

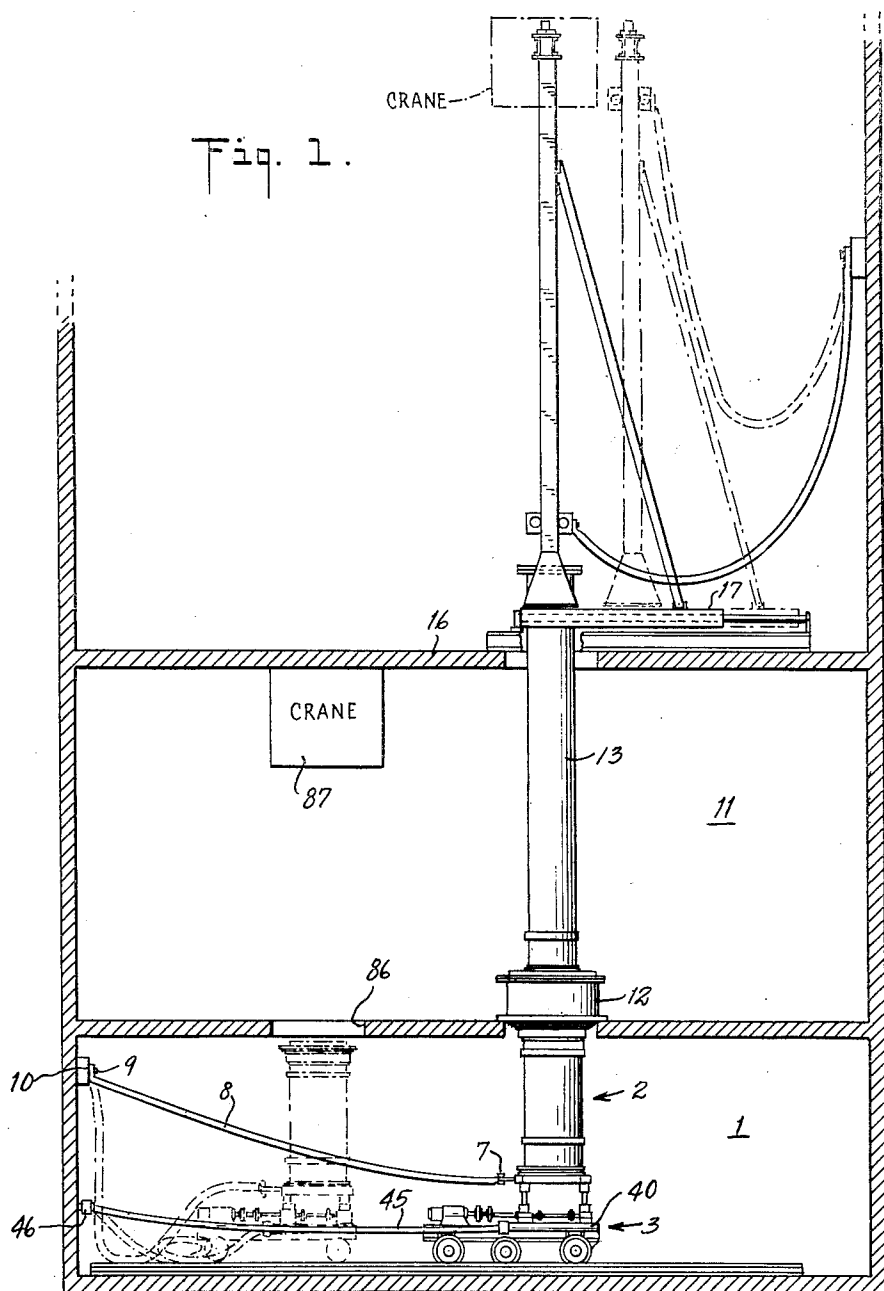
May 23, 1961

R. J. GARMY
ELECTRIC FURNACE CRUCIBLE

2,984,876

Filed July 18, 1957

4 Sheets-Sheet 1



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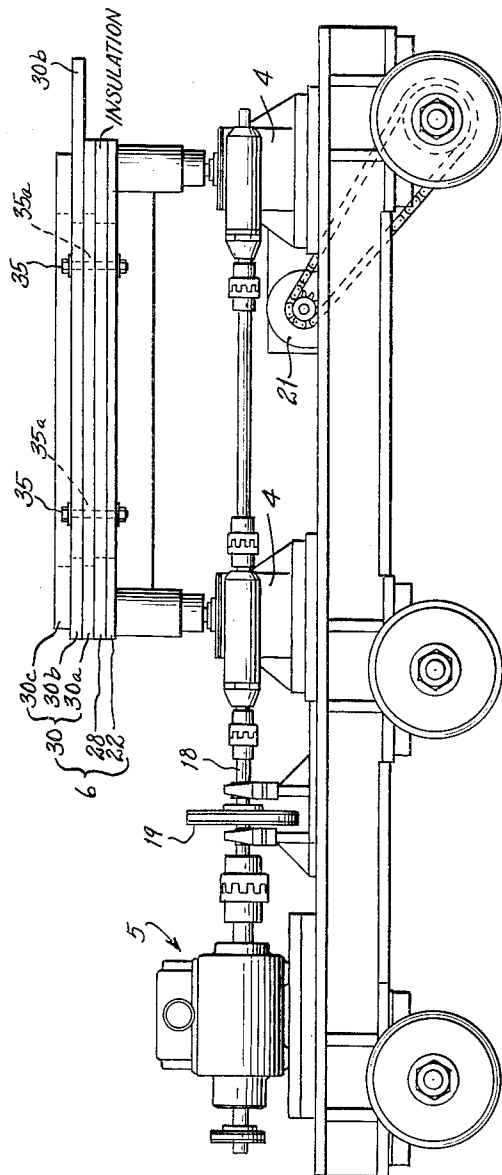
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Fig. 2.



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Fig. 3.

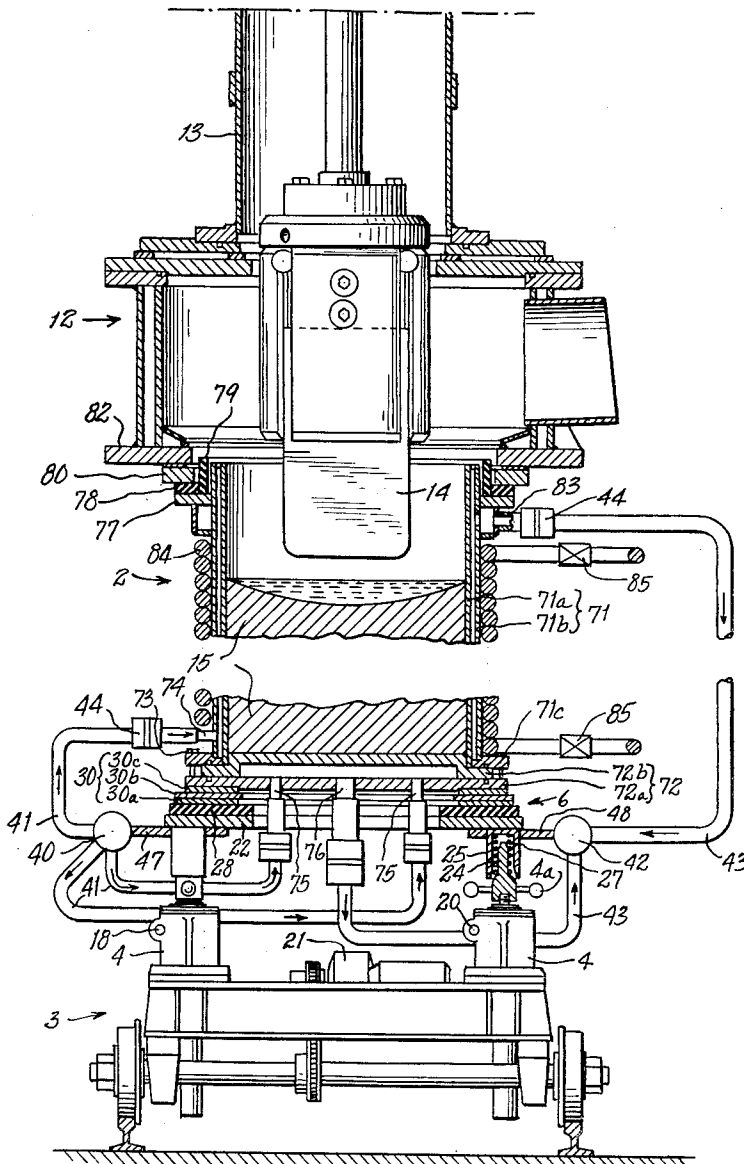
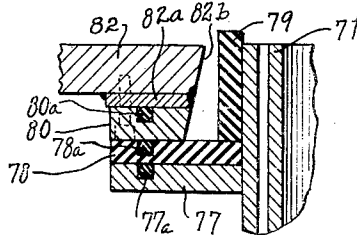


Fig. 3A.



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Fig. 4.

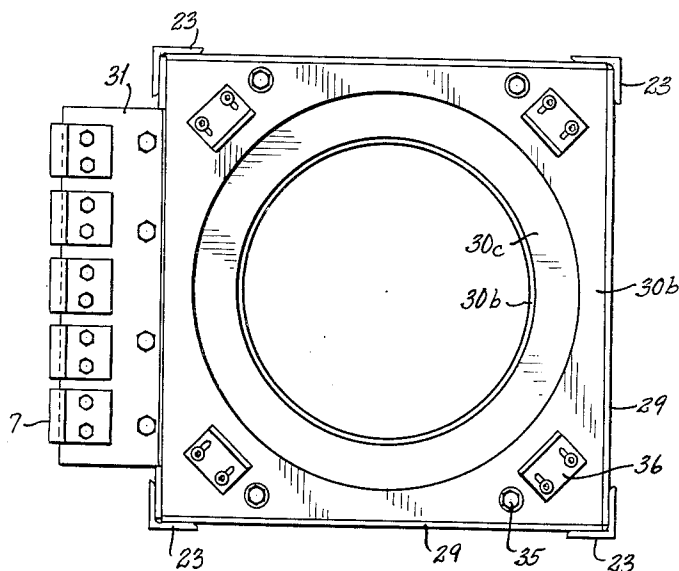


Fig. 5.

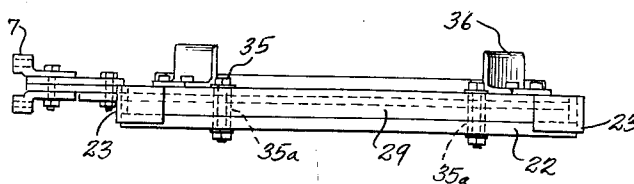
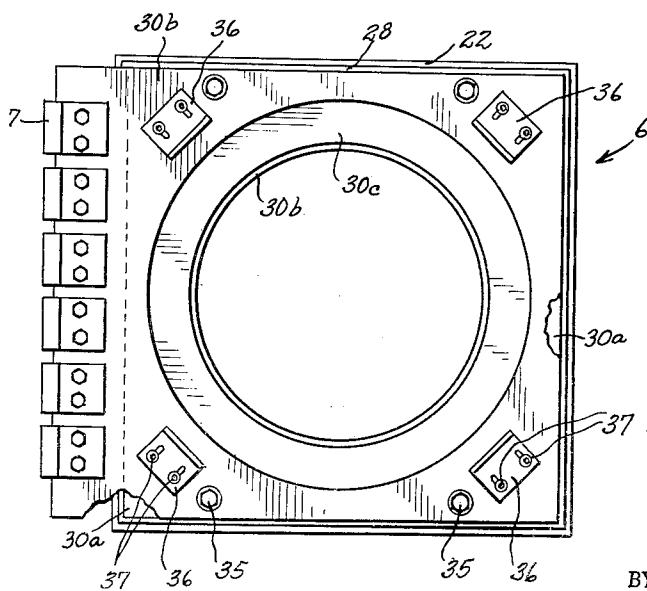


Fig. 6.

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ELECTRIC FURNACE CRUCIBLE

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Filed July 18, 1957, Ser. No. 672,603

9 Claims. (Cl. 22—57)

This application is a continuation-in-part of my copending application Serial No. 391,549, filed November 12, 1953, entitled "Method and Apparatus for Forming Ingots," now United States Patent No. 2,800,519, dated July 23, 1957, and of my copending application Serial No. 651,328, filed April 8, 1957, now U.S. Patent No. 2,950,094, issued August 23, 1960, entitled "Cooling Arrangement for Electric Furnace."

This invention relates to electric furnaces and particularly to furnaces for producing metallic ingots of high purity. The furnace described herein was designed especially for use with and has successfully been used with metals such as titanium, zirconium and the like, which are difficult to melt because of their high melting points and also because of their high chemical activity at their melting points. This furnace has also been successfully used with other metals, e.g., steel, where an ingot of high purity was desired.

It has been the practice, in electric arc furnaces of the type described, to form the ingot in an electrically conductive crucible, since the heavy arc current must be conducted through the ingot, and such a crucible provides a path for that current. Copper is preferred for the crucible, because of its high electrical conductivity and high thermal conductivity. The crucible must be cooled in order to keep it below its melting point, which is substantially lower than the melting point of titanium. In order to facilitate the cooling of the ingot, it is desirable to keep the mass of the crucible as low as possible consistent with the necessary electrical conductance and with strength and safety requirements.

There is a demand for the production of larger and larger ingots. As the size of the ingots has increased, the crucible structures of the prior art have also increased in size and mass so as to have sufficient strength to support the finished ingot.

While copper satisfies the heat conductivity and electrical conductivity requirements for a crucible, it is relatively weak, and therefore presents difficult stress problems in connection with crucibles for the larger sized ingots. The stress problems encountered are of two different types, one relating to stresses typical of the ingot-forming phase of operation of the furnace, the other relating to stresses to which the crucible is subject during unloading of the ingot therefrom.

Another problem in connection with the unloading of ingots from such furnaces is the electrical disconnection of the crucible from the electrical current supply system.

The ingot and the crucible in which it is formed must carry the current flowing through the arc. When the electrode is melted down and the ingot is to be unloaded from the furnace, a disconnection of the electrical circuit from the crucible is required as well as a physical removal of the ingot. Because of the high currents involved, this disconnection has in the past been a complex operation or a cumbersome one.

A somewhat similar problem is encountered with regard to the connection and disconnection of the system

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for supplying coolant to the crucible cooling jackets, such connection and disconnection being respectively required during attachment and removal of the crucible.

An object of the present invention is to provide an improved crucible for an electric furnace of the type described.

Another object is to provide improved mechanism for electrically connecting and disconnecting such a crucible from a heavy-duty electrical circuit.

Another object is to provide improved mechanism for attaching a crucible to and removing it from a furnace of the type described. A further object is to provide such a mechanism in which the crucible has cooling jackets, and in which the crucible may be separated from the furnace without disturbing the coolant circulating system.

Another object is to provide improved crucible structure which facilitates unloading of a finished ingot therefrom.

The foregoing and other objects of the invention are attained in the furnace described herein, which comprises a crucible mounted on a truck which is movable horizontally along a set of rails. The crucible is supported on the truck by means of a set of jacks so that it may be raised and lowered on the truck. When in its operating position, the crucible is raised on the truck so that its upper end engages the periphery of an opening at the bottom of a furnace shell.

At the end of the ingot-forming operation, the crucible is lowered on its jacks to clear the bottom end of the furnace. The truck is then moved horizontally on its track to an unloading position. The crucible includes a generally cylindrical vertical side wall unit and a base plate unit. The two units are fastened together by means of bolts. In unloading the crucible, the two units are first separated. The wall unit is then freed from the ingot inside it and is stripped from the ingot, as by a crane. The ingot may then be similarly lifted off the base plate. The base plate may then be removed by the same crane and a new crucible put in its place, the new crucible having been previously assembled.

The crucible rests on a platform on the truck, the platform being insulated from the truck and hence from the ground. Electrical cables are attached to the platform and are long enough and have slack enough to permit the necessary horizontal movement of the truck between its operating and loading positions. The only electrical connection necessary for the arc circuit is that of placing the new crucible on the platform and the only electrical disconnection necessary in that circuit is that of removing the crucible parts.

The crucible is provided with a water jacket in its side wall unit and another in its base plate unit. These jackets are supplied and drained through hose connections which, like the electrical cables, are long and slack enough to permit movement of the truck between its operating and loading positions.

Other objects and advantages of the invention will become apparent from the following description and claims, taken together with the accompanying drawings.

In the drawings:

Fig. 1 is an elevational view of a furnace embodying the invention, with certain parts omitted for reasons of clarity;

Fig. 2 is a fragmentary view, similar to Fig. 1 but on an enlarged scale, showing the crucible supporting platform and truck;

Fig. 3 is a view, partly in end elevation and partly in cross-section, showing the crucible of Fig. 1 and its supporting platform and truck, certain parts being omitted for clarity;

Fig. 3A is a fragmentary view, on an enlarged scale,

of a part of the crucible and the shell, and related sealing structures;

Fig. 4 is a plan view of a modified form of crucible supporting platform, with the crucible removed;

Fig. 5 is an elevational view of the platform of Fig. 4; and

Fig. 6 is a plan view, similar to Fig. 4, showing the platform of Figs. 2 and 3, with certain parts broken away.

General furnace structure—Fig. 1

The furnace shown in this figure has three operating levels. The lowest level comprises a crucible chamber 1 in which a crucible 2 and a crucible supporting truck 3 are located and where the crucible 2 and the ingot formed therein are unloaded.

As best seen in Fig. 2, the truck 3 carries four jacks 4 (only two of which appear in that figure) which may be driven concurrently by means of a motor 5 and suitable gearing. The jacks 4 support a platform 6 having its upper surface formed of electrically conductive material. The bottom of the crucible 2 rests on the platform 6. One edge of the platform 6 is adapted for attachment of a plurality of terminals 7 (Figs. 1 and 6) of heavy current carrying capacity. The terminals 7 are connected by a plurality of flexible cables 8 (Fig. 1) to a like plurality of stationary terminals 9 mounted on a bus bar 10. The cables 8 are long enough and have sufficient slack so that the truck 3 may move between its operating position as shown in full lines in Fig. 1, and its loading and unloading position, shown in dotted lines, without disconnecting either the terminals 7 or the terminals 9.

The second level of the furnace is the furnace chamber shown at 11 in Fig. 1. On the floor of this chamber there is mounted a furnace shell 12. An electrode receiving tube 13 is mounted on the top of the shell 12 and extends upwardly therefrom a substantial distance, e.g., 12 to 15 feet. The electrode tube 13 is provided to enclose a consumable electrode such as shown at 14 in Fig. 3, which is being fed to the furnace and melted by an arc to form an ingot 15 in the crucible 2.

The third or upper level of the furnace 1 has a floor 16 a short distance (2 or 3 feet) below the upper end of the electrode receiving tube 13. This floor supports the electrode feeding and driving mechanism. That mechanism is all supported on a carriage 17 which moves horizontally between an operating position shown in full lines in Fig. 1 and a loading position shown in dotted lines. The electrode feeding and driving mechanism illustrated forms no part of the present invention, being described and claimed in my copending application Serial No. 698,259, filed November 22, 1957, now U.S. Patent No. 2,940,588. As far as the present invention is concerned, the furnace might be fed with titanium sponge, as shown in my application Serial No. 391,549, now United States Patent No. 2,800,519, mentioned above, instead of by a consumable electrode.

Crucible structure and support—Figs. 2 to 5

The motor 5 drives, through suitable gearing, a shaft 18 aligned with and operatively connected to two of the jacks 4. The shaft 18 carries a sprocket wheel 19 connected by a chain to another sprocket wheel (not shown) on a shaft 20, which is aligned with and operatively connected to the other two of the jacks 4. All four of the jacks may thereby be simultaneously driven by the motor 5 to raise or lower the platform 6.

Each of the jacks 4 has a handwheel, one of which is shown at 4a in Fig. 3, by means of which it may be raised or lowered independently of the other three jacks. The handwheels 4a are used for leveling purposes.

The jacks 4 are mounted on a frame which is supported on six wheels, mounted in pairs on three axles. As best seen in Fig. 2, one wheel is located under each of the four corners of the platform 6, and these four wheels carry most of the load of the ingot.

In addition to the motor 5, the truck 3 carries another electric motor 21 for driving the wheels of the truck during its movement between its loading and operating positions. The motors 5 and 21 may be supplied with electricity and controlled through flexible cables (not shown).

The platform generally indicated at 6, which supports the crucible, comprises a generally rectangular steel plate 22 having a large circular aperture in its center. Upwardly extending guide pins 24 of the jacks 4 are received in downwardly opening cups 25 welded to the bottom of the plate 22. Coil springs 27 are retained in compression between each cup 25 and the associated jack pin 24, so that the four jacks yieldably support the platform and crucible.

On the upper surface of the plate 22 rests a plate 28 of insulating material, similar in shape to the plate 22, but slightly smaller in its horizontal dimension.

On the insulating plate 28 rests a composite plate 30 consisting of a lower steel lamination 30a, an intermediate copper lamination 30b, and an upper copper annulus 30c. These laminations are welded together over their entire abutting surfaces. The copper lamination 30b projects outwardly beyond the steel lamination 30a to the left as it appears in Figs. 1 and 6, although it may be arranged, if convenient, with its projecting edge in any of four orientations. See for example, Fig. 2, where it is shown projecting to the right. The composite plate 30 and the insulating plate 28 are bolted to the plate 22 by means of four bolts 35, which are surrounded by insulating sleeves 35a. On the top of the composite plate 30 and outside the annulus 30c, adjacent the four corners of the platform there are mounted four steel angles 36. The angles 36 are held in place by bolts 37 which pass through slots in the angles 36. By loosening the bolts 37, the angles 36 may be moved radially in and out with respect to the center of the platform 6.

The crucible 2 comprises a generally cylindrical wall section 71 and a base plate 72. The wall section 71 comprises an inner copper shell 71a and an outer steel shell 71b defining between them a water jacket supplied through a series of peripherally spaced inlets 74 around the bottom of the jacket. The wall section 71 is provided at its lower end with an outwardly extending flange 71c which is attached by means of a plurality of peripherally spaced bolts 73 to the peripheral edge of the base plate 72.

The base plate 72 comprises a lower plate 72a and an upper plate 72b which define between them a water jacket supplied through a number of spaced inlets 75 and having a central outlet 76.

The details of the water jacketing structures, form no part of the present invention, being described and claimed in detail in my copending application Serial No. 651,328, mentioned above.

When the crucible is in place on the platform 6, it rests on the copper ring 30c, which conducts the electric current from the crucible to the composite plate 30 and thence out through the terminals 7.

As best seen in Fig. 3, there is provided near the upper end of the crucible wall section 71 an outwardly projecting flange 77. On the flange 77 rests an insulating ring 78. An insulating cylinder 79 encircles the upper edge of the crucible wall section 71. The insulating ring 78, Fig. 3A, is adapted to engage the under side of a centering ring 80 which is bolted on the under surface of a boss plate 82a on a base ring 82 forming a part of the furnace shell 12. The base ring 82 and the centering ring 80 are beveled as shown at 82b, to guide and center a crucible moving into operating position. The upper surfaces of the flange 77, insulating ring 78, and centering ring 80 are grooved to receive O-ring seals respectively shown at 77a, 78a and 80a in Fig. 3A. The cylinder 79 extends above the wall section 71 and the base

ring 82 so as to aid in preventing short-circuits due to objects, e.g., electrode fragments, falling across the gap.

A rigid inlet manifold 40 is mounted on a bracket 47 on one side of the truck 3, and is connected through flexible hoses 41 to the inlets 74 of the crucible water jacket and the inlets 75 of the base water jacket. A rigid outlet manifold 42 is similarly mounted on a bracket 48 on the other side of the truck 3, and is connected through flexible hoses 43 to the outlets 83 of the crucible water jacket and the outlet 76 of the base water jacket. Quick-disconnect couplings 44, of any suitable conventional type, are provided between the hoses 41, 43 and the several inlets and outlets to which they are connected.

The manifolds 40 and 42 are connected through elongated hose connections, one of which is shown at 45 in Fig. 1, respectively to stationary coolant supply and drain pipes, one of which is shown at 46 in Fig. 1. The hose connections 45 are long enough and have sufficient slack to permit movement of the truck between its operating and loading positions without disconnection thereof.

The stabilizing coil 84 which is wound around the outside of the crucible wall section 71 is also provided with quick-disconnect couplings 85. This coil carries a relatively low current as compared to the current flowing through the electrode and the ingot, and the disconnection of electrical conductors for these relatively small currents is a simple matter and requires little time.

Unloading of crucible and ingot—Figs. 1 and 3

After an ingot has been finished in the crucible the current is turned off, and the water in the cooling jackets has run for a time long enough to complete the solidification of the ingot, then the interior of the furnace is opened to the atmosphere by opening a relief valve (not shown), thereby breaking the vacuum in the furnace. The jacks 4 are then operated to lower the crucible 2 with the ingot therein, bringing the upper end of the crucible downwardly away from the furnace shell 12 far enough to clear the lower end of the shell and the adjacent floor structures. The motor 21 is then operated to drive the truck 3 to the left as shown in Fig. 1 to the dotted line position underneath an opening 86 in the floor of the furnace chamber 11. This opening may be normally closed during furnace operation by means of a manhole cover or the like. During this movement, the supply and drain connections for the water jackets are maintained, so that the cooling of the ingot continues. Separation of the crucible from the shell 12 in this manner permits internal cleaning of the shell during this continued cooling of the ingot.

After the cooling has continued long enough so that the ingot may be handled, then the quick-disconnect couplings 44 for the water jackets and the couplings 85 for the electrical connections are separated. The bolts 73 are then removed so that the wall section 71 of the crucible is freed from the base section 72. The cooling of the ingot causes it to shrink away from the wall section of the crucible so that the latter section may now be readily stripped off by a crane 87, shown as being located at the top of the furnace chamber 11. After the wall section of the crucible is removed, the finished ingot is accessible and may be lifted out by the same crane and removed to the next stage of its manufacturing operation. The base section 72 of the crucible is now lifted off and the truck is then ready for the installation of a cleaned crucible assembly.

The new crucible has had its wall section assembled to its base section at another location, and has had a layer of titanium sponge deposited in the bottom of the crucible to assist in starting the arc. This layer may be an inch or so deep over the whole surface, rising in a cone to about two or three inches at the center of the crucible. After the crucible is placed on the truck, by the same crane, the truck is run back horizontally to the operating position and the new crucible is then lifted

by the jacks to bring its upper end into abutment with the lower end of the furnace shell. The quick-disconnect couplings 44 and 85 are re-established and the crucible is then ready to proceed with the next melting operation of the furnace.

It may be seen that in this unloading and loading operation, there is no separate action required to make or break the heavy duty electric contacts between the crucible and the power supply cables 8. The cables 8 being flexible, simply sag to the dotted line position shown in Fig. 1, when the truck is moved to the loading and unloading station. Simply placing the new crucible on the supporting platform establishes the electrical connection between the crucible and that platform.

Furthermore, it should be noted that no part of the crucible is stressed in tension by the ingot, either during the unloading operation or at any other time.

During the operation of jacking the new crucible up against the shell, the beveled surface 82b cooperates with the upper end of the shell to correct any minor misalignment. In this connection, it should be noted that the angles 36 are not set to engage the edge of the crucible tightly, but on the contrary, are fixed to allow a substantial range of lateral movement of the crucible. Consequently, if there is any misalignment which causes the ring 79 to engage the beveled surface 82b, the crucible may easily move or be moved laterally within the angles 36 to correct that misalignment.

Although the crucible and its supporting structure are described as being used in connection with a furnace whose interior is evacuated or filled with an inert gas, it will be recognized that this invention is in no way limited to any particular atmospheric composition or pressure condition within the furnace, and might be used in furnaces using any suitable internal atmosphere or pressure condition.

The crucible 2 is moved by the jacks 4 into and out of sealing engagement with the shell 12 quickly and without the necessity of removing bolts or other threaded members. The crucible can thus be moved away from the shell while the cooling of the ingot therein continues. As mentioned above, this cooling time may be utilized to clean the shell and prepare it for the next melt.

While the inner crucible shell 71a is described as being preferably formed of copper, other suitable materials may alternatively be used within the scope of the invention.

Figs. 4 and 5

These figures illustrate a modified form of supporting platform. In these figures, those parts which are the same as corresponding parts in Figs. 1 to 3 and 6 have been given the same reference numerals and will not be further described.

The plate 22 in Fig. 4 has fixed on its four corners angle members 23, which serve to retain insulating strips 29 extending alongside the composite plate 30.

Instead of having the plate 30b project and carry the terminals 7 directly, as in Fig. 6, a filler plate 31 is attached to the plate 30b, and the filler plate carries the terminals 7.

While I have shown and described a preferred embodiment of my invention, other modifications thereof will readily occur to those skilled in the art, and I therefore intend my invention to be limited only by the appended claims.

I claim:

1. An electric furnace, comprising a furnace shell open at its bottom end, an electrode supported within said shell and adapted to project downwardly through said open end, a crucible of electrically conductive metal for receiving a charge of electrically conductive material to be treated therein, means supporting said crucible comprising a truck, an electrically conductive platform mounted on said truck and adapted to receive the bottom of the crucible, means on the truck for raising and lower-

ing the platform to bring the crucible into engagement with the shell and to separate it therefrom, said truck being movable along a horizontal path between an operating position below said shell and a loading and unloading position spaced laterally from said shell, means for supplying electric current to said furnace including said platform, terminals on said platform, stationary terminals, and flexible cables connected between said stationary terminals and said platform terminals and having sufficient slack to accommodate, without disconnection, the truck movement between said positions.

2. An electric furnace having a crucible and comprising an electrically conductive generally vertical wall of the crucible extending about a space open at the lower end thereof, said wall having at said end thereof an annular surface disposed transversely of said wall, an electrically conductive base plate providing the bottom wall of said crucible and closing said space at said lower end thereof, said base plate having at the upper face thereof a surface transverse to said wall and providing for electrically conductive engagement with said annular end surface of said wall, means for removably attaching said wall to said base plate with said annular end surface of said wall in said electrically conductive engagement with said surface of said base plate, means disposed below said crucible for supporting said base plate and said wall and the ingot formed within said crucible, an electrically conductive member supported on said supporting means and providing an upper surface transverse to said wall, said base plate having at the lower side thereof a surface disposed for electrically conductive and bearing engagement with said upper surface of said electrically conductive member, said upper and lower engaging surfaces of said base plate providing for separation of said crucible from said base plate and separation of said base plate from said supporting means at said engaging surfaces and when engaged providing for conducting through said engaging surfaces the current carried by said vertical wall and said base plate, whereby the crucible may be removed from the ingot and the base plate and the base plate may be removed from the electrically conductive member.

3. An electric furnace as defined in claim 2 in which said electrically conductive member comprises an annulus of conductive material disposed below and extending generally along said annular surface of said wall and having an upper surface providing for said electrically conductive engagement with said lower surface of said base plate.

4. An electric furnace as defined in claim 2 which comprises electrically conductive means connected to said member for carrying current flowing through said engaging surfaces between said member and said base plate.

5. An electric furnace as defined in claim 2 which comprises an electrode disposed above said supporting means, a supporting structure for said electrode, and means cooperating with said supporting means for effecting upward and downward movement of said supporting means and said conductive member for producing upward and downward movement of said base plate and said crucible wall to and from an operating position of said crucible with respect to said electrode.

6. An electric furnace as defined in claim 2 in which said supporting means comprises a truck movable between an operating position and a loading and unloading position spaced from said operating position, a source of

electric current for supplying current to said furnace, and flexible cables connected between said source and said electrically conductive member, said cables having a length to provide slack to accommodate without disconnection for said movement of said truck to and from said operating position from and to said loading and unloading position.

7. An electric furnace as defined in claim 2 in which the weight at least of said vertical wall and said base plate serve to hold said engaging surfaces in said electrically conductive and bearing relation for support of said crucible and to maintain electrical conduction through said engaging surfaces.

8. An electric furnace as defined in claim 2 in which said means for supporting said base plate and said wall and said ingot comprises a truck movable between an operating position and a loading and unloading position spaced from said operating position, said crucible being provided with a jacket cooperating with said vertical wall and said base plate for cooling said crucible, a coolant supply, drain means, and flexible hose connections connected between said coolant supply and said jacket and between said drain means and said jacket, said hose connections having a length to provide slack to accommodate without disconnection for said movement of said truck to and from said operating position from and to said loading and unloading position.

9. An electric furnace as defined in claim 2 which comprises a generally cylindrical shell, means for supporting said shell above said crucible and with its axis substantially vertical, said shell being open at its lower end, means for supporting an electrode within said shell adjacent the axis thereof, said means for supporting said base plate and said wall and said ingot comprising a platform and a plurality of jacks disposed in horizontally spaced relation below said platform for vertical movement of the movable elements of said jacks, a corresponding plurality of springs supported on said jack elements and engaging said platform, said jacks being operable to move said platform and said base plate and said vertical wall upwardly and downwardly to move said wall into and out of engagement with said shell, said springs being effective during such engagement to equalize pressures around the periphery of the crucible and the shell.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,984,876

May 23, 1961

Robert J. Garmy

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 51, for "698,259" read -- 698,256 --;
same column 3, lines 51 and 52, strike out ",now U. S. Patent
No. 2,940,588".

Signed and sealed this 24th day of October 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents

USCOMM-DC

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