

March 25, 1930.

A. E. GREENE

1,751,912

ELECTRIC INDUCTION FURNACE

Original Filed Jan. 3, 1913 4 Sheets-Sheet 1

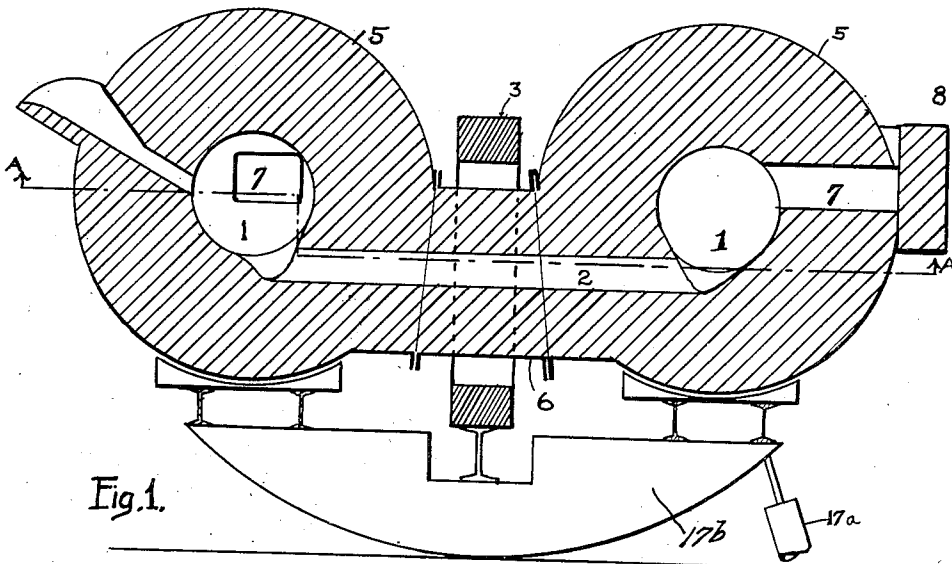


Fig. 1.

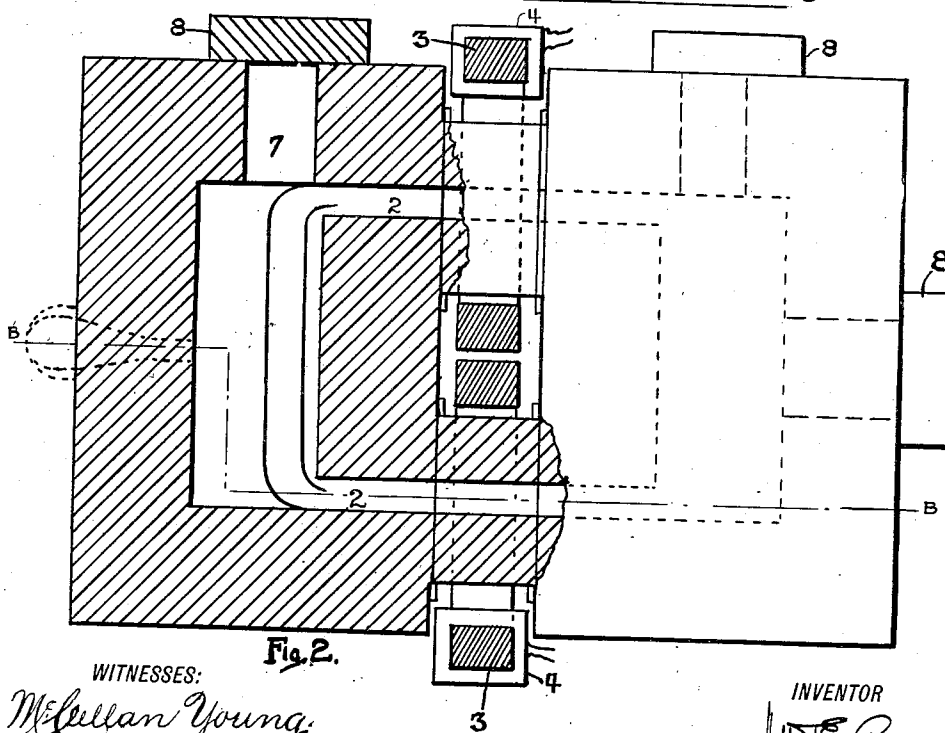


Fig. 2.

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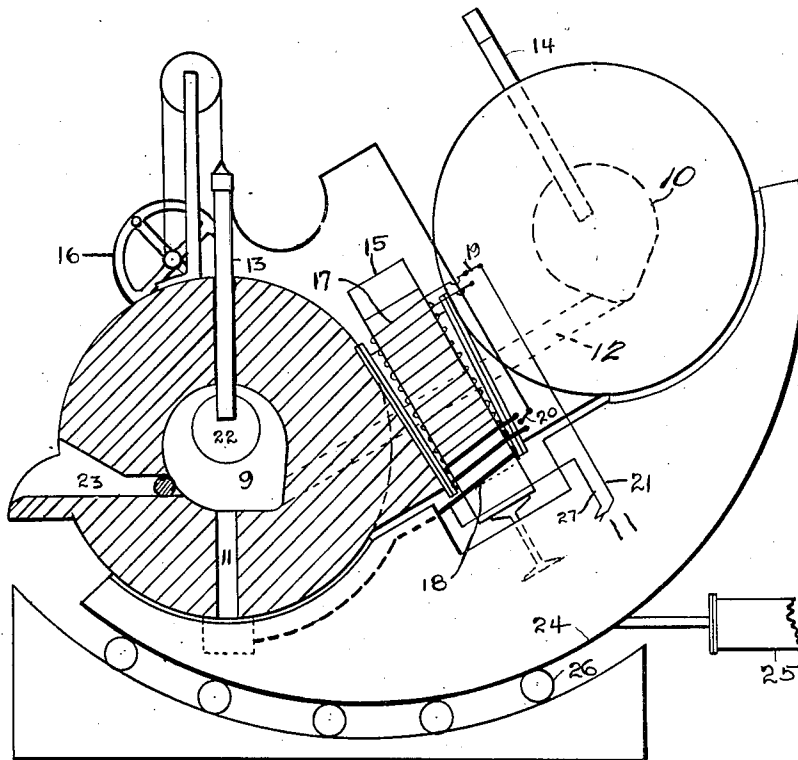


Fig. 3.

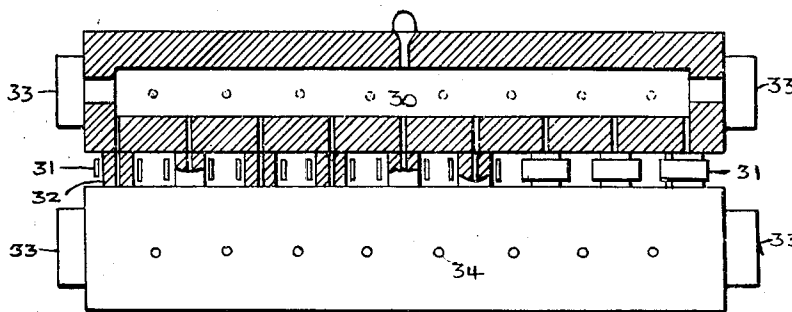


Fig. 4.

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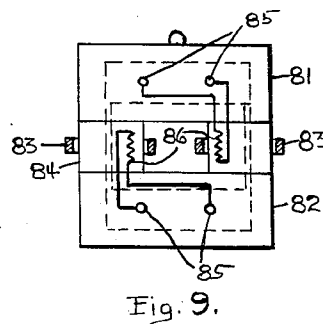
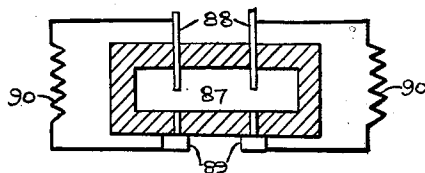
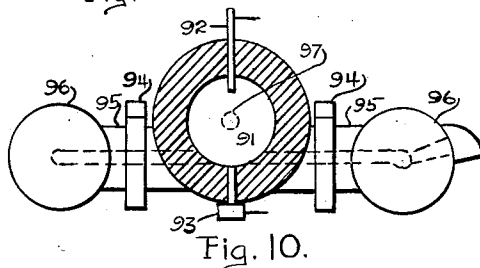
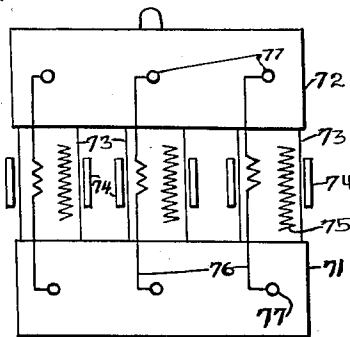
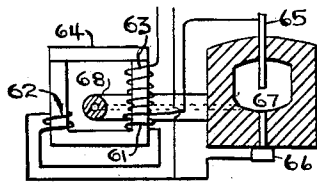
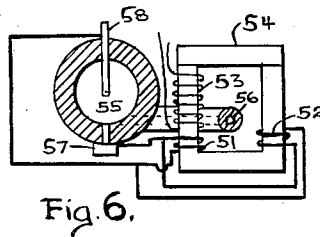
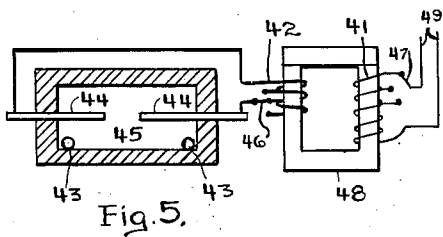
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ELECTRIC INDUCTION FURNACE

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March 25, 1930.

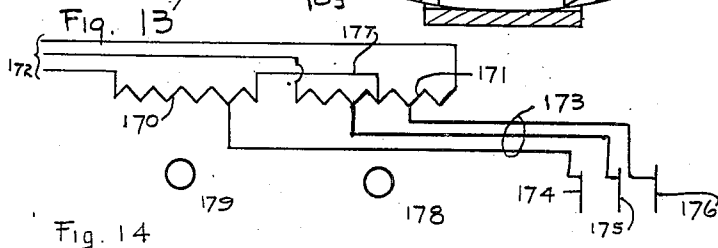
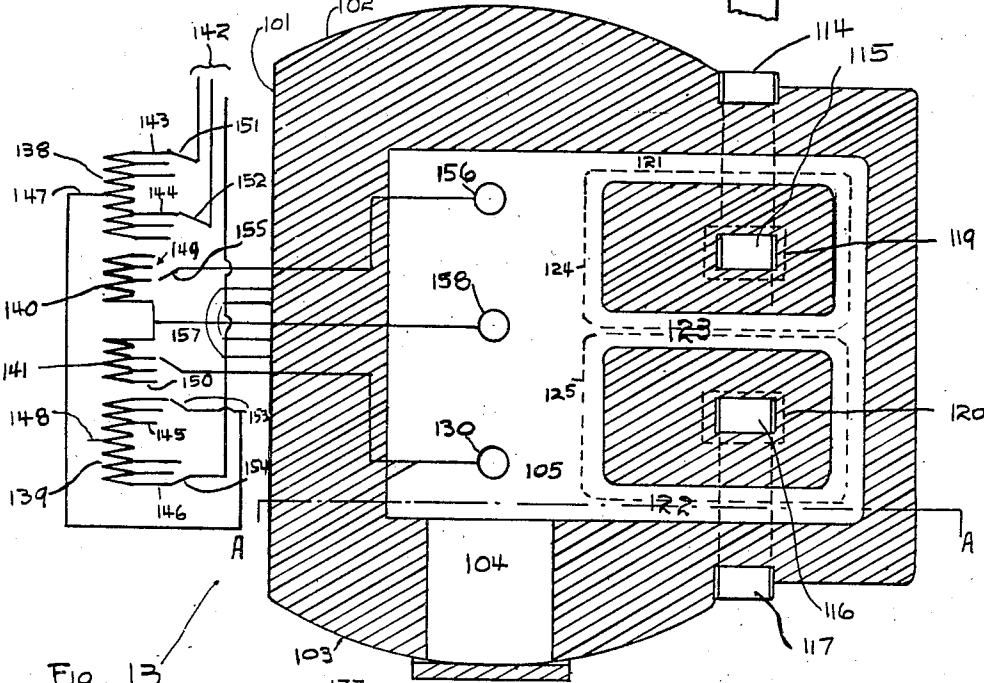
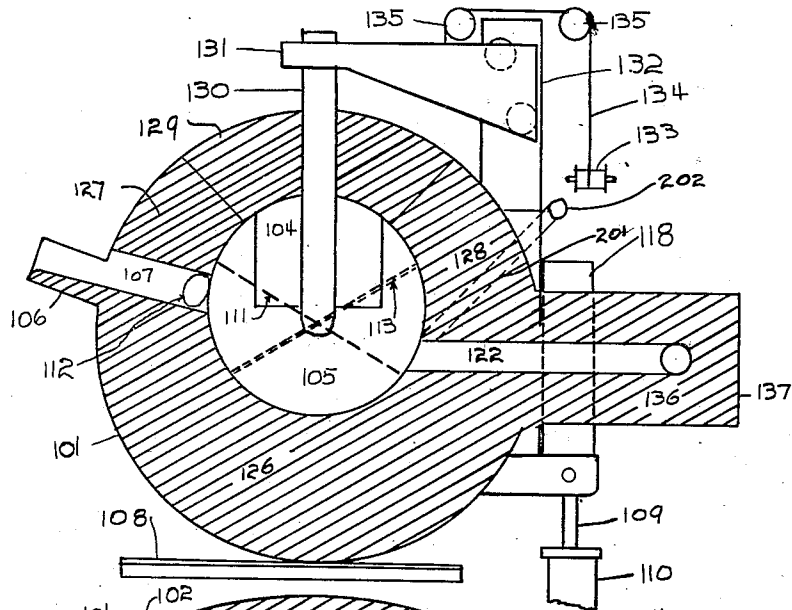
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1,751,912

ELECTRIC INDUCTION FURNACE

Original Filed Jan. 3, 1913 . 4 Sheets-Sheet 4

Fig. 12



UNITED STATES PATENT OFFICE

ALBERT E. GREENE, OF SEATTLE, WASHINGTON

ELECTRIC INDUCTION FURNACE

Original application filed January 3, 1913, Serial No. 740,034. Divided and this application filed August 30, 1920. Serial No. 406,894.

My present invention relates to electric induction furnaces and particularly to an improved design which is more economical to construct and to operate.

5 This application is a division of my U. S. Application for patent Sr. No. 740,034, filed Jan. 3, 1913.

Induction furnaces heretofore have been built on two general plans with reference to 10 the shape of the channels or secondary circuits; first, the type of furnace having circular channels represented by the Kjellin type; and second, the types having two or more secondary channels encircling magnetic 15 cores and having a common hearth, this type being represented by furnaces of the Roechling-Rodenhauser class. In both of these types the steel containing shells have larger radiating surfaces than equal capacity furnaces of the arc type such as the Girod furnace. Furthermore, the channel sections of induction furnaces usually hold a large percentage of the total furnace charge and such channel sections have especially large radiation 20 surfaces. The channels are long and in addition to presenting lining problems of a serious nature they often require special cooling means in certain parts. In none of these types of induction furnaces is the mass of the metal held in a crucible even approximating as efficient a shape as the crucible of an arc furnace.

Another serious objection to the induction furnaces has been its requirement of hot metal, that is molten metal, or else solid rings for starting.

My invention has for its main object the provision of a furnace structure in which the aforementioned objectionable features of the 40 heretofore customary types of apparatus have been eliminated. The invention contemplates the provision of hearths of efficient shapes and constructions, and steel shells of improved construction for the hearths and 45 channels. The invention further contemplates the provision of removable containers for the metal channels between the main hearths.

A further object of my invention is to provide an induction furnace which can be start-

ed on cold stock such, for example, as cold steel scrap or ore without the use of solid or molten rings. This object is accomplished by heating the charge in one chamber, as by arc or resistance heating means, while the furnace is in a tilted position. Such heating means may be controlled independently of the induction heating means. 55

The invention further contemplates the provision of one or more horizontal, cylindrical shells to hold the refractory material of the main hearth or hearths, and the provision of steel shells of relatively small diameter to hold the refractory material of the connecting channels. 60

The invention will be better understood from a consideration of the following description in conjunction with the accompanying drawings, in which 65

Fig. 1 is a sectional elevation of a two-hearth, tilting induction furnace constructed in accordance with my invention; 70

Fig. 2 is a plan, partly in section, of the furnace shown in Fig. 1;

Fig. 3 is an elevation, partly in section, of a furnace constructed in accordance with the invention, and showing arc heating means for starting the operation of the furnace with cold stock; 75

Fig. 4 is a plan, partly in section, of a two-hearth multiple channel, tilting induction furnace; 80

Fig. 5 is a diagrammatic elevation illustrating a method of connecting an arc circuit to permit regulation of the voltage from a transformer forming part of the induction furnace; 85

Fig. 6 is a sectional elevation of a furnace embodying the invention and showing the conductor for supplying current to the arc circuit divided into two sections which are connected in parallel; 90

Fig. 7 is a sectional elevation of a furnace constructed in accordance with the invention in which an arc circuit is connected directly to the main winding of the furnace transformer and in which the primary and secondary circuits constitute an auto transformer; 95

Fig. 8 is a plan of a three-phase furnace embodying the invention;

Fig. 9 is a plan of a furnace embodying the invention in which one arc circuit is connected to each of two transformers and current passes through two arcs or resistances in series;

Fig. 10 is an elevation, partly in section, of a furnace constructed in accordance with the invention and provided with three main chambers;

Fig. 11 is a sectional elevation of a main furnace chamber provided with two arc or resistance circuits having separate transformer windings and electrodes;

Fig. 12 is a sectional elevation of an induction furnace constructed in accordance with the invention, and having one main chamber; the section being taken substantially along line A—A of Fig. 13;

Fig. 13 is a sectional plan of the furnace shown in Fig. 12, but showing, in addition, transformer windings associated therewith; and

Fig. 14 shows an arrangement of transformer windings suitable for use with furnaces embodying the invention.

Referring more particularly to the form of my invention shown in Figs 1 and 2, the furnace there shown is of the tilting, two-hearth induction type for single phase current. The main constructional features of this furnace are the two main hearths which are approximately cylindrical in shape with their axes horizontal. The hearths 1 are connected by channels 2 extending through refractory material and together with the latter form the secondary circuits for the induced currents in the molten metal. The furnace has two separate magnetic cores 3 each encircling a secondary circuit and on these cores are located primary windings 4.

The two hearths are of similar size and considerably larger than the channels which connect them together. Both hearths and channels are extended through suitable refractory material contained in steel or metal shells. These shells are preferably round and similar to pipes. The roofs of both of the main shells and of the connecting channels are preferably made removable for repairing. The connecting channels may however be entirely removed when worn and replaced by newly lined ones.

This type of container construction for induction furnaces is much more economical than any heretofore proposed. The radiating surface per ton of charge of the main hearths is much less than in other induction furnaces and yet it is possible to give the necessary thickness to the lining to get conservation of the heat generated. The costly construction of long curved channel shells such as are customary now in other induction furnaces is avoided and short straight pipes

are substituted in place. These pipes, shown at 6 may be made very short and the loss of heat in them is proportionately small. The refractory lining in them is of less thickness than for the main hearths and the outside dimensions are therefore small so that the magnetic cores may likewise be made small and the magnetic leakage reduced to a minimum. I have found it possible to operate these channels with walls as thin as only $2\frac{1}{2}$ inches for long periods of time, for example for as much as 80 hours, without any repairs whatever. I am able also to get a very good power factor on the furnace by making the cores small.

The shells, cores, etc., are held on a suitable tilting or rocking frame 17^b, operated, for example, by a hydraulic motor 17^a. The axis of revolution is parallel to the axes of the main hearths and arranged in such a manner as to lift one hearth and the connecting channels above the other hearth. By this arrangement it is possible to transfer the charge from one hearth and the connecting channels into the other and thereby permit of repairs while the furnace is in operation.

This type of furnace is generally started with hot molten metal which is poured into the spout in sufficient quantity to allow the furnace to take current without the pinch effect. The melting of further charge may then take place by charging it thru the doorways 7, these being closed by suitable doors 8.

For use in localities where molten metal is not available the modification of my invention shown in Fig. 3 is preferable for it permits of starting with cold steel scrap for example without molten metal or solid rings. It may be used for various purposes such as melting scrap metal or smelting ore charges.

The use of solid cast rings to start induction furnaces is a very inefficient method involving loss of time in placing the rings and in getting started and does not permit of the best kind of heat insulation of covers. My present invention utilizes applied heat, such as produced by an electric arc for melting enough cold charge to permit of the furnace operating by induction. I am aware that this has been proposed but no satisfactory means of preventing the metal as it melts from running thru the channels and freezing in them has been proposed. Herein lies an important feature of my present invention, namely, that while melting sufficient cold stock in one chamber of the furnace I prevent it from entering the parts of the furnace where it would freeze and I do this by keeping the furnace in a tilted position in which the melting hearth is on a lower level than the channels and the other hearth.

The construction embodying these features of my invention will be apparent from the drawings. The type of furnace shown in Fig. 3 is similar to that shown in Fig. 1 ex-

cept that it is fitted with an arc circuit for causing an arc to play between an electrode and the charge. Referring to the Fig. 3, there are two main chambers 9 and 10 having walls of refractory material and connected together by channels such as shown in dotted lines 12. Entering chamber 9 is a top electrode 13 held and regulated in any suitable way such as on a cable operated by a hand wheel 16. In the bottom of chamber 9 is a bottom electrode 11 which may be of steel. A magnetic core 15 encircles the channel thru which one of the conduits 12 passes. The core has a winding whose terminals 21 and 27 connect it to a source of alternating current. The winding here shown is divided into two parts, one of which, shown at 18 is of heavier cross section than the other and designed to carry heavy currents to the arc circuit thru the bottom electrode to which one end of the winding is connected and thru the switch 20 leading to the top electrode. The switch 20 serves to connect the desired number of turns of the heavy part of the winding to the arc circuit. The other part of the winding is of lighter carrying capacity and is connected thru the switch 19 to the line 21. This switch serves to regulate the number of turns of the whole winding connected to the source of power and it therefore regulates the voltage induced in the secondary molten metal circuit when the furnace is operating by induction. By these two switches 19 and 20 the voltages of the arc circuit and of the induction circuit may be regulated independently of one another. Another electrode 14 may be connected up in any suitable way and used in the other chamber. Thus when the furnace is in the horizontal position the two top electrodes may operate in parallel, or in any of the other various ways such as those described later on. The shells and cores etc., are supported on a suitable revolving base 24 on rollers 26 and this may be operated in any suitable way as by a hydraulic cylinder 25. The connecting channel shell is here shown as tapered for the purpose of withdrawing and replacing by new channels.

The operation of the furnace for the melting of cold steel scrap will now be described. The furnace is revolved out of the horizontal position into the one shown in Fig. 3 where the connecting channels 12 and the hearth 10 are above the level of the hearth 9. In this position, and with the tap hole 23 plugged, cold steel scrap is charged into the hearth 9 thru the door 22 and an arc formed to the scrap from the top electrode. The core 15 is of course magnetized for this purpose and the proper connections of switches made. The chamber 9 is charged until it is well filled with molten steel. The capacity of this chamber 9 bears such relation to the capacity of the channels and groove in the bottom of chamber 10 that when the furnace is re-

volved back to the horizontal position the molten metal sufficiently fills the channels and hearths to let the furnace operate by induced currents in the metal. The furnace may however be started by melting just enough metal to fill the channels to a height of an inch or two and arcs used in both hearths until enough cold stock has been melted in this way. The electrode 14 may form an arc which completes its circuit thru the bottom electrode 11 and avoid troubles which might occur from breakage of the metal circuit in one of the channels.

Of course the arcs may be operated simultaneously with the induction heating and this is specially advantageous in certain cases as for example in the treatment of ores.

The construction shown in Fig. 3 is adaptable to large furnaces by a multiplication of the connecting channels as shown in Fig. 4, which represents a plan view of a two hearth furnace with nine connecting channels.

In Fig. 4 one of the main chambers is shown at 30; connecting channels 32 and these surrounded by magnetic cores 31. The doors 33 provide closures for the charging openings. Electrodes 34 are located in each hearth, their numbers here corresponding with the number of separate cores, there being two electrodes for each core. The number and arrangement of electrodes may be varied as desired, but their connections to electrical circuits should be arranged to permit proper control.

The use of a plurality of magnetic cores is preferable for the purpose of minimizing the magnetic leakage, inasmuch as smaller cores can be located nearer the molten metal secondary circuit. The result of this design is improved power factors and the avoidance of installing special low frequency generators for the operation of large induction furnaces.

The electrical circuits of furnaces built in accordance with my invention may be arranged in various ways as set forth in Figs. 5 to 11 inclusive and certain of these methods will be described in detail.

The use of the transformer core to induce current in a molten metal secondary and at the same time to supply current to an arc circuit with which the furnace may be started is a feature of my invention which is important. The winding which magnetizes the core may be wound for any standard voltage such as 220 volts and either single phase, or two or three phase, and with a very small additional expense to give greater carrying capacity to a part of the winding or to supply an additional winding serving as a secondary circuit to the transformer, the usefulness of the same piece of furnace apparatus is greatly broadened. If it were necessary to supply current to the arc circuit from a special transformer the installation cost of

the plant is much increased and likewise the operating cost and furthermore part of the equipment is out of service when the other part is not.

In the circuit arrangement shown in Fig. 5, the primary is separate from the secondary. The primary and secondary windings 41 and 42 are mounted on a core 48 and provided with taps by means of which any desired numbers of turns may be connected in circuit through the switches 46 and 47. The winding 41 may be connected through the switch 47 to the supply lines 49. The ends of the channels of the induction circuit are shown at 43. Electrodes 44, which are adjustable toward and away from one another, project into the main chamber 45 and are suitably connected to the winding 42.

The apparatus shown in Fig. 6 comprises a main chamber 55 and an induction channel 56 communicating therewith. The primary windings 53 and secondary windings 51 and 52 are separately mounted on a core 54 encircling the induction channel 56. The two secondary windings 51 and 52 are connected in parallel in the electrode circuit which includes the bottom and top electrodes 57 and 58 associated with the main chamber 55. The secondary winding 52 is so located as to increase the reactance in the secondary arc circuit.

The arrangement shown in Fig. 7 is similar to that shown in Fig. 6 except that the primary windings 63 and secondary windings 61 and 62 are connected to provide an auto transformer. The transformer windings are mounted on the core 64 which encircles the induction channel 68. The induction channel communicates with a main chamber 67 having electrodes 65 and 66 associated therewith.

Fig. 8 shows a furnace comprising main chambers 71 and 72 connected by means of induction channels 73 and provided with cores 74 and windings 75. Electrodes 77 are associated with the main chambers 71 and 72 and are connected by means of conductors 76.

In the arrangement shown in Fig. 9, two main chambers 81 and 82 are connected by means of induction channels 84 and are provided with electrodes 85. Suitable induction coils 83 encircle the induction channels. The electrodes are suitably connected to the windings 86. In the arrangement shown in this figure, one arc circuit is taken from each transformer and a current passes through two arcs or resistances in series.

Fig. 10 shows a furnace provided with three main chambers 91 and 96 connected by means of induction channels 95 having magnetic cores 94 associated therewith. The central chamber 91 is provided with top and bottom electrodes 92 and 93 and a charging opening 97.

Fig. 11 shows a main chamber 87 and two arc or resistance circuits comprising separate transformer windings 90 leading to bottom electrodes 89 and top electrodes 88 which may be operated as two-phase or polyphase circuits.

Fig. 12 shows an improved construction of induction arc furnace, and Fig. 13 is a plan view in section of the same furnace and includes a diagram of the transformer windings. The shell 101 is provided with outwardly dished ends or heads 102 and 103. The main chamber 105 is provided with an opening 104 in the head 103. A tap hole 107 communicates with the interior of the main chamber and is provided with a spout 106. The furnace may be tilted, for example, by rolling it over on a rail track 108 by any suitable means, such as the connecting rod 109 of a hydraulic cylinder 110. The furnace may be tilted either backwards or forwards. When tilted forwards the line 111 may represent the level of the melted metal in the main chamber, in which case the tap hole 107 would be suitably closed, for example, by plug 112. The furnace may be tilted backward into such position as shown by the double line 113 representing the level of the melted metal when the furnace is tilted backward.

Connected to the back of the furnace are one or more magnetic cores, one of these is shown at 114 and 115. A second core is shown in section at 116 and 117. Fig. 12 shows the elevation of one of these cores. The complete core consists of a U-shaped piece comprising the two upright legs 114 and 115 and a bottom leg connecting these two to a top removable yoke 118. The yoke may be removed from either core for purposes of setting the primary coils in place and for construction and repair of the refractory lining between the cores. Primary windings are shown diagrammatically at 119, encircling leg 115, and at 120 encircling leg 116. In the plan view induction channels are shown encircling the core leg 115 and also the other core leg 116. These channels are shown at 121 and 122, and 123 represents the common channel opening into the main chamber 105. Dotted lines 124 and 125 show the path which induced current would take when induced in molten metal which might fill the induction channels and main chamber 105. Fig. 12 shows the section through channel 122 and shows this channel as entering the main chamber 105 above the bottom of the hearth of that chamber 105. When the furnace is in the normal upright position shown in Fig. 12 and the metal level is high enough, the metal will fill the induction channels 122, 123 and 121. When the furnace is tilted forward the metal may be entirely removed from the induction channels into the main chamber and when desired may be tapped out of the furnace through the tap hole 107; or it

may be retained in chamber 105 for any desired purpose as more fully explained later on. The refractory lining of the main chamber is shown at 126 and walls at 127 and 128, and arched roof at 129. Extending through this arched roof is electrode 130, held in a suitable holder 131 which operates upward or downward by engaging the surfaces of an I-beam 132, and a drum 133 is shown which serves to wind a cable 134 over sheaves 135 so as to raise or lower the electrode 130. The drum 133 may be operated by a worm gear not shown, or any other suitable means. The refractory lining around the induction channel 122 is shown at 136 and may be held in a suitable shell 137 attached to the magnetic cores.

The transformer windings for this furnace are shown diagrammatically in the lower figure. One primary winding is shown at 138 for the magnetic core 115, and the other primary for the other magnetic core is shown at 139. Secondary windings for two cores 115 and 116 are shown respectively at 140 and 141. A three phase power line is shown at 142, suitable switches not shown would of course be supplied for making this line alive so as to carry current to the primaries. Taps 143 and 144 are shown at either end of the winding of the primary 138, and taps 145 and 146 are shown at each end of primary winding 139. The center tap 147 is shown on the winding 138, and center tap 148 is shown on the winding 139. The taps on secondary 140 are shown at 149, and taps on the secondary 141 are shown at 150. A switch 151 serves to connect one of the taps 143 with one line of the three phase supply. A switch 152 serves to connect one of the taps 144 with a second conductor of the three phase supply. A switch 153 serves to connect one of the taps 145 by means of a suitable conductor with the center tap 147 of the transformer 138. A switch 154 serves to connect one of the taps 146 with the third conductor of the three phase supply line. A switch 155 serves to connect one of the taps 149 with the electrode 156, and a switch 157 serves to connect one of the taps 150 with the electrode 130; and the other terminals of the secondaries may be connected by a suitable conductor with the center electrode 158.

Having described the general construction details of this furnace, I will now describe its method of operation.

It is particularly adapted to melting non-ferrous metals, like brass, aluminum, bronze and copper containing metals. The purpose of construction is to provide means of melting the metal in the main chamber while the induction chamber is tilted upward so as to be kept free from metal, and then after the metal has been melted in the main chamber it may be caused to fill the induction channels by properly tilting the furnace backward.

The heating circuit through the electrodes may be of suitable low voltage, the voltage preferably between ten and fifty volts on this circuit, so that at times there will be practically a resistance circuit between the electrodes and a very small amount of arcing so that vaporizing of the metal will be kept to a minimum. The windings on the magnetic cores may be separated as shown on the diagrammatic view Fig. 13, or the windings may be connected together as an odd auto transformer or they may be connected in any suitable way, as for example, open delta or straight three phase. These primary windings may be connected to a 220 volt three phase circuit, so that the furnace is adapted for operation without installation of special electric furnace transformers.

When the furnace is operating through the electrode circuit only and the induction channels are empty, the voltage of the arc circuit may be controlled as desired by means of the taps shown. After the charge is melted sufficiently to fill the induction channels the furnace may be tilted back and the current will be induced in the melted metal if the primary windings are connected with the power line. During this stage of the process the use of the electrode heating circuit may be discontinued, if desired, by raising the electrodes out of proximity to the charge. The use of the induction heating minimizes vaporization of volatile metal like zinc.

I may start the furnace on scrap copper and brass, using the electrode heating circuit and subsequently discontinue the electrode heating circuit and finish the melting with the induction heating and during this stage make the necessary additions of low melting point metals like zinc.

I may use a slag to cover the metal in the main chamber so as to prevent oxidization, and one such slag is described in my U. S. Patent No. 1,185,394 on what is known as the Greene slag process.

The electric circuits may be modified in any way such as shown in the various figures in this specification. The three electrodes may be operated straight three phase if desired.

There is special advantage in the combination of two magnetic cores as shown in Fig. 13, tending to cause movement of the metal through the induction channels into the main chamber 105 from the channel 123. The direction of current in any of these channels may be varied as desired with respect to each other. The arc and induction circuits may be operated either together or independently, and the voltage of the separate circuits may be controlled independently of each other and the voltage of any one circuit may be controlled irrespective of the voltage of any other circuit.

The furnace shown and described in my

present application, in its several modifications, is applicable to melting and treating cast iron or any kind of alloy of iron as well as brass and other alloys. The furnace shown in Fig. 12, may be used for treating molten iron by means of a blast, which may be forced into the metal or against the metal through a tuyère 201 by means of air or any suitable gas which may be provided through a pipe shown diagrammatically at 202. This tuyère 201 may open into the chamber in the channel 123 so as to tend to cause circulation of the metal from the main chamber around through the two induction channels 121 and 122.

The electrical connections may be combined in any of the various ways described in this specification or shown in the drawings. The primary and secondary winding may be connected together and thus constitute an auto-transformer winding; or they may be connected together in such a manner that the primary and secondary windings have a common connection; or the primary and secondary windings may be entirely separate from one another. In the modification of my invention, which embodies the use of two magnetic cores, with a primary winding on each core, I may connect the two primaries to a three-phase circuit in such manner that one of the primary windings is connected between one conductor of the three phase circuit and the middle of the other primary, whereby the secondary windings on these magnetic cores would be in two phase relation; and then I may connect two portions of windings or two sets of coils, one on each core to each other by connecting the center of one set of coils to one end of the other set of coils and then leading conductors from the other ends, three in number, to three electrodes entering the furnace chamber, whereby heat may be generated from a three phase electrode circuit. This arrangement is shown diagrammatically in Fig. 14.

Fig. 14 shows the diagrammatic view of transformer connections for a furnace such as that shown in Fig. 13. One primary winding is shown at 170, connected to the center of the other primary winding 171 by means of conductor 177, and these two primary windings are connected to a three phase supply circuit shown diagrammatically by three conductors 172, one conductor leading to a terminal of the winding 170 and the other two conductors leading respectively to the two terminals of the windings 171. Three other conductors 173 lead from the two transformer windings to electrodes, three in number, shown at 174, 175 and 176. The two primaries are inter-connected to the three phase circuit in such manner as to produce secondary currents of quarter phase relation to each other. The secondary induction circuits are represented diagrammatically at

179 and 178. The electrode conductors are connected to the circuits on the magnetic cores in such manner as to generate currents of three phase relation to each other through the three electrodes. This arrangement may be modified by making the portions of the primaries, which are inter-connected to the electrodes, a part of the whole primary winding, whereby each transformer constitutes an auto transformer and the numbers of turns in the different circuits may be varied by suitable switches which are not shown, but which merely connect the proper number of turns to each circuit. If desired, the portions of the windings which supply current to the electrodes may be independent of the portions of the windings which magnetize the cores from the supply circuit. The number of windings connected to the supply circuit may be regulated by means of taps on the primary windings and the portions of the windings connected to the electrode circuit may also be provided with taps so that the required number of turns may be in circuit as desired, and whereby the several circuits may be controlled independently of each other.

What I claim is:—

1. An electric furnace comprising a horizontal cylindrical shell lined with refractory material forming a main chamber within, means for tilting about an axis parallel to that of the horizontal cylindrical shell to tilt said shell backwards or forwards, a transformer attached to said furnace having a primary winding for magnetizing the core, an induction channel encircling said core and connecting with the main chamber at one side thereof, means for heating charge in the main chamber by current through electrodes entering said chamber and means for independently heating the metal in the induction channels by inducing current therein when desired.

2. An electric furnace comprising a main chamber, an induction channel connecting therewith, means for melting metal in the main chamber, means for tilting the furnace to keep the induction channel above the level of the metal in the hearth of the main chamber and for tilting the furnace and causing the melted metal to fill the induction channels, and means of heating the melted metal by induction currents therein.

3. The process of melting metal in a suitable chamber provided with electrodes and communicating with a loop conduit whereby when desired the metal melted by the electrodes may be heated by induced current in said conduit, said process consisting in melting electrically a charge of metal in said chamber while preventing it from entering said conduit, and after sufficient metal is melted by the use of the electrodes, then causing the molten metal to enter said conduit

and heating such molten metal while in such conduit by inducing electric current in such molten metal.

4. The process of melting a charge of metal having a low melting point by means of a low voltage current between electrodes and a suitable chamber while keeping the chamber tilted so as to prevent the melted metal from entering induction channels connecting with said chamber and after the metal is melted causing it to fill the induction channels and finishing the heating by induced current.

5. The process of melting metal in an induction furnace which consists in starting the furnace by passing current through it from electrodes connected with the transformer winding and finishing the heating by causing melted metal to fill the induction channels encircling said transformer winding and inducing current in the metal in the said induction channels.

6. The combination consisting of a shell and main metal chamber, a magnetic core associated therewith and winding thereon, channels for containing molten metal connecting with the main chamber, means of charging metal into the main chamber and melting it therein, means for keeping metal from entering the induction channels while melting it and for subsequently causing the melted metal to enter the channels, and means for heating it by current induced therein.

7. In an induction furnace, the combination of a main chamber, a loop section constituting part of the secondary metal circuit conduit, and one or more straight replaceable sections completing the secondary circuit channel.

8. An arc and induction furnace comprising a heating chamber, an electrode extending into said heating chamber and adapted to electrically heat a charge therein to melt the same, an extension from said heating chamber provided with induction channels communicating with said chamber, means for controlling the operation of the furnace to effect melting of the charge by means of said electrode while preventing the molten metal from entering said induction channels, and means for inducing electric current through the molten metal after being flowed into said induction channels.

9. In combination with an electric induction furnace, a straight metal pipe containing refractory material adapted to connect with two parts of the furnace shell so as to form a replaceable unit forming part of the molten metal secondary container.

10. An electric furnace comprising a shell lined with refractory material forming a main chamber within, means of tilting said shell; a transformer attached to said furnace, having a primary winding thereon for mag-

netizing a core; an induction channel encircling said core and connecting with said main chamber; means of heating the main chamber by an arc circuit connected with the transformer windings, and means of inducing current in the secondary channel when desired.

11. An electric induction furnace comprising a transformer core, a primary winding thereon, a channel in refractory material encircling said core for containing a molten metal secondary circuit, a main chamber connecting with said channel, electrodes entering said main chamber for heating a charge therein, said electrodes being connected to a winding on the said transformer core, and means of operating either the electrode circuit or the induction circuit separately or together as desired.

12. In an electric induction furnace having a molten metal secondary circuit, a replaceable section of the secondary channel of refractory material in a metal shell.

13. An induction arc furnace comprising a plurality of magnetic cores, secondary channels in refractory material, one surrounding each core, primary windings on said cores for magnetizing them, a main chamber for holding a charge, said chamber connecting with said channels, means of connecting the separate windings to separate phases of a polyphase supply circuit, means of connecting an electrode in circuit with windings on said cores, said electrode entering the main chamber for generating heat in the charge therein, and means of controlling the voltage induced in the separate circuits of the furnace.

14. An induction furnace for operation from a three phase power circuit, said furnace comprising two magnetic cores, a primary winding on each core, means of interconnecting these primary windings to a three phase circuit, and means of connecting three electrodes to the windings on the two magnetic cores, said electrodes entering a main chamber, said main chamber having an induction channel connecting therewith and encircling each of the said cores, and means of passing three phase current through the electrodes into the charge in the main chamber at the desired voltage between electrodes.

15. An induction arc furnace comprising a main chamber, a plurality of magnetic cores, primary windings thereon, channels in refractory material encircling said cores and connecting with the main chamber, means of connecting the windings on the separate cores to separate phases of a polyphase power circuit, electrodes entering said main chamber, and means of generating heat in the said main chamber by drawing current through said electrodes from windings on said magnetic cores.

16. An electric induction furnace compris-

ing a main chamber, electrodes for supplying current to heat a charge in said chamber, a conduit extending horizontally from the lower part of said chamber, and means for
 5 tilting the furnace to prevent entrance of molten metal into the conduit and for lowering the elevation of the conduit to fill it with metal from the main chamber when desired.

17. An electric furnace comprising metal
 10 shells each of cylindrical shape and mounted to tilt about an axis parallel to the horizontal axes of said cylindrical shells, linings of refractory material for said shells to form chambers therein respectively, metal con-
 15 tainers connecting said shells but suitably insulated to minimize induced current in the shells and containers, linings of refractory material for said metal containers to form a plurality of comparatively small connecting
 20 conduits between said chambers, means for tilting the furnace, and means for inducing current in the metal in the said conduits.

18. An electric induction furnace comprising a magnetic core, a chamber for receiving
 25 a charge to be melted, electrodes within said chamber for maintaining an arc between the ends thereof, a transformer winding on said magnetic core, means for controlling the supply of current to said electrodes from said
 30 transformer winding, conduits connected with said chamber for containing metal to be heated by induced current, and means for inducing electric current in the metal in said conduits.

35 19. An electric induction arc furnace comprising a magnetic core, a winding thereon distributed partly on one portion of the core and partly on another portion thereof, an arc
 40 winding to such arc circuit through the chamber of the furnace so as to regulate the leakage flux through the coils of said winding, and means for controlling the supply of current to effect magnetization of the core.

45 20. An electric induction furnace comprising a main chamber, a loop channel communicating with said main chamber and adapted to receive molten metal from said main chamber, electrodes extending through the top and
 50 bottom of the furnace for effecting heating in said main chamber, a magnetic core inter-looped with said loop channel, and transformer windings and connections for effecting the energization of said magnetic core to induce current in the molten metal in said loop
 55 channel and for supplying to said electrodes to effect heating in said main chamber.

21. An electric induction furnace comprising two main chambers, electrodes extending
 60 into each of said chambers, channels connecting said chambers for containing metal in which current may be induced, magnetic cores encircling said connecting channels, windings on said cores for magnetizing the
 65 latter, and means for effecting the passage

of electric current through said channels and through said electrodes in series.

22. An electric induction furnace comprising a magnetic core, a winding thereon, one or more adjustable electrodes, extending into
 70 the furnace chamber, and circuits and connections for supplying current to the electrode circuit from the winding on said core.

23. In an electric induction furnace, the combination with a chamber for containing a
 75 charge of metal to be treated, of electrodes entering said chamber, channels communicating with said chamber and adapted to contain metal for induction of current therein, a magnetic core encircling one of said channels, and a winding on said core connected to
 80 said electrodes.

24. In an electric induction furnace, the combination with a plurality of shells, of linings of refractory material in said shells to
 85 form chambers therein, a plurality of comparatively short containers, linings of refractory material in said containers to form conduits of comparatively small cross-sectional area communicating with said chambers to form a closed secondary induction
 90 circuit of molten metal in said chambers and in said conduits, and means for detachably securing said containers to said shells.

25. In an electric induction furnace, the
 95 method of operation which consists in passing current from electrodes entering two different enlarged chambers connected together by smaller ducts so that the current passes from one electrode thru the metal in the duct
 100 and out the other electrode, and subsequently heating the metal by inducing current thru the metal in the ducts.

26. An electric induction furnace having
 105 two hearths, tubular channels connecting said hearths and means whereby current may be induced in metal in said channels and hearths, and other means comprising an electrode entering each hearth chamber whereby current
 110 may be caused to flow thru the metal in the connecting channels from one chamber to the other.

In witness whereof I hereunto subscribe my name this 22nd day of July, A. D. 1920.

ALBERT E. GREENE.