Dec. 14, 1937. D. L. SUMMEY 2,102,582

ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

Original Filed April 14, 1932 8 Sheets-Sheet 1

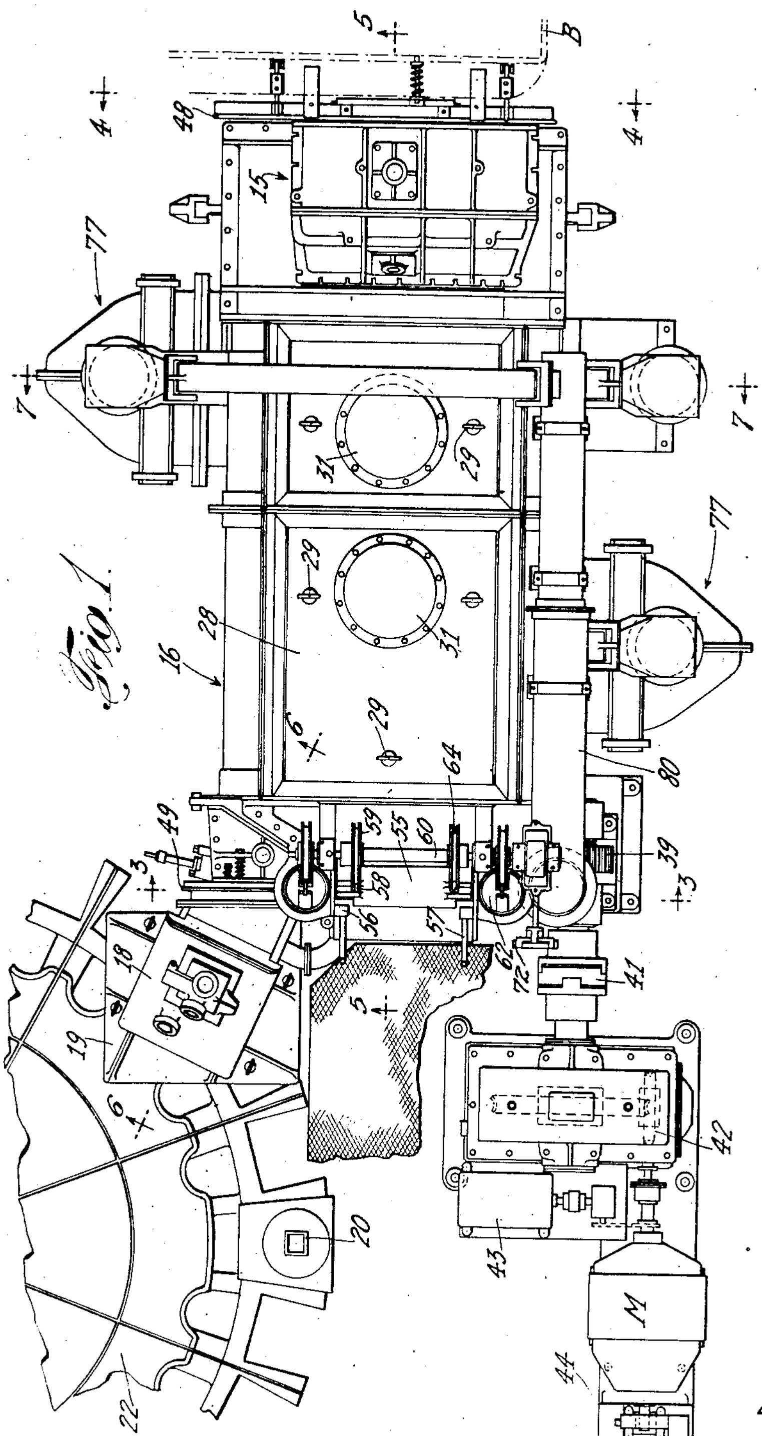

Fig. 1

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ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

Original Filed April 14, 1932 8 Sheets-Sheet 2

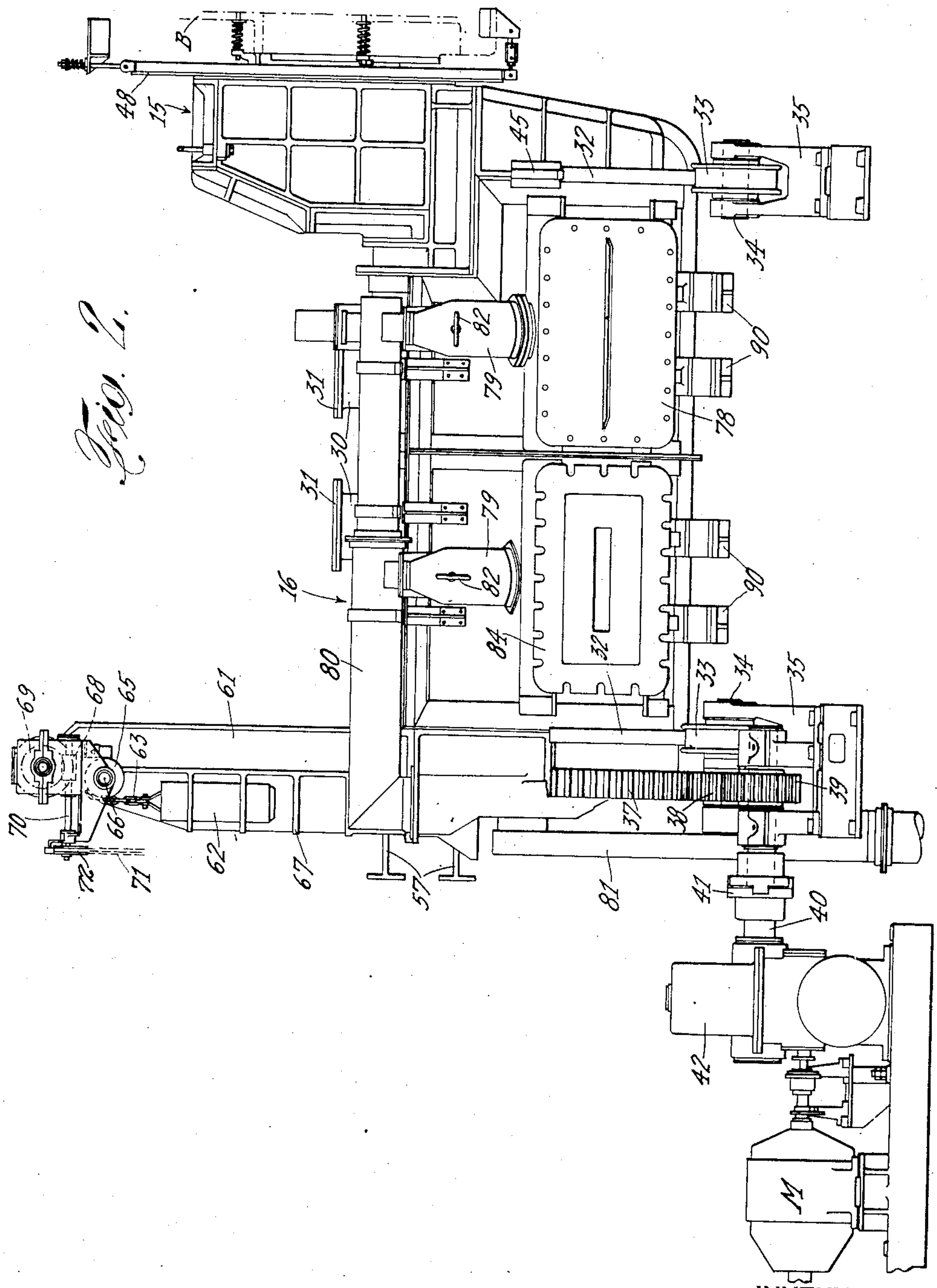

Fig. 2.

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ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

Fig. 3.

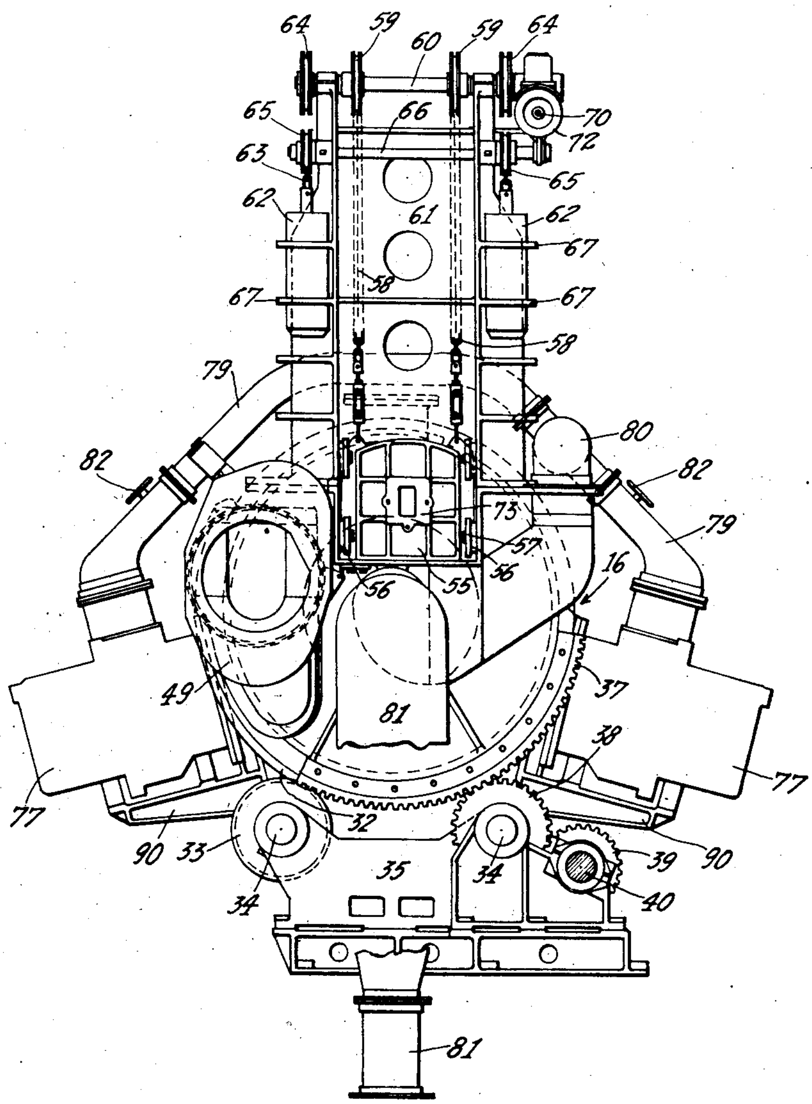

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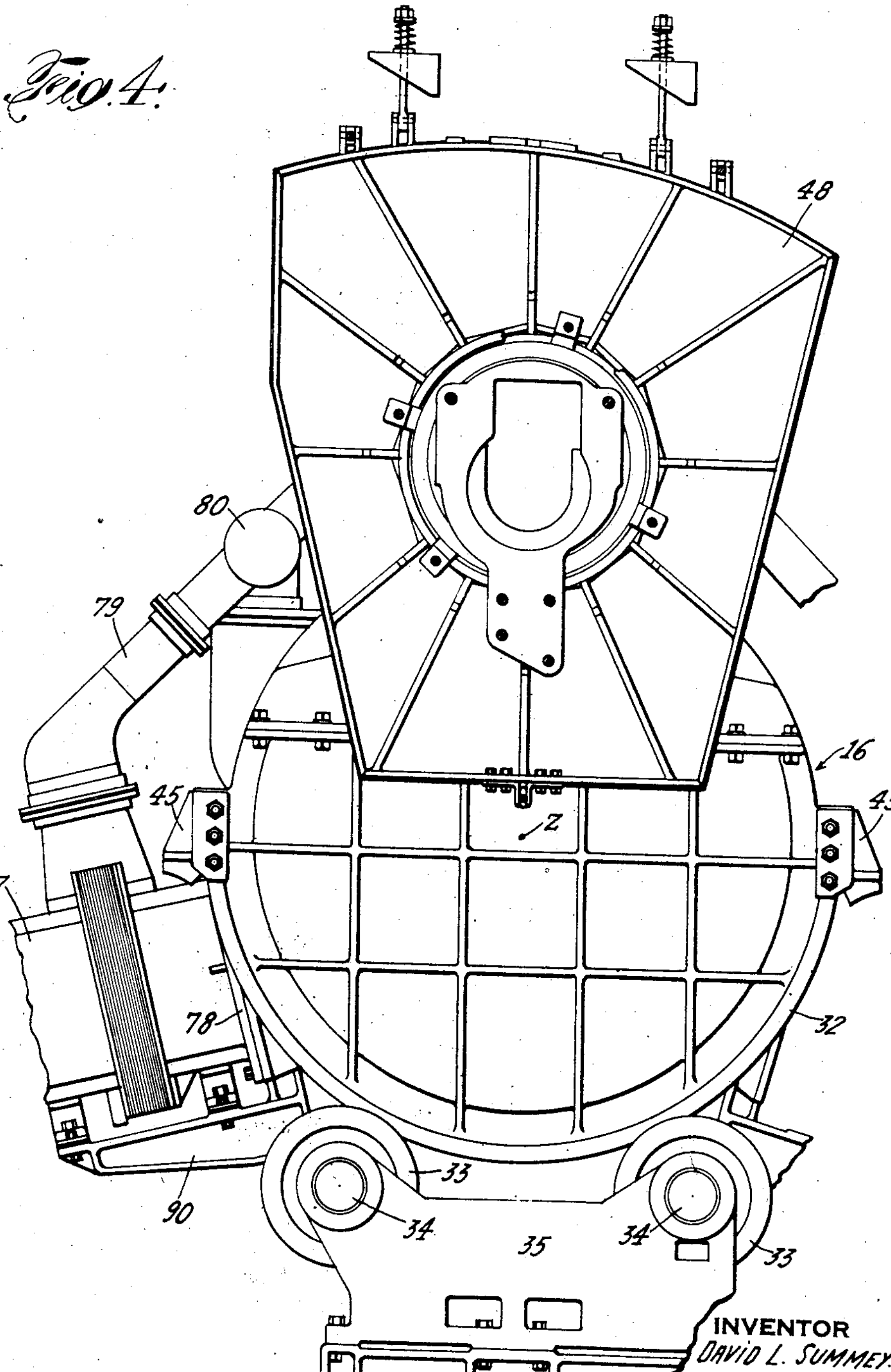
Fig. 4.



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ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

Original Filed April 14, 1932 8 Sheets-Sheet 5

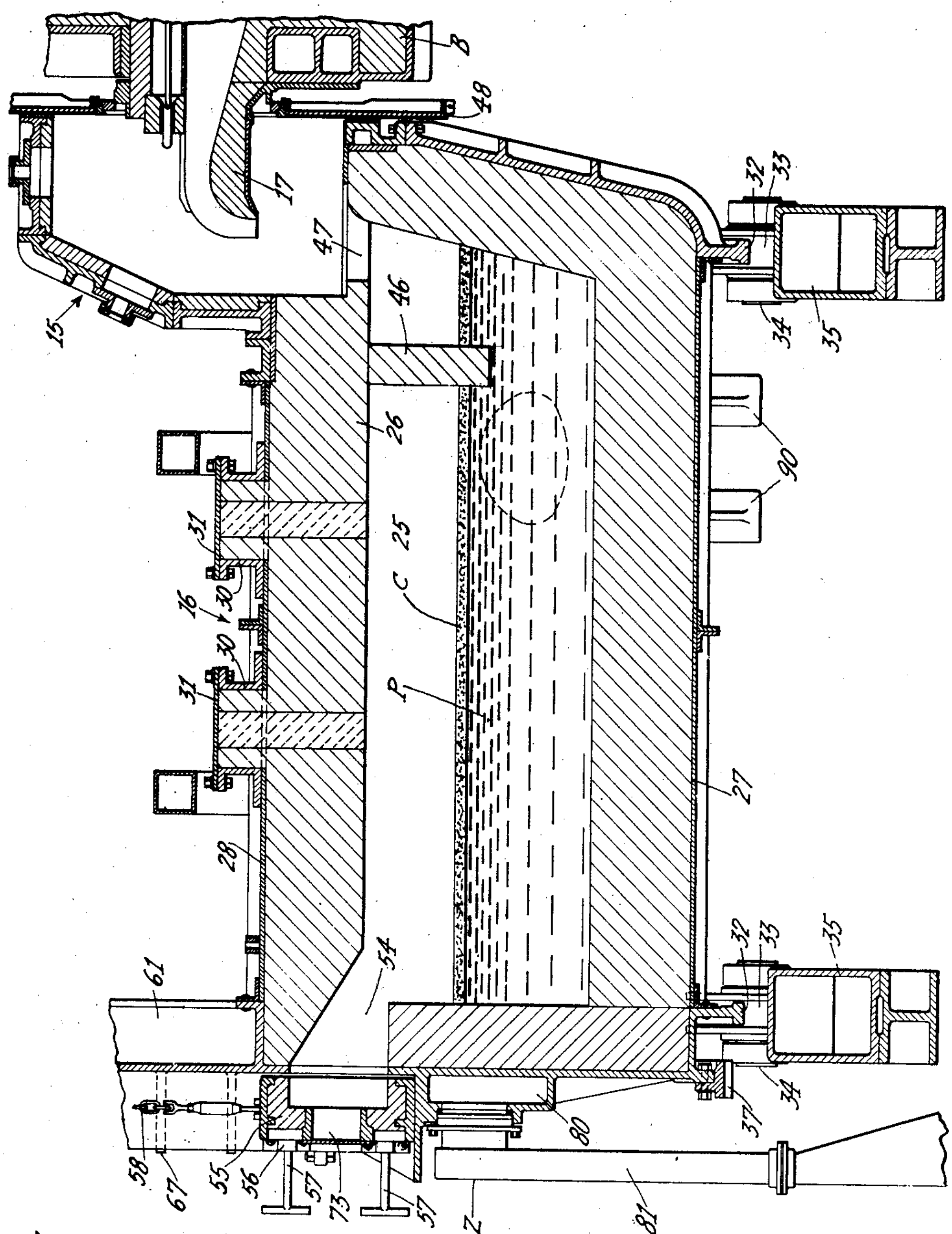

Fig. 5.

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Dec. 14, 1937. D. L. SUMMEY 2,102,582

ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

Original Filed April 14, 1932 8 Sheets-Sheet 6

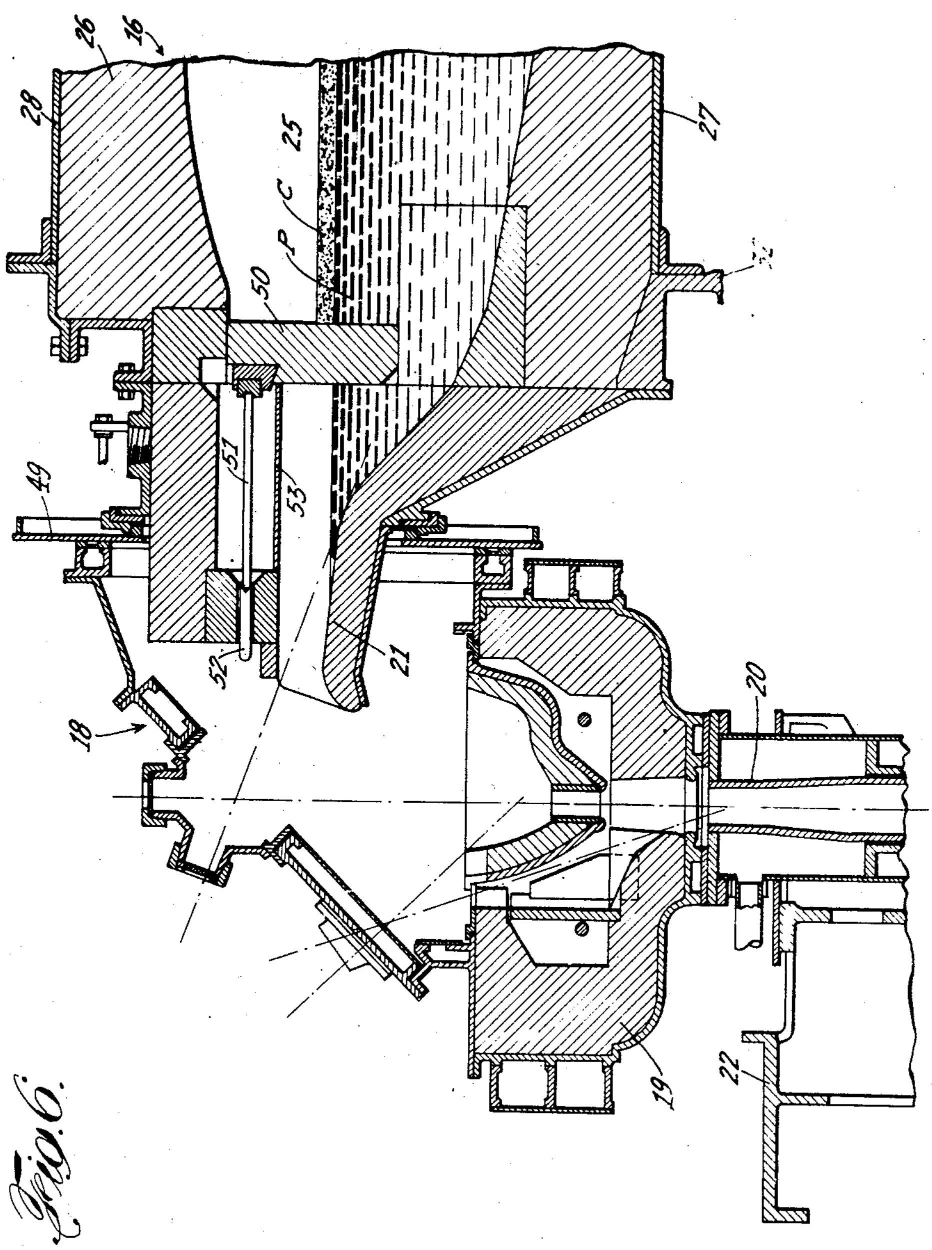

Fig. 6.

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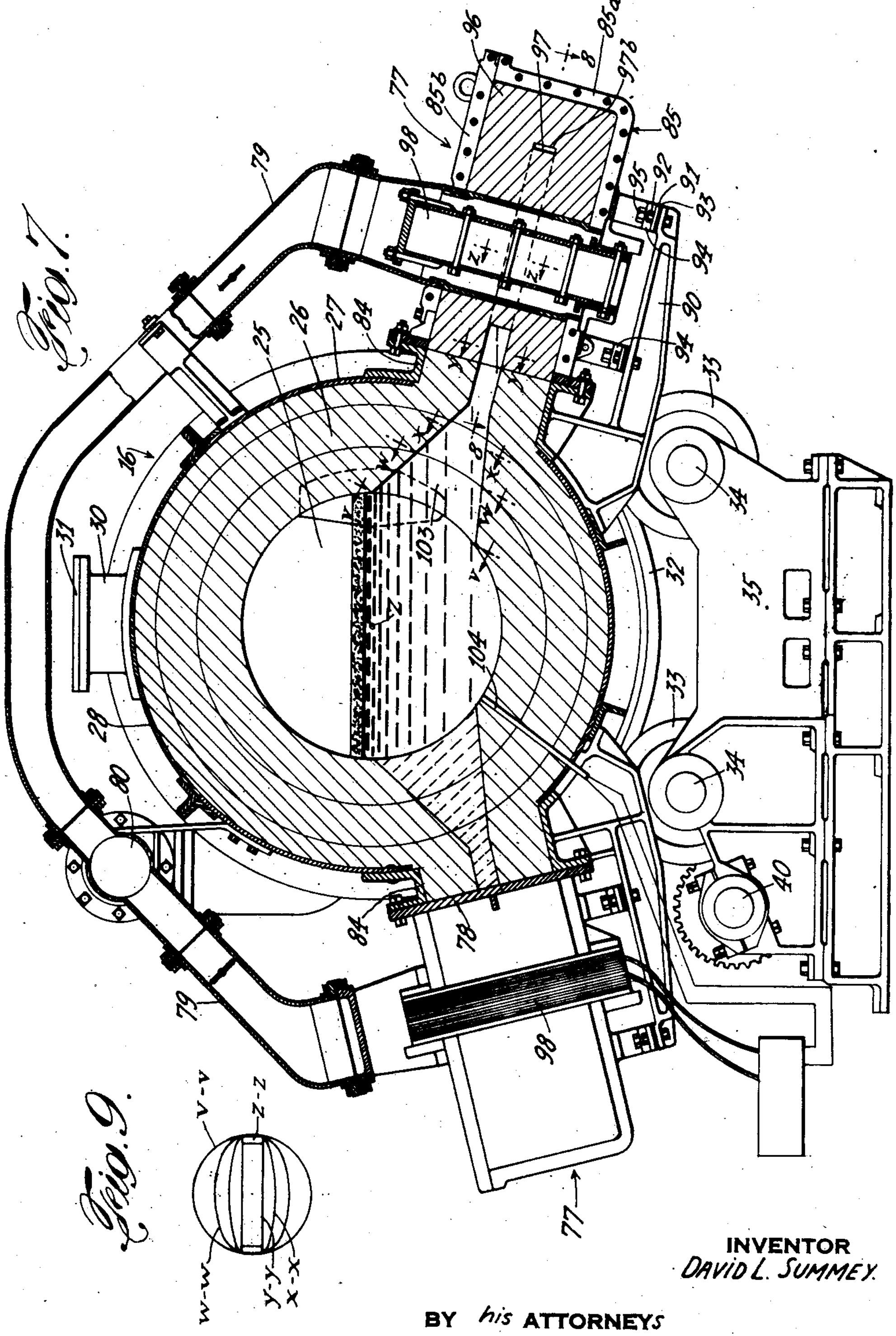
Dec. 14, 1937. D. L. SUMMEY 2,102,582

ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

Original Filed April 14, 1932 8 Sheets-Sheet 7



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ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

Original Filed April 14, 1932 8 Sheets-Sheet 8

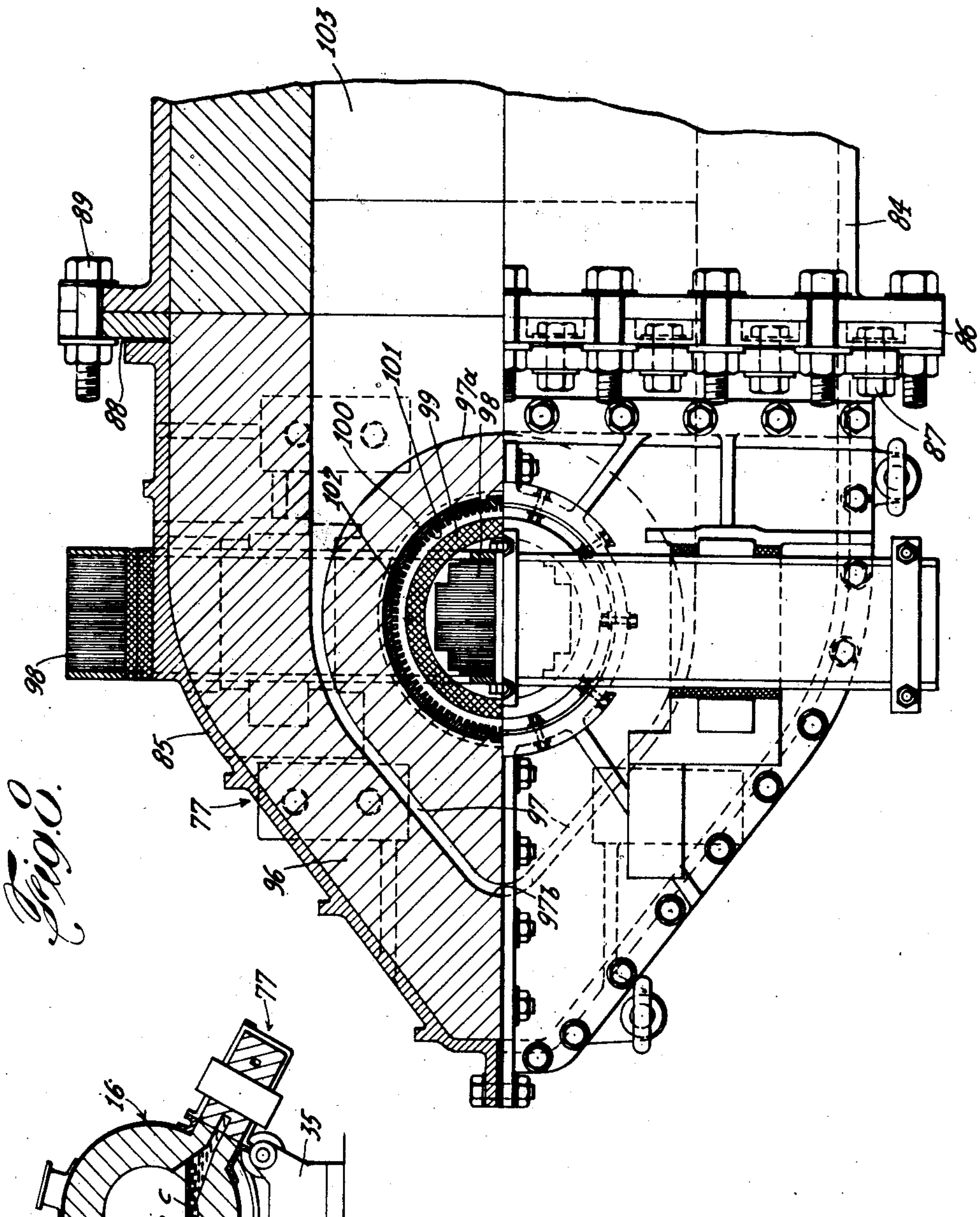

Fig. 8.

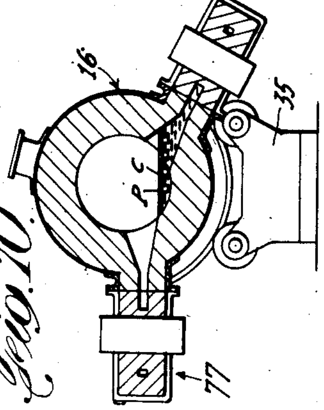

Fig. 10.

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Patented Dec. 14, 1937

2,102,582

UNITED STATES PATENT OFFICE

2,102,582

ELECTRIC INDUCTION FURNACE AND METHOD OF OPERATING THE SAME

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Application April 14, 1932, Serial No. 605,147
Renewed June 18, 1935

35 Claims. (Cl. 13—29)

This invention relates to metallurgical apparatus, particularly to an electrical furnace for melting metal or for maintaining it in a molten condition and to the method of operating the same, and has for an object the provision of improvements in this art. The apparatus is applicable to the melting or treatment of various metals and alloys but inasmuch as the present embodiment has been employed and is illustrated in conjunction with related apparatus for refining copper and other easily oxidizable metals, it will be described with special reference to such an employment; but this is done without any intention of limiting the scope of the invention thereby.

In the accompanying drawings which illustrate this embodiment of the invention;

Fig. 1 is a plan view of the electrical furnace which is the special subject of the present application, together with certain related apparatus;

Fig. 2 is a side elevation of the furnace with one of the heating units removed;

Fig. 3 is an elevation of the pouring end of the furnace taken on the line 3—3 of Fig. 1;

Fig. 4 is an elevation of the charging end of the furnace taken on the line 4—4 of Fig. 1;

Fig. 5 is a vertical axial section taken on the line 5—5 of Fig. 1;

Fig. 6 is a vertical section taken on the line 6—6 of Fig. 1;

Fig. 7 is a transverse vertical section taken on the line 7—7 of Fig. 1;

Fig. 8 is a section taken on the line 8—8 of Fig. 7;

Fig. 9 is a composite diagram showing the shape of the metal channel for a heating unit taken at several places indicated in Fig. 7; and

Fig. 10 is a diagrammatic view of the furnace in position for the removal of a heating unit.

The plant with which the present apparatus has herein been illustrated is shown in full in my co-pending application Serial Number 619,474 filed June 27, 1932, Patent Number 2,060,134, November 10, 1936, and is shown in substance in my co-pending application Serial Number 535,829, filed May 8, 1931, Patent Number 2,060,133, November 10, 1936. Those parts of the plant which are closely associated with the present apparatus are shown in Fig. 1 and comprise the hearth B of a two-hearth oscillating furnace, a hood 15 enclosing the space between the hearth B and the furnace 16 about the spout 17 (see Fig. 5), a hood 18 and strainer 19 enclosing the space between the furnace 16 and a mold 20 about the spout 21 (see Fig. 6), and a wheel 22 for supporting a plurality of molds.

As shown in Fig. 7, the furnace 16 comprises a single horizontal cylindrical hearth or chamber 25 which is oscillatable about its axis Z for pouring metal or for tilting the furnace for the removal of a heating unit. "Cylindrical" here does not necessarily refer to a right circular cylinder but is used in its broad sense to refer to a hearth which is of substantially uniform cross section throughout its length in the lower metal holding portions thereof. The furnace chamber 25 is lined with refractory material 26 which is supported by a substantial metal casing 27. The lining may either be of rammed material or of shaped firebrick, the latter being employed in the furnace as actually built. A sheet of asbestos is preferably placed between the lining and the shell for heat insulation. The casing may be formed by sheets of steel reinforced by angle bars which are bolted together. The upper sheets form a top 28 which may be unbolted and removed by hoisting means, lifting eyes 29 being provided for this purpose, to provide access to the interior for placing the lining. Openings 30 which are normally sealed by the caps 31 and which are plugged up, as shown, when not used, permit gases of any desired kind to be piped into the furnace.

Supporting rails 32 are secured beneath the hearth casing and these rails rest (Figs. 2 and 3) upon flanged wheels 33 supported upon shafts 34 carried by bases 35.

Means are provided for oscillating the furnace. Referring to Figs. 2 and 3, an arcuate rack 37 is secured to one end of the casing. Upon one of the roller shafts 34 there is rotatably disposed a gear 38 which is in mesh with the rack 37. A drive pinion 39 is mounted upon a pinion shaft 40 in operative relationship with the gear 38. The shaft 40 is provided with a flexible connection 41. Referring to Figs. 1 and 2, the shaft 41 is driven through a gear train of the non-back-drive type housed within a gear case 42 by a motor M. For normal operations the angle of movement of the furnace to either side of a central position is restricted to a predetermined value by a limit switch device 43. Lugs 45 are attached to the right hand rail (Figs. 2 and 4) to form an extreme limit means. A solenoid brake 44 quickly stops the motor when the current is cut off.

The furnace may be charged with solid metal which is to be melted or with molten metal which is to be maintained in the molten condition until it is poured. Herein the furnace is shown to be equipped for the latter scheme of operation, so, as shown in Fig. 5, it is provided with an opening 47 in the top at one end for receiving molten metal from the spout 17 of the melting furnace. While the furnace is shown as a unit of a plant wherein molten metal is supplied, the furnace itself is constructed for separate melting. For this purpose it is provided with a baffle 46 extending from the roof down below the normal lowest metal line. This keeps the solid and coldest metal (which is also the most impure) near the charging end and away from the pouring end of the furnace. It also retains gaseous elements created during the refining, as for example, zinc components when melting brasses.

The plant or system is designed to produce metal of great purity. In particular atmospheric oxygen is kept out of the system. The furnace 16 and the hearth B of the melting furnace have movement relative to each other, so the connecting enclosure is articulated to accommodate this movement while at the same time excluding air. Herein (Fig. 5) the end of the hood 15 is rigidly attached to the furnace 16 and is provided with a flat vertical end surface which slides along the face of a vertical plate 48 which is attached to the hearth B. The plate is adjustable and spring pressed against the end of the hood and in all positions remains sealed about the spout 17. This articulated hooded connection need not be considered in detail herein since it is fully described in another application.

At the pouring end of the furnace there is likewise relative movement between the spout 21 and the mold 20. The articulated connection here (Fig. 6) includes the hood 18 and the strainer 19. The strainer is vertically movable so that it may be seated upon the upper end of a mold when the latter arrives therebeneath, or may be raised when the mold is full of metal. As shown in Fig. 6 the hood 18 is rigidly secured to the strainer and its flat vertical end face is slidable along the face of a vertical plate 49 which is secured to the furnace 16. The plate is adjustable and spring pressed against the end of the hood and is at all times sealed about the spout 21. This articulated connection is also described in detail in another application.

Not only are the furnace and all of its connections sealed but a non-oxidizing or deoxidizing condition is maintained within the furnace for keeping the metal pure or for purifying it if it should be contaminated. This may be produced by gas injection or by a suitable covering for the molten metal. Herein a covering of carbon C is shown upon the bath P of metal in the furnace. Carbon is a strong deoxidizing agent and also serves to maintain carbon monoxide gas in the furnace chamber under a slight pressure whereby if there is any leakage through the articulated connections it will be outward and not inward.

A baffle 50 extends downward toward the spout 21 to retain the covering within the furnace. The metal beyond this baffle does not enter fully into the general circulation which is maintained within the main bath and is likely to freeze. If metal freezes here it is difficult to remove since the enclosing hood makes it inaccessible. So means are provided for heating the metal here to keep it molten. This means, as shown in Fig. 6, comprises resistors 51 connected in an electrical circuit by electrodes 52. The resistors and electrodes are placed above the metal but are subject to injury by splashing metal so a thin refractory plate 53 is placed between them and the metal to protect them.

An opening 54 (Fig. 5) is provided in the end of the furnace for charging carbonaceous or other material, for sighting into the furnace, or for attaching a frame carrying a pyrometer for measuring the temperature in the furnace. This opening is closed by a refractory lined door 55. The door is vertically slidable behind guides 56 and may be sealed tightly against the furnace by hand screws 57 threaded through the guides. The door is supported by chains 58. Referring to Figs. 2 and 3, the chains are suspended from pulleys 59 which are fast on a hoist shaft 60. The shaft is rotatably supported on columns 61 which are secured to the top of the furnace casing. The weight of the door is partially balanced by counterweights 62 suspended by cables 63 attached to pulleys 64 fast on the shaft 60. The cables pass forward over idler pulleys 65 fast on an idler shaft 66 which is supported in bearings upon the columns. The counterweights are kept in alignment in all tilted positions of the furnace by strap guides 67. The shaft 60 is rotated by a worm and gear connection 68, 69 from a shaft 70 by a chain 71 passing around a notched sheave 72 fast on the shaft.

The door is provided with a removable sight glass mounting 73 for affording a view into the interior of the furnace.

Means are provided for heating the bath of metal and stirring it into frequent and intimate contact with the carbon covering. The heating means preferably comprises a plurality of electrical transformer units 77. As shown in Figs. 1 and 2, there are two such units in use and a third position for another unit, which is blanked off by lining material and a cap 78. If desired more units may be provided and preferably each unit is supplied with current from one phase of a multi-phase source of current.

The transformer units require cooling and for this purpose air is supplied by branch conduits 79 leading from a trunk conduit 80. The branch conduits are provided with control dampers 82. As shown in Figs. 3 and 5, the conduit 80 extends to the end of the furnace where it is turnably connected at the axis of oscillation Z of the furnace with a supply conduit 81.

Referring to Figs. 7 and 8, the furnace casing 27 is provided with a flanged tubular extension 84 for each heating unit. To this is bolted the shell 85 of the unit. It is desirable to electrically insulate the heating transformer shell from the furnace casing. This is done in such a way as to avoid the installation of the insulation at the time when the unit is attached to the casing. It will be realized that the units may be replaced while the furnace is in operation and in such a case the replacement must be effected so quickly that there is little time for placing insulation. As seen in Fig. 8, this is accomplished by bolting a plate 86 to the shell by insulated bolts 87, with a sheet of insulating material 88 placed between the shell and the plate. This can be done before the units are brought to the furnace. When attaching the unit to the furnace the plate **86** is bolted directly to the extension **84** by bolts **89**, no electrical insulation being used.

The heating units are supported upon brackets **90** which are attached to the furnace shell. The mounting of the unit upon the brackets is also designed for speed of replacement. Plates **91** are secured by electrically insulated bolts **92** to the brackets, there being electrical insulating sheets **93** between the plates and brackets. When attaching the heating unit to the furnace it is placed with its feet **94** upon the plates **91** and slid endwise until it connects with the flanged extension **84**. The feet **94** are then secured to the insulated plates **91** by bolts **95**, no electrical insulation being necessary unless the bolts pass through the plate **91**. Even then no insulation is required between the feet **94** and the plates **91**, so that the sliding movement may be quickly effected and without injury to any insulation.

The shell **85** of the heating unit, which is preferably of a non-magnetic material like bronze, comprises a lower portion **85a**, including bottom and sides, and a cover **85b**. This construction permits the refractory lining **96** to be rammed into place in a sidewise direction with respect to the plane of the loop channel **97** which is produced, thus insuring ease of ramming, a more perfect lining, and a ready inspection of the same. Both the bottom and cover of the shell are divided and electrically insulated in a medial plane which is perpendicular to the plane of the loop and axially aligned with the axis of the loop. The general features of the divided induction heating casing providing for convenient placing of lining material are described and claimed in my Patent No. 2,060,136, November 10, 1936. The method of ramming the lining material in such a casing is disclosed and claimed in my Patent No. 2,008,732, July 23, 1935.

A transformer core **98** in the shape of a closed **E** has its central leg inserted through the shell within the channel loop. A primary coil **99** is placed upon this central leg within the opening through the shell. The coil is partly within the plane of the channel loop. When metal is disposed in the loop it forms the secondary of the transformer. The plane of the transformer core is perpendicular to the plane of the channel loop and also perpendicular to the axis of the loop, i. e. perpendicular to the vertical plane of division of the shell **85**.

The through opening of the shell is encased by a tubular shell member **100**, which is insulated from the other portions of the shell and which is preferably composed of a non-magnetic material such as bronze. This member is provided with axial ribs **101** on its inner surface for more rapid and efficient cooling by the air blast from the conduits **79** and is lined on its outer surface by a strip of high melting point metal **102** such as steel in the plane of the channel loop to avoid leakage of metal to the transformer coil. Any leakage through the refractory lining would most likely occur in the plane of the channel loop.

Here it may be noted that the plane of the channel loop is parallel to and passes considerably below the axis of rotation Z of the furnace. This permits both legs of the loop to be filled with metal simultaneously from the bottom upward when the furnace is tilted for that purpose, it being understood that the tilting is not too sudden. The arrangement is also conducive to good circulation of metal across the furnace beneath the carbon covering so as to obtain good contact therewith. At no time in normal operation do the planes of the channel loops drop below 45 degrees with the horizontal.

The loop is circular on its inner surface **97a** at the side toward the furnace. Beyond this a pocket **103** extends into the furnace through the lining thereof in a width which is equal to the greatest diameter of the outside of the loop, which diameter lies in the plane of the transformer core. The loop on the side away from the furnace is somewhat in the shape of the letter **V** is rounded at **97b** across the junction of the legs of the **V**. It does not come to a sharp angle or point. In fact if the straight sides were extended the junction thereof would lie wholly outside the actual end of the loop. This shape is much more durable than a pointed shape would be and produces very effective circulation of metal.

The legs of the channel loop are rectangular in cross section with the major axis perpendicular to the plane of the loop. The pocket **103** which is formed in the furnace lining at the inner side of the loop, as shown in Fig. 9, expands from rectangular to circular as it approaches the inner surface of the furnace lining. The diameter of the circle is the same as the length of the major axis of the rectangle. This construction also greatly aids the circulation of the metal in that it distributes the metal both toward the surface of the bath to react with the covering material and also to a more limited extent toward the bottom of the bath to keep the metal there from freezing. This shape also permits the lining thereabout to have maximum strength and durability. The axis of the pocket is radial and passes through the axis of rotation Z of the furnace. This causes the metal to be principally directed upward toward the surface.

No attempt is made herein to explain the mechanical, electrical or other primary causes of this circulation but if such an explanation is ever required or found desirable, the right is reserved to introduce it in so far as it is an inherent function of the construction which is disclosed. The heating effects of the loops are such that a unit has been started with frozen metal (copper). This, however, is not the usual practice. There is no noticeable breaking of the loop circuit even when tested with delicate electrical instruments, and this in spite of the fact that in certain positions of the furnace the hydrostatic head of metal on the loop may become relatively small. The location of the loops is a matter of considerable importance. They are placed low enough, as noted, so that the column of metal is not broken by the current used when the loops are in their highest normal positions. They are not placed so low as to carry too high a head of metal; this would tend to cause metal to force its way into or through the lining. They are directed below the axis of the hearth whereby there will be some flow of metal across the bottom of the hearth to prevent freezing there. This also permits emptying with minimum turning. They are arranged on opposite sides so that one set may keep the metal molten while some or all of the other set are removed. Here again a high position is beneficial since the minimum turning of the hearth is required to empty the set which is elevated.

The location of the pouring spout is also a matter of importance. It is designed to obtain the maximum flow of metal with the least possible movement and is placed where it will cooperate easily with the strainer hood in its movements while still maintaining a tight seal therewith. It is placed near the central horizontal plane of the hearth for here the cross section of the hearth and the amount of metal are the greatest. Also when the hearth is turned for the removal of a heating unit the spout does not go so low as to drain all of the metal. It is placed near the side of the hearth for here the movement required for pouring a given quantity of metal is the least. In fact, it is inclined horizontally outward. It is placed in the end of the furnace for here it cooperates best with the associated units and the stream of metal from the spout is caused to strike at about the same place in the strainer for all pouring positions. It would be otherwise if the spout were radial, i. e. placed in the side of the hearth. The metal level is kept near the central horizontal plane of the hearth. For constant or continuous pouring this level can be closely maintained. For interrupted or batch pouring it can be approximately maintained by pouring often. If the metal level is thus located the change of level for the pouring of a given quantity of metal is least.

The relationship of the pouring spout and the heating units to each other and to the body of metal and covering material carried in the furnace chamber is such that the covering material will not be carried into the spout nor will surges of metal be produced in the spout. This is due to the fact that the zone of pronounced circulation from the heating units is not directed toward the spout opening. There will, of course, be some circulation of metal throughout the entire body of metal just as there always is in any continuous body of fluid when a disturbance is created in any part thereof; but it is only the zone of pronounced circulation which requires control. In the specific embodiment herein illustrated, this relationship is obvious. For example, it may be observed from Figs. 1 and 6 that the spout and nearest heating unit are located well away from each other and that the spout opening is near the bottom of the main chamber and well below the covering material; and it may be observed from Figs. 1 and 7 that the heating unit channels or chambers are directed transversely of the axis of the main furnace chamber and open into the main chamber near the bottom and well below the material and are directed downwardly away from the main chamber. If vertical planes parallel to the central axis of the zone of circulation were placed on either side of the heating unit chamber so as to enclose it, the nearest of these planes would be located well to one side of the spout opening. In this particular embodiment the planes would be perpendicular to the longitudinal axis of the furnace.

The temperature of the bath may be controlled by a thermo-couple 104 or other suitable temperature controlling device placed in the bath near the pouring end and connected properly for supervision of the current applied to the heater units. The thermo-couple is protected by a refractory tube, the high purity of the metal in the furnace permitting of this here, whereas before it was believed to be impractical for copper on account of the very rapid corroding effect of the oxygen-bearing metal on the refractory tube.

When the baffle 46 is used at the intake end of the hearth and solid metal is charged beyond it, a separate heating unit may be used beyond the baffle if desired to produce a good circulation there.

From the preceding description it will be seen that the furnace embodies advantageous constructional features which render the circulation of metal more efficient, which reduce stray electrical effects, which permit quick replacement of heating units, which establish proper cooperation with adjacent units of the plant to produce a metal of high quality, which provide close and accurate temperature and refining control, and which in other respects constitute a distinct advance in the art.

While only one embodiment of the invention has been illustrated and described it is to be understood that the invention is not limited to this particular embodiment but may be variously changed and have other forms within the scope of the subjoined claims.

I claim:

1. An electric induction furnace comprising in combination, a horizontal cylindrical-bottomed hearth, a plurality of induction heating units thereon some of which are on each side of a vertical plane through the axis of the hearth, said heating units each including a secondary metal channel loop the plane of which is parallel to the axis of the hearth and normally inclined at an angle to both vertical and horizontal planes, and a pocket in said hearth connecting the chamber thereof with the secondary channel loop, said pocket being rectangular in section where said loop enters it and spreading as it approaches the hearth chamber until it becomes circular in section with a diameter equal to the length of the major axis of the rectangular section.

2. An electric induction furnace comprising in combination, a horizontal cylindrical hearth mounted to turn about its longitudinal axis, and induction heating units disposed on each side of a vertical plane through the axis thereof, said hearth being provided with a pouring spout the inner opening of which is disposed between the inner ends of said heating units, each unit having a secondary channel loop whose plane is parallel to the axis of the hearth, the heating units being located below the level of the pouring spout whereby those on both sides are kept full of metal during normal pouring from the furnace, and whereby the heating units on one side are kept full of metal when those on the other side are emptied for removal or repair.

3. A furnace as set forth in claim 2 in which the heating units are disposed at an angle to a horizontal plane and in which the planes of the loops in normal operations never make an angle of over 45 degrees with a horizontal plane.

4. A furnace as set forth in claim 2 which further includes a pocket connecting the loop with the hearth chamber, the axis of the pocket passing through the axis of the hearth.

5. A furnace as set forth in claim 2 which further includes a pocket joining the loop with the chamber of the hearth, said pocket being flared vertically as it approaches the hearth chamber.

6. An electric induction furnace comprising in combination, a horizontal cylindrical-bottomed hearth mounted to rotate about its horizontal axis and provided with a charging opening at one end and a pouring opening at the other end, the pouring opening being located at one side of the axis of rotation, and an induction heating unit secured exteriorly thereto, said unit including a

secondary channel loop whose plane is parallel to the axis of the hearth.

7. An induction furnace comprising in combination, a hearth having a lining and a retaining shell, a secondary heating loop disposed wholly outside the hearth lining and shell, and a deep pocket extending entirely through the lining of said hearth and connecting both legs of the loop in common with the chamber within said hearth, said pocket being nowhere smaller in cross-sectional area than the greatest trans-planar area circumscribed by the loop and extending from the secondary loop for a distance which is considerably greater than the thickness of the secondary channel before it becomes greater in cross-sectional area than at the loop.

8. In an electric induction furnace in combination, a hearth provided with a metal casing, an induction heating unit therefor provided with a metal shell, said casing and shell being provided with mating attaching faces, a support on said casing for said shell, said support extending alongside said shell and being provided with an attaching surface aligned with the direction in which said shell must move to bring said faces together in parallel relationship, and means for attaching and insulating said shell on said support.

9. An induction furnace as set forth in claim 8 in which said attaching and insulating means includes an intermediate member which is initially secured to and insulated from the metal parts of the casing or shell and to which the final attaching means are anchored, whereby the parts may have relative sliding movement during assembly on surfaces other than the insulated surfaces.

10. An electric induction furnace as set forth in claim 8 in which said supporting means includes brackets, and insulated plates on said brackets upon which said heating unit is seated, and later slid into final position.

11. The method of exchanging a heating unit on a horizontal cylindrical furnace provided with removable heating units on each side having secondary loops parallel with the axis of the furnace, which comprises shutting off current from a heating unit which is to be removed from one side while maintaining the current on a unit on the other side, turning the furnace about its axis until the first heating unit is empty, and then removing the empty heating unit and replacing it with another.

12. An electrical furnace comprising in combination, a horizontal cylindrical-bottomed hearth oscillatable about its axis, a plurality of electrical heating units located in a row along the length of the hearth, a pouring spout at the end of the hearth which is inclined outwardly from the axis and which is located for normal operations near the central horizontal plane of the hearth, whereby the maximum quantity of metal may be poured from the spout with the minimum rotation of the hearth and whereby the spout will cooperate with a simple and relatively small movement with related articulated elements.

13. An electrical furnace comprising in combination, a horizontal cylindrical-bottomed hearth oscillatable about its longitudinal axis, heating units disposed on each side of the hearth below the central horizontal plane having channels normally directed upwardly at an angle to the vertical and horizontal planes, the angles with the horizontal plane being smaller than with the vertical plane, and a pouring spout in the hearth arranged to pour metal in an axial direction, said spout being located near the central horizontal plane of the hearth, all for the purposes set forth.

14. An electrical furnace comprising in combination, a hearth oscillatable about a horizontal axis, upwardly inclined heating units on either side of said axis, having channels entering the hearth below the axis, and an axially directed pouring spout on one side of the axis and normally at the same elevation as the axis.

15. An electrical furnace as set forth in claim 14 in which said inclined channels are directed toward a line which is substantially below the axis of the hearth.

16. An electrical furnace as set forth in claim 14 in which said inclined channels are directed toward a line which is substantially below the axis of the hearth, and which further includes a pocket for each channel which is flared vertically and has its axis radial to the hearth axis.

17. In an electrical furnace, in combination, a horizontally elongated hearth mounted to turn about its longitudinal axis, means for charging metal at one end of the hearth and means for pouring metal at the other end of the hearth, a baffle near the charging end extending downward from the roof of the hearth into the metal, and means for heating the metal in the hearth which produces an effective circulation of metal on both sides of said baffle.

18. An electric induction furnace for molten metal, comprising in combination, a metal-holding hearth supported for tilting movement about a horizontal axis, an induction heating unit, including a loop channel for molten metal and induction heating means for the metal in the channel disposed on the side of the hearth with the channel approximately radial to the axis, and a pouring spout located at one side of and approximately aligned with said axis.

19. An electric induction furnace for molten metal, comprising in combination, a horizontal cylindrical metal-holding hearth supported for tilting movement about its longitudinal axis, an induction heating unit, including a loop channel for molten metal and induction heating means for the metal in the channel disposed on the side of the hearth with the channel approximately radial to the axis, and a pouring spout located in the end of said hearth at one side of and approximately aligned with said axis.

20. Apparatus as set forth in claim 19 in which said spout in normal pouring position of the furnace is disposed approximately in a central horizontal plane.

21. An induction electric furnace, comprising in combination, a hearth for holding a bath of molten metal, means for supporting the hearth to turn about a horizontal axis, external independent induction heating units removably disposed on each side of the horizontal axis, and means for pouring metal from the hearth at a point located between the heating units, the hearth construction and heating unit arrangement being such that by tilting the furnace either of the units may be emptied while the other and a portion of the hearth is left full of metal, whereby a body of the metal may be maintained in molten condition on one side while a unit on the other side is made accessible for replacement or repair.

22. An induction electric furnace, comprising in combination, a horizontal cylindrical-bottomed

hearth oscillatable about its longitudinal axis, and external removable induction heating units disposed on each side of the horizontal axis, the hearth construction and heating unit arrangement being such that by tilting the furnace either of the units may be emptied while the other and a portion of the hearth is left full of metal, whereby a body of the metal may be maintained in molten condition on one side while a unit on the other side is made accessible for replacement or repair.

23. A furnace as set forth in claim 22 in which each unit comprises a loop channel outside the hearth and electric induction heating means therefor.

24. In an electrical furnace, in combination, a horizontally elongated hearth turnable about its longitudinal axis, said hearth having a charging opening at one end and a pouring spout at the other end, said pouring spout being located at one side of the axis of the furnace, and electric induction means for heating metal at a plurality of points along the length of the hearth.

25. An induction electric furnace, comprising in combination, a horizontal cylindrical-bottomed hearth having a refractory lining and a metal shell, and a plurality of loop-channel induction heating units having refractory linings and metal shells detachably secured to the hearth shell at spaced points along its length, the units being disposed on both of the opposite sides of a vertical plane through the axis of the hearth, whereby units on one side may be exchanged while those on the other side keep the metal in the molten condition.

26. An induction electric furnace comprising in combination, a hearth, an induction heating unit having a loop-shaped secondary channel, and an elongated pocket connecting the inner ends of the loop channel together and with the hearth, said pocket being flared from its minimum cross sectional area adjacent the loop-shaped channel in a substantially funnel-like shape through the hearth lining to its maximum cross-sectional area at the inside surface of the hearth, whereby the frictional resistance to circulation is minimized.

27. An electric furnace comprising in combination, a horizontal cylindrical-bottomed hearth oscillatable about its longitudinal axis, heating units disposed on each side of the hearth below the central horizontal plane having channels directed upwardly at an angle to the vertical and horizontal planes, the angles with the horizontal plane being smaller than with the vertical plane.

28. An electrical furnace as set forth in claim 27 in which said inclined channels are directed toward a line which is substantially below the axis of the hearth.

29. An electrical furnace as set forth in claim 27 in which said inclined channels are directed toward a line which is substantially below the axis of the hearth, and which further includes a pocket for each channel which is flared vertically and has its axis radial to the hearth axis.

30. An electrical furnace comprising in combination, a horizontal cylindrical bottomed hearth oscillatable about its longitudinal axis, the furnace being normally charged with metal to a level above the horizontal axis and the metal being covered with a bed of carbon, heating units disposed on each side on the hearth below the central horizontal plane having channels directed upwardly at an angle to the vertical and horizontal planes in the normal mid-position of the furnace, the angles with the horizontal plane being smaller than with the vertical plane, whereby metal heated in the heating units is directed upward and across beneath the covering of carbon on the metal.

31. A furnace for producing purified copper, copper alloys or the like comprising: a main chamber for holding a quantity of molten metal; a leg chamber of relatively small cross-sectional area communicating with the bottom of said main chamber and extending downwardly therefrom; means for heating metal in said leg chamber; and a pouring spout communicating with said main chamber only adjacent the bottom thereof and well away to one side from the vertical planes enclosing said downwardly-extending leg-chamber.

32. A furnace for producing purified copper, copper alloys or the like comprising: a main chamber for holding a quantity of molten metal; a loop chamber communicating with the bottom of said main chamber and extending downwardly therefrom; means for heating metal in said loop chamber; and a pouring spout communicating with said main chamber only adjacent the bottom thereof and well away to one side from the vertical planes enclosing said downwardly extending loop-chamber.

33. A furnace for producing purified copper, copper alloys or the like comprising: a main chamber for holding a quantity of molten metal; a leg chamber of relatively small cross-sectional area communicating with the bottom of said main chamber and extending downwardly therefrom; means for heating metal in said leg chamber; a pouring spout communicating with said main chamber only adjacent the bottom thereof and well away to one side from the vertical planes enclosing said downwardly-extending leg-chamber, and independent means for heating metal in said spout.

34. A furnace for producing purified copper, copper alloys and the like, comprising: a main chamber for holding a quantity of molten metal with a layer of covering material thereon; an auxiliary metal holding chamber communicating with said main chamber near the lowest part of the bottom thereof and well below the normal bottom surface of said covering material, said auxiliary chamber extending downwardly from the main chamber; means for heating metal in said auxiliary chamber whereby to produce a vertical zone of circulation of metal in said main chamber and to direct metal upward against said covering material; and a pouring spout communicating with said main chamber only at a point well beneath the normal bottom surface of said covering material and well toward the bottom of the main chamber, whereby to prevent floating covering material from entering the spout, said spout opening being disposed well away to one side of the zone of circulation from said auxiliary chamber, whereby to avoid circulation of metal in and the entry of admixed covering material into said spout.

35. A furnace for treating molten metal in the presence of floating material and adapted to deliver the metal to a pouring spout free from surges of metal and free from floating material, comprising in combination, a main chamber for holding a quantity of molten metal, an auxiliary chamber and heating means therefor, said auxiliary chamber communicating with the lower portion of said main chamber where it will be completely submerged beneath the metal and ex-

tending downwardly from its inner communicating end whereby to produce a major upwardly directed zone of active circulation of metal in the main chamber, and a pouring spout communicating only with the lower portion of said main chamber where the communicating opening will be submerged beneath the metal, said spout opening being located sufficiently to one side of the major zone of circulation of metal in said main chamber to prevent surges of metal in the main chamber or floating material from entering the spout.

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