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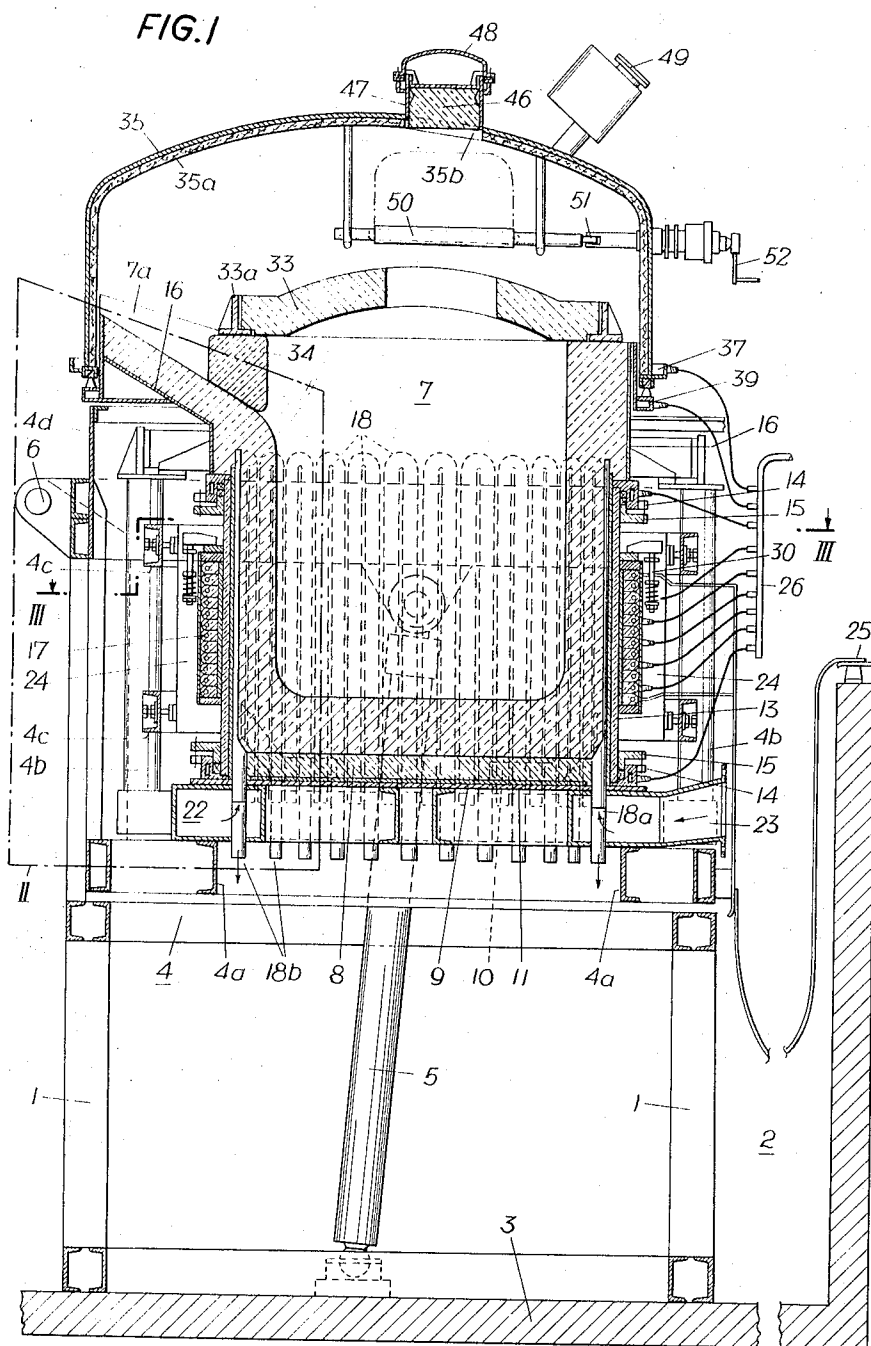
O. JUNKER

3,303,259

VACUUM INDUCTION FURNACE

Filed June 15, 1964

4 Sheets-Sheet 1



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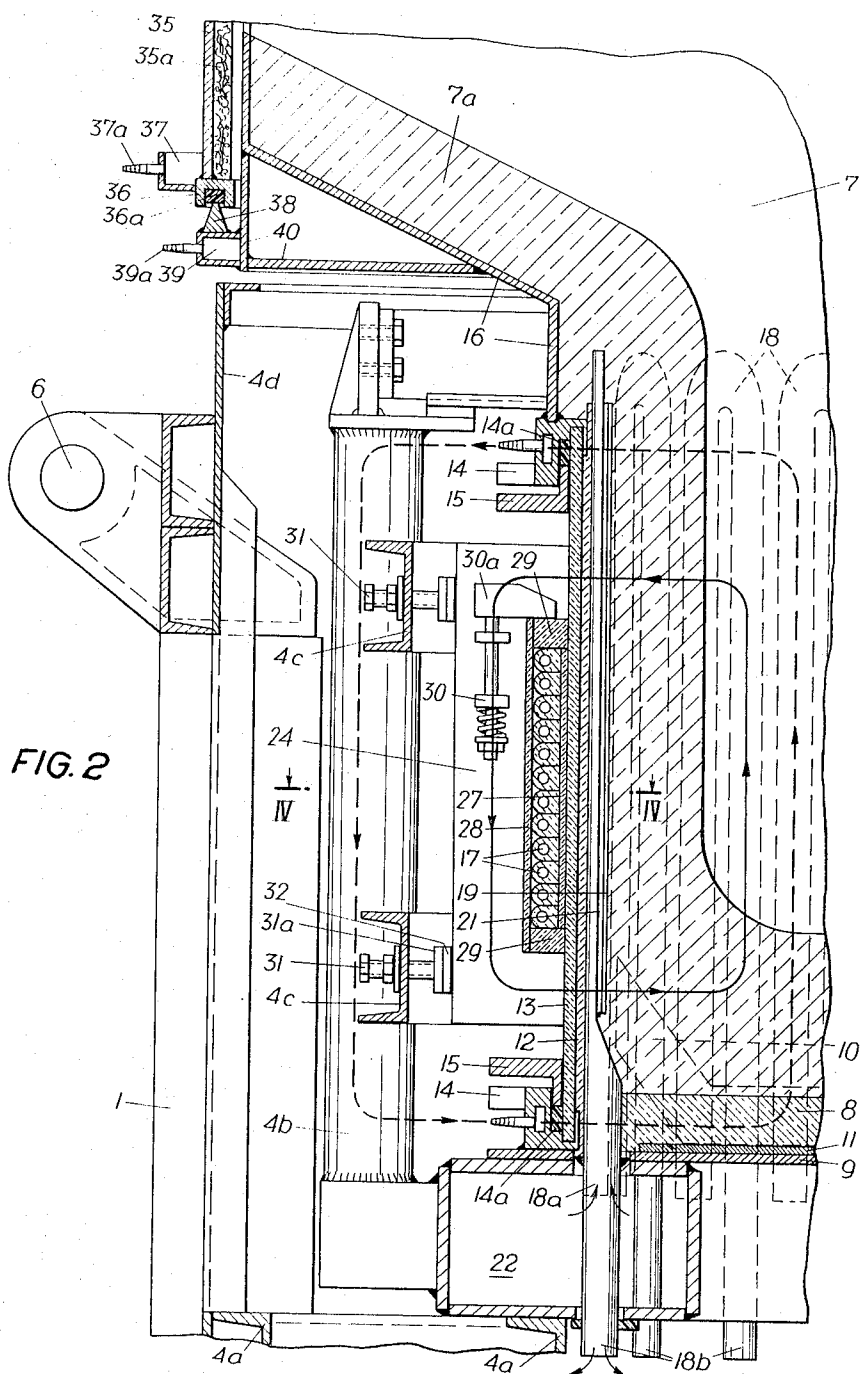
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VACUUM INDUCTION FURNACE

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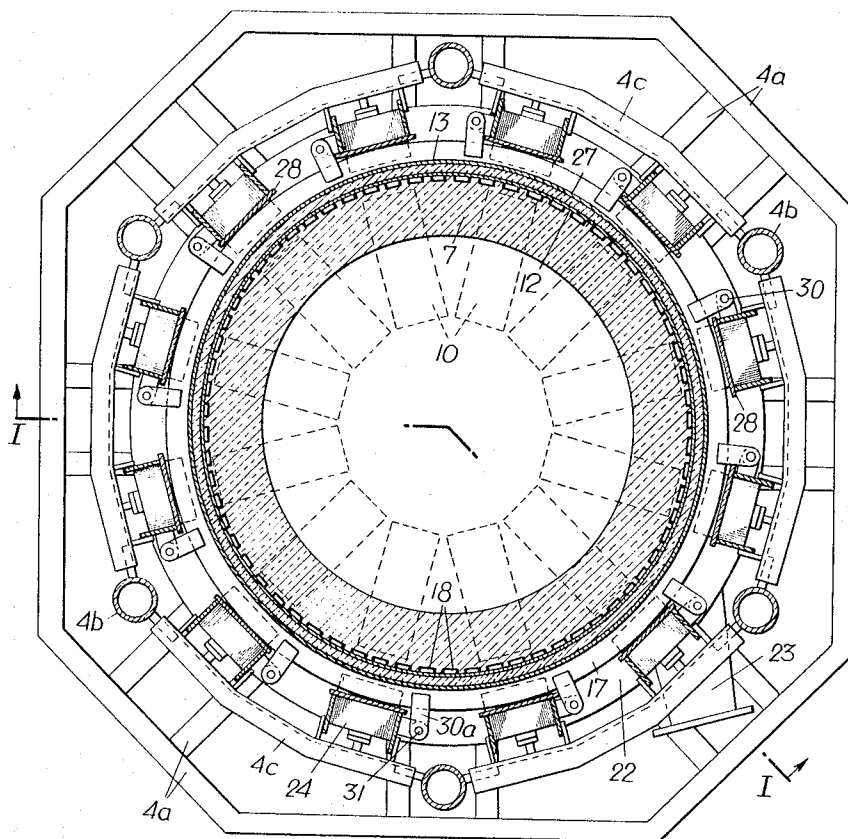
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# VACUUM INDUCTION FURNACE

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**FIG. 3**



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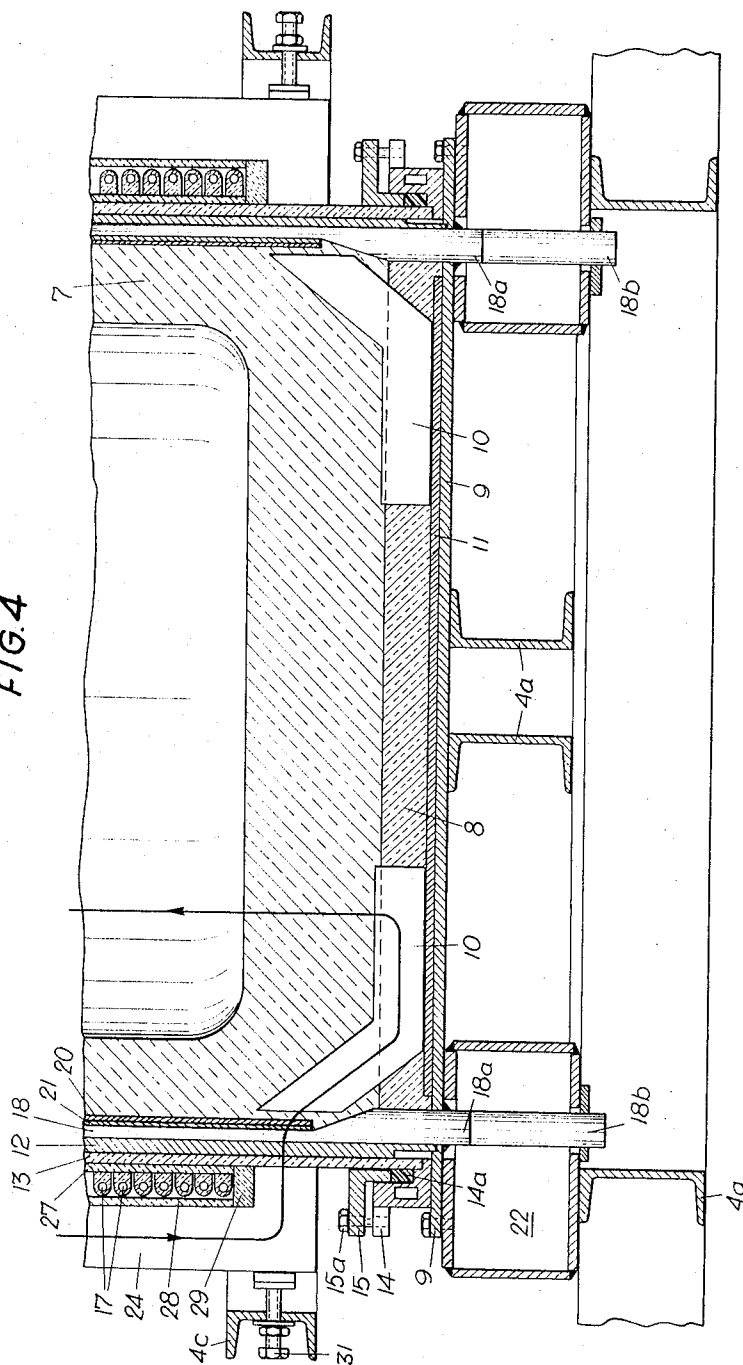
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VACUUM INDUCTION FURNACE

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FIG. 4



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## VACUUM INDUCTION FURNACE

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Filed June 15, 1964, Ser. No. 375,163

Claims priority, application Germany, June 20, 1963,  
J 23,902

7 Claims. (Cl. 13—27)

The invention relates to vacuum induction furnaces, and relates more particularly to coreless induction vacuum furnaces for large capacity charges, for either melting or holding under rarefied air.

Reference is had to my Patent No. 3,056,847 dated October 2, 1962.

To melt, or to hold, metal under rarefied atmospheric conditions has many advantages, among which there is the removal of gaseous substances from the surface of the metal bath.

The invention relates to melting furnaces, as well as to holding furnaces, and wherever herein below one of these types is mentioned, it will be understood that this mentioning also is meant to include the other type.

For the large scale vacuum melting of steel, the use of coreless induction furnaces, especially of line frequency induction furnaces, also known as network frequency induction furnaces, of a network frequency of, for instance, about from 50–60 cycles, is particularly attractive.

These furnaces may be installed into the steel melting process before the pouring of the steel into molds; these line frequency induction furnaces may be connected with their induction coil directly to the existing network. The large, though controllable, bath movement that is characteristic of coreless induction furnaces offers the advantage that the de-gasing of the steel melt is intensified and accelerated, as the gases are constantly moved from the interior of the metal bath to the surface, where they are removed by the prevailing vacuum.

Some of the difficulties in using large capacity electric induction vacuum furnaces prior to the advent of my aforesaid Patent No. 3,056,847 are recited in that patent. Patent No. 3,056,847 relates to a coreless electric vacuum induction furnace for large capacity charges. The furnace includes an upper part and a lower part, a crucible that extends between these parts and holds the molten metal bath, a primary induction coil, and vacuum sealing means. The vacuum sealing means include a gas-tight sleeve between the coil and the crucible and upper and lower closures which define with the sealing means a vacuum chamber. Cooling means for the sleeve are provided which are disposed adjacent the inner surface of the sleeve. The induction coil is surrounded by a series of spaced outer yokes.

The connection to the source of rarefied air is disposed near the upper closure.

Reference is had to my three co-pending applications Ser. Nos. 375,164, 375,165, and 375,166, filed concurrently herewith.

Experience has shown that in electric vacuum induction furnaces of this type, in spite of the provision of outer yokes that are mounted on the outside of the induction coil, there still occur losses caused by electro-magnetic stray fields generated by the coil, particularly in the closed metallic bottom plate of the vacuum chamber of the furnace. It is, however, desirable to keep the metallic bottom plate, on one hand because of its great strength owing to its metallic nature and, on the other hand, for its vacuum tight closing of the vacuum chamber of the furnace.

It is accordingly among the principal objects of the invention to avoid, or at least to minimize, the aforesaid stray field losses of the metallic bottom plate.

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It is a further object of the invention to shield the bottom plate against the occurrence of electric energy, generated by the stray field of the induction coil, within the aforesaid bottom plate.

It is still another object of the invention to make at least that part of the bottom plate which faces the induction coil, of non-ferritic material.

It is still a further object of the invention to provide between the bottom section of the crucible and the aforesaid bottom plate an insulating layer composed of refractory bricks, or the like.

It is yet another object of the invention to provide a bottom plate of the aforesaid type that is made of austenitic steel comprising 18 percent chromium and 8 percent nickel.

It is yet a further object of the invention to provide such a bottom plate to which there is applied on the side facing the crucible a layer that is composed of a material, such as copper, having high electric conductivity characteristics.

It is still another object of the invention to provide in the bottom part of the furnace magnetic bottom yokes which are arranged radially of the crucible and the upper portions of which terminate near the ends of the aforesaid yokes that surround the induction coil, for flux flow continuity.

It is a still further object of the invention to provide such bottom yokes which are composed of laminated transformer lacquer-coated steel sheets.

The foregoing and other objects of the invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawings, wherein:

FIG. 1 is a fragmentary vertical sectional view of a vacuum induction furnace in accordance with the invention;

FIG. 2 is a fragmentary large scale vertical sectional view of a detail framed at II in FIG. 1;

FIG. 3 is a large scale horizontal sectional view taken on the line III—III of FIG. 1; and

FIG. 4 is a fragmentary large scale vertical sectional view similar to FIG. 1 but showing a detail thereof, and taken on the line V—V of FIG. 3.

In carrying the invention into effect in one of the embodiments which has been selected for the illustration in the accompanying drawings and for description in this specification, and referring now particularly to FIGS. 1 and 2, there is provided an electric vacuum induction furnace which is supported on a framework 1. The framework 1 rests on a foundation 3 in a depression 2. A frame 4 is provided that is tiltable about hinges 6, and surrounds and is connected to and supports the furnace housing which, in turn, surrounds the crucible 7; the housing, on the other hand, is surrounded by and supports the coil and its reinforcements. Furnace tilting means are provided which include a hydraulic cylinder 5 that is supported by the foundation 3 and can be actuated to tilt the frame 4 and therewith the furnace housing including the crucible 7 and the coil 17 about the substantially horizontal axis X of the hinges 6.

The frame 4 comprises a bottom structure that is composed of interconnected elongated steel beams and a series of six upright columns 4b which are arranged evenly distributed around a circle, furthermore of channel irons 4c that interconnect the columns 4b to each other, and lastly an outer structure 4d. The frame 4 also comprises beams 4a that support the bottom of the crucible 7. The columns 4b serve to anchor the upper part, a steel mantle 16, of the housing for the crucible 7 to the lower part of that housing, as the furnace including its housing comprises an upper part and a lower part which are gastightly sealed on the exterior.

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The bottom of the crucible 7 rests on a layer of refractory bricks 8 which, in turn, are supported by a bottom plate 9 that covers the beams 4a. The plate 9 is made of non-ferritic metal and forms the lowermost closure of the vacuum chamber of the furnace. The bottom plate 9 may be composed of austenitic steel containing 18 percent chromium and 8 percent nickel.

In order to restrain losses by the occurrence of a stray field (shown in broken lines in FIG. 2, the direction of the stray currents being indicated by arrows) near the bottom of the crucible 7, and to impart instead to the stray field a desired extent and shape (shown in FIG. 4 in solid lines), there are provided near the bottom additional magnetic bottom yokes 10 composed of laminated heat insulated transformer steel sheets.

In order to shield still further the plate 9 against the stray field of the coil 17, there is provided a layer 11 that is composed of a material having high electric conductivity characteristics, such as copper. The layer 11 is disposed below the yokes 10 and below the bricks 8.

As best shown in FIG. 3, the outer wall section of the crucible 7 includes an insulating layer 12 that may be composed of mica, asbestos, or fireproof felt. A cylindrical sleeve 13 is placed without play around the insulating layer 12. The sleeve 13 is composed of a gas impermeable material of high mechanical strength, but of low electric conductivity, such as synthetic plastic or thermo-setting synthetic material or synthetic resin with or without reinforcements; this sleeve 13 forms the lateral vacuum seal for the crucible 7.

Vacuum sealing means are provided which comprise the cylindrical sleeve 13 that is composed of gas impermeable material having low electric and magnetic conductivity characteristics, such as synthetic plastic, plastic impregnated paper, or the like. The lower edge of the sleeve 13, as best shown in FIGS. 2 and 4 is inserted into an annular groove that is formed by an annular flange 14 that is welded to the plate 9 and projects upwardly therefrom. The flange 14 may be hollow to provide a conduit for a cooling fluid, and is provided with connections for the entrance and exit of the cooling fluid.

The sealing of the sleeve 13 in the aforesaid annular groove is carried out by means of a packing 14a that is cooled by the aforesaid cooling unit. The packing 14a is pressed downwardly by a pressure ring 15 that is forced down by screws 15a that connect the ring 15 with the annular flange 14 adjustably in the manner of a stuffing box. The pressure ring 15 is composed of an electrically non-conducting material, such as plastic, self-hardening resin, or non-ferritic metal; when it is made of non-ferritic metal, the pressure ring 15 is provided with at least one radial slot to prevent the passage of electric current.

The sleeve 13 extends downwardly beyond the coil 17, and extends upwardly beyond the electric range of influence of the coil 17. The upper end of the sleeve 13 is vacuum sealed in a manner similar to that of the lower end of the sleeve 13.

The packing 14a is received in a hollow groove that is formed by an annular flange 14 that has an internal conduit for a coolant. The annular flange 14 of the upper part of the sleeve 13 is, however, connected to the steel mantle 16 that forms part of the housing of the furnace, and also, like the sleeve 13, forms part of the vacuum sealing means, and surrounds the upper part of the crucible 7 and surrounds the spout 7a.

The crucible 7 and the spout 7a are formed of rammed refractory material.

At the height of the alternating field that emanates from the coil 17, there are provided cooling means to cool the sleeve 13. These cooling means are provided inside the sleeve 13 and include a series of hair-pin shaped tubes 18. As best shown in FIG. 2, each tube 18 is bent back upon itself and is preferably composed of austenitic, heat resistant steel.

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The tubes 18 are embedded into the rammed mass of the crucible 7 and are disposed inwardly of an insulating layer 12 that is interposed between the tubes 18 and the sleeve 13. The tubes 18 are surrounded by a particularly fine ramming mass 19 composed of highly refractory material.

Each tube 18 is shaped like an inverted U and has both open ends 18a and 18b directed downwardly. Each tube 18 has a circular cross section at the entrance end 18a and the lower exit end 18b, while throughout the remainder of its length throughout which including its bend it is embedded in the mass, it has a flat cross section, narrow in the radial plane of the sleeve 13. This flat squeezed shape serves the purpose to increase the cooling surface of the tubes 18 for the sleeve 13.

Cross braces 18c are provided that interconnect the long sidewalls inside the tubes 18, and extend throughout the tube length, which serve to compensate for the reduced static strength in the aforesaid radial plane; these cross braces 18c preferably also are composed of austenitic, heat resistant steel.

In order to make the walls of the tubes 18 as thin as possible, sheets 20 are provided to take up pressures that are exerted by the molten metal radially outwardly, and between the sheets 20 and that side of the tubes 18 which faces the center of the crucible, there is provided an additional insulating layer 21. Each sheet 20 is preferably also made of austenitic steel, while the layer 21 is composed of material that has low electric and heat conductivity characteristics.

As best shown in FIGS. 1, 2 and 4, the shorter entrance ends of the tubes 18a terminate in an annular channel 22 that forms a part of the bottom support structure for the crucible 7. The annular channel 22 is provided with an entrance pipe for the connection to a blower for the cooling fluid (not shown).

The annular channel 22 is supported on the beams 4a of the tiltable frame 4, and serves on one hand to support the bottom plate 9, and on the other hand serves to be connected to the columns 4b. The longer leg of each tube 18 has its exit end 18b projecting axially through the annular channel 22 into the atmosphere, for the discharge of the cooling fluid.

The sleeve 13 is surrounded, along a portion of its height, by the coil 17. A series of twelve outer C-yokes 24 are arranged evenly spaced from each other circularly about the coil 17 to the exterior thereof. Each yoke 24 is composed of lamellae of transformer sheet metal.

As best shown in FIGS. 3 and 4, the bottom yokes 10 are arranged radially in the crucible 7. Each bottom yoke 10, as best shown in FIG. 3, is assigned to an outer yoke 24, and each bottom yoke 10 includes an outer end portion that extends upwardly obliquely and terminates near the lower end of an outer yoke 24 (FIG. 4); the inner end portion of each bottom yoke 10 is disposed between the bottom section of the rammed mass of the crucible 7, and the bottom plate 9. As previously stated, the yokes 10 are composed of laminated heat insulated transformer steel sheets. This heat insulation may be accomplished by lacquer-coating the individual steel sheets.

As best shown in FIG. 1, a terminal 25 is provided for the electric current for interconnecting the coil 17 with the network; and a connection 26 is provided for interconnecting the coil 17 with a cooling liquid that courses, in a well-known manner, in the interior of the hollow coil 17. The conduits 14 for cooling the sealing devices heretofore described are also connected to the connection 26. The cooling conduits for the sealing devices hereafter described are also connected to the connection 26.

As best shown in FIGS. 2 and 4, the space between the inner surface of the coil 17 and the outer surface of the sleeve 13 is filled with a layer 27 of liquid self-hardening resin, in order to take up the radially outward-

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ly directed pressures of the ceramic material of the crucible 7, and to transfer it to the frame of the furnace.

An insulation 28 composed of mica, asbestos or fireproof felt is provided between the coil 17 and the yokes 24 that surround the coil 17.

As best shown in FIG. 2, the coil 17 is supported at its lower end by the inner leg of the yokes 24 and an insulating layer 29 thereon. To take up the electro-mechanical forces which occur in the windings of the coil 17 during the operation of the furnace, there are provided fingers 30a and a spring loaded anchor bolt 30. The fingers 30a press, by means of an insulating layer 29 against the upper portion of the coil 17. Each spring loaded anchor bolt 30 is connected to a yoke 24.

Reference is had to my Patent 2,852,587 dated September 16, 1958.

The crucible 7 is open on top and is covered, except for that part which leads into the spout 7a, by an inner cover 33. The cover 33 is vaulted and is composed of refractory bricks which are held together by a metal frame 33a. When the furnace is in operation, a stopper 34, which is also composed of refractory material, closes the open channel that leads to the spout 7a.

A bell-shaped outer lid 35 is provided that surmounts the crucible 7, the inner cover 33, as well as the spout 7a. The outer lid 35 is composed of steel sheet, and is lined on the interior with a fireproof insulation layer 35a.

The lower rim of the outer lid 35 has an inverted annular groove 36 which is filled with a deformable sealant 36a. On the exterior, the lid 35 has near the groove 36 an annular cooling conduit 37 which is provided with fittings 57a to be connected to the cooling connection 26.

The lid 35 rests with the sealant 36a on the apex of an annular wedge-shaped upright sealing ridge 38 that is formed on an annular carrying flange 39. The carrying flange 39 is hollow and has an internal conduit for a cooling fluid including a fitting 39a to be connected to the cooling connection 26. The carrying flange 39, by means of connecting struts 40, is welded to said steel mantle 16, and therefore is united therewith.

The inner cover 33 has a central aperture or opening 33b and the outer lid 35 has an opening 35b in register therewith. These openings 33b and 35b serve for the sampling of the molten metal mass or the adding of alloying material. Both openings may be closed. The opening 35b may gastightly be closed by a stopper 46 and, in connection with a superstructure 47, be sealed with a cap 48 which works according to the same principle as the lid 35 itself in connection with the sealing device that comprises the deformable sealant 36a, the ridge 38 and the cooling conduits 37 in the flange 39, as previously described. An objective 49 is provided that is sealed to the outer lid 35 and which permits viewing through the aperture 33b of the crucible 7 during operation of the furnace. The aperture 33b of the inner cover 33 may be closed by a flap 50 that is composed of refractory material and is manipulated from the exterior at 52 and is pivoted at 51.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

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Having thus described the invention, what I claim as new and desire to be secured by Letters Patent is as follows:

1. In a coreless induction furnace for large capacity charges, the combination of, an upright crucible including a bottom section, a primary induction coil adapted to be fed from an electric source surrounding said crucible, vacuum sealing means comprising a sleeve including gas impermeable material having low electric and magnetic conductivity characteristics disposed between said coil and said crucible and gastight upper and lower closure means operable for airtightly closing the upper and, respectively, the lower ends of said vacuum sealing means and defining a vacuum chamber housing said crucible, and cooling means for said sleeve disposed adjacent the inner surface of at least a portion of said sleeve, said lower closure means comprising a metallic bottom plate, and shielding means operable for restraining the occurrence of electric energy, generated by stray fields of the induction coil, within said bottom plate.

2. In a coreless induction furnace, as claimed in claim 1, said shielding means comprising at least a part of said bottom plate facing the coil being composed of non-ferritic material.

3. In a coreless induction furnace, as claimed in claim 1, said shielding means comprising a heat insulating layer between the bottom section of said crucible and said bottom plate, said insulating layer comprising refractory bricks.

4. In a coreless induction furnace, as claimed in claim 1, said bottom plate being composed of austenitic steel containing 18 percent chromium and 8 percent nickel.

5. In a coreless induction furnace, as claimed in claim 1, said shielding means comprising a layer disposed on the upper side of said bottom plate facing the crucible, said layer being composed of a metal having high electric conductivity characteristics.

6. In a coreless induction furnace, as claimed in claim 1, a series of outer upright yokes arranged evenly spaced from each other about the circular exterior of said induction coil, said shielding means comprising a series of bottom yokes, one assigned to each outer yoke, said bottom yokes being disposed in said crucible radially, each bottom yoke including an outer end portion extending upwardly obliquely and terminating near the lower end of an outer yoke, and each bottom yoke including an inner end portion disposed between said bottom plate and the bottom section of the crucible.

7. In a coreless induction furnace, as claimed in claim 6, said bottom yokes being composed of laminated heat insulated transformer steel sheets.

#### References Cited by the Examiner

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RICHARD M. WOOD, *Primary Examiner*.

L. H. BENDER, *Assistant Examiner*.