open contactors 156 and 158 which are adapted to be closed at the time the operating coil of the relay is energized to open the energizing circuit for the auxiliary heating units and to insert the protective resistance 114. In this case, the contactors 156 and 158 control energizing circuits for two electromagnetic coils 160 and 162 which upon energization attract the cores 78 to raise the crucibles so that they encompass the terminal and heater element ends 82 and 84. Inasmuch as the relays 114 or 114' in either modification of Figs. 1 and 2 are energized when the temperature of the secondary chamber is somewhat above the melting point of the liquid in the crucibles, it is manifest that crucible 72 will be maintained in lowermost position during the time the metal therein is being heated to a molten state and is only raised after that state has been reached. Fig. 3 also shows series-connected protective resistances 144' disposed in the secondary chambers. It is also manifest that the embodiment of Fig. 3 can be applied to the furnace of Fig. 1 with the controls of either Fig. 1 or Fig. 2 and is not deemed necessary to burden the description with these obvious modifications.

While we have described our invention in certain preferred forms and controls thereof, it is obvious that many changes may be made within the scope and spirit thereof, as, for example, the heating units 50 and 52 might be connected in parallel rather than in series, or the energizing circuits may be controlled by other forms of temperature responsive devices. Accordingly, we desire that the appended claims be given their broadest interpretation and limited only by the prior art.

We claim as our invention:

1. An electric furnace having a main heating chamber and a secondary chamber, electrical heating means for said furnace comprising an element which is substantially non-conducting at ordinary temperatures but has a negative resistance-temperature coefficient rendering it conducting at higher temperatures, said element being disposed primarily in said heating chamber but having a terminal end in said secondary chamber, heat-insulating means between said chambers, and auxiliary heating means in said secondary chamber.

2. The structure of claim 1 in which said element comprises a hollow tube.

3. The structure of claim 1 including means responsive to the temperature in one of said chambers for controlling the heat supplied by said auxiliary heating means.

4. An electric furnace having a main heating chamber and a secondary chamber, electrical heating means for said furnace comprising an element having a negative resistance temperature coefficient and which is substantially non-conducting at ordinary temperatures, said element being disposed primarily in said heating chamber but with a terminal end in said secondary chamber, said secondary chamber being adapted to receive an auxiliary heating means for heating said end, means so insulating said secondary chamber from the heat of said main chamber that in operation of the furnace, the temperature of said secondary chamber is below that of the said main chamber but high enough to make said terminal end a conductor.

5. An electric furnace having a heating chamber and two secondary chambers, each of the last being contiguous to said heating chamber, electrical heating means for said furnace comprising an element disposed primarily in said heating chamber but having downwardly extending terminal ends in each of said secondary chambers, movable crucibles containing a meltable substance, one for each of said terminal ends, means for raising and lowering each of said crucibles, and means for conducting electrical power to said crucibles.

6. An electric furnace having a heating chamber and two secondary chambers, each of the last being contiguous to said heating chamber, electrical heating means for said furnace comprising an element disposed primarily in said heating chamber but having downwardly extending terminal ends in each of said secondary chambers, movable crucibles containing metal, one for each of said terminal ends, means for raising each of said crucibles to encompass its said associated terminal end when said metal is molten and lowering said crucible out of contact with the last said terminal end before said molten metal solidifies, and means for conducting electrical power to said crucibles.

7. An electric furnace having a heating chamber and two secondary chambers, each of the last being contiguous to said heating chamber, electrical heating means for said furnace comprising an element disposed partly in said heating chamber, but having terminal ends in said secondary chambers, said element being tubular, and substantially non-conducting at ordinary temperature but having a negative resistance-temperature coefficient rendering it conducting at higher temperatures, auxiliary heating means for said secondary chambers, and means in said secondary chamber for conveying electrical power to said terminals.

8. The structure of claim 7 including means responsive to the temperature of one of said chambers for controlling the heat supplied by said auxiliary electrical heating means.

9. The structure of claim 5 wherein said element is tubular and hollow.

10. The structure of claim 6 wherein said element is tubular and hollow.

11. An electric furnace having a heating chamber and two secondary chambers, each of the last being contiguous to said heating chamber, electrical heating means for said furnace comprising an element disposed primarily in said heating chamber but having downwardly extending terminal ends in each of said secondary chambers, movable crucibles, one for each of said terminal ends and containing metal, means for raising each of said crucibles to encompass its said associated terminal end when said metal is molten and lowering said crucible out of contact with the last said terminal end before said molten metal solidifies, electric power leads extending into said secondary chambers and having downwardly projecting portions in proximity to said terminal ends whereby said crucibles in raised position encompass the said projecting portions also.

12. An electric furnace having a heating chamber and two secondary chambers, each of the last being contiguous to said heating chamber, electrical heating means for said furnace comprising an element disposed partly in said heating chamber, but having terminal ends in said secondary chambers, said element being substantially non-conducting at ordinary temperature but having a negative resistance-temperature coefficient rendering it conducting at higher temperatures, means for supplying electric power to said terminals, said last means including a protective resistance in series with said element, and disposed in said secondary chambers, and temperature-responsive means for shunting said resistance at relatively lower temperatures and removing said shunt at relatively higher temperatures.

13. An electric furnace having a heating chamber and two secondary chambers, each of the last being contiguous to said heating chamber, electrical heating means for said furnace comprising a hollow, tubular element disposed partly in said heating chamber, but having terminal ends in said secondary chambers, said element being substantially non-conducting at ordinary temperature but having a negative resistance-temperature coefficient rendering it conducting at higher temperatures, auxiliary heating means for said secondary chambers, means for supplying electrical power to said terminals, said last means including a protective resistance in series with said element, and means responsive to the temperature in one of said secondary chambers for shunting said resistance at relatively lower temperatures and removing said shunt at relatively higher temperatures, said last means also controlling the heat supplied by said auxiliary heating means.

14. An electric furnace having a heating chamber and a secondary chamber, contiguous to said heating chamber, electrical heating means for said furnace comprising an element having a portion disposed primarily in said heating chamber but having an enlarged downwardly extending terminal end in said secondary chamber, said element being of the refractory metallic-oxide type which is a relatively poor conductor of electricity at ordinary temperatures with a negative resistance-temperature coefficient rendering it conducting at higher temperatures, a movable crucible in said secondary chamber, said crucible containing a metal, such as silver, meltable at an intermediate temperature, means for raising into co-operative relation to said terminal end, and lowering said crucible out of such relation, and means for conducting electrical power to said metal in its molten state.

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