

March 21, 1961

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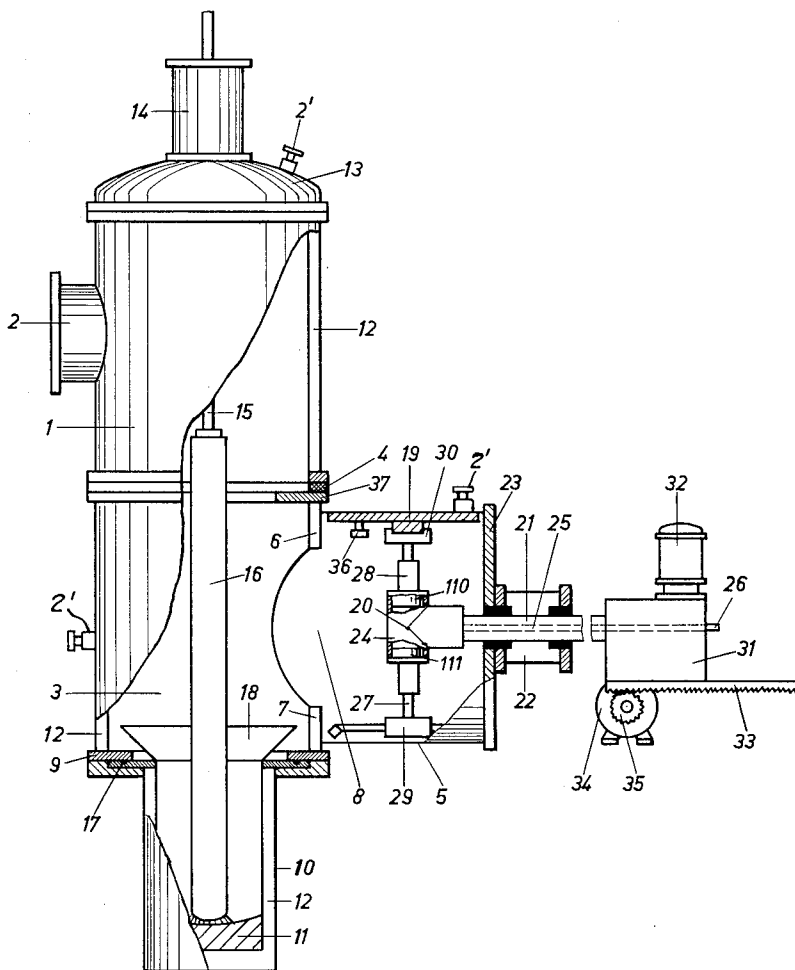
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VACUUM SMELTING FURNACE AND METHOD OF OPERATION

Filed May 2, 1957

6 Sheets-Sheet 1

FIG 1.



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FIG. 2

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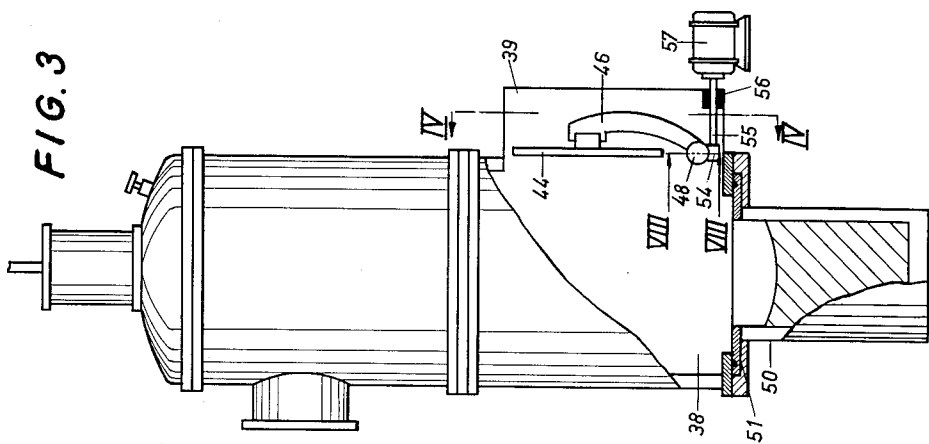
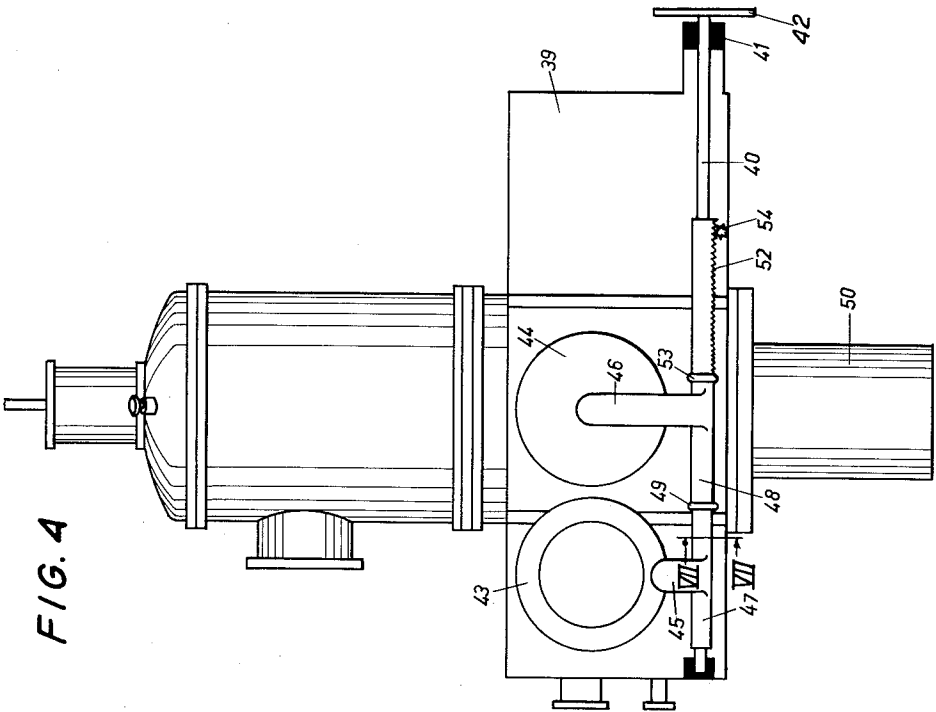
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6 Sheets-Sheet 3



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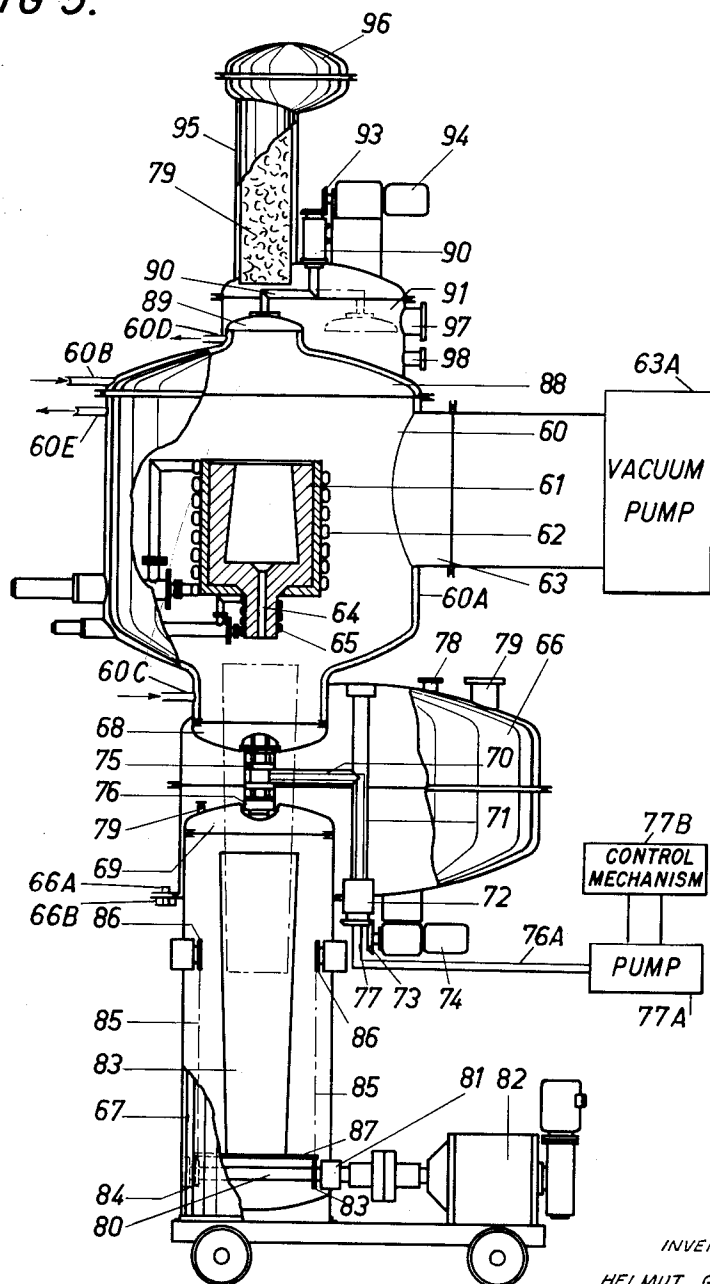
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FIG 5.



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VACUUM SMELTING FURNACE AND METHOD OF OPERATION

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FIG 6.

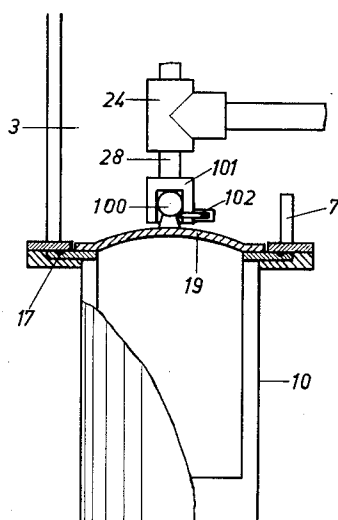


FIG 7.

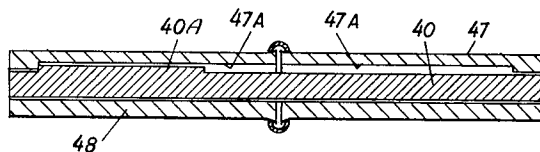
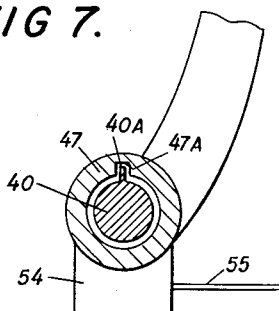


FIG 8.

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VACUUM SMELTING FURNACE AND METHOD OF OPERATION

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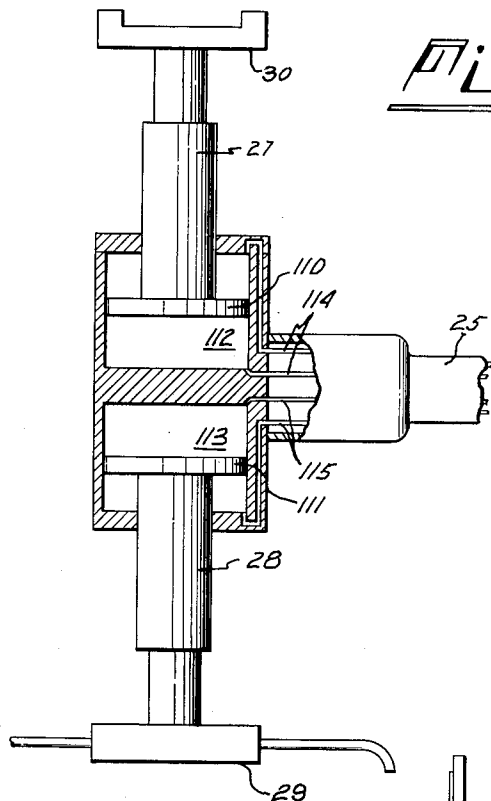


Fig. 9.

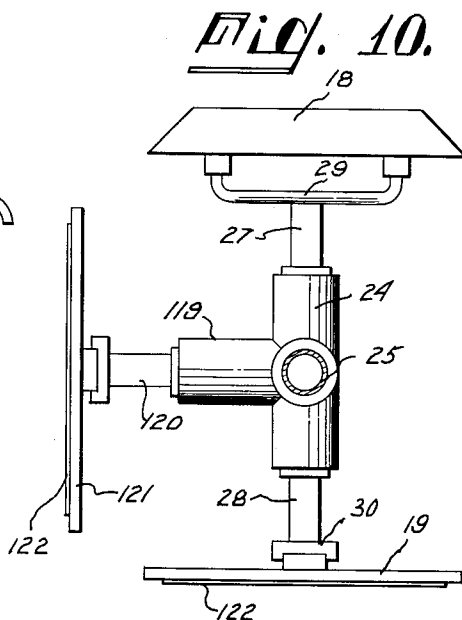
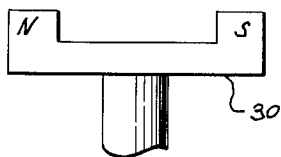


Fig. 10.

Fig. 11.



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VACUUM SMELTING FURNACE AND METHOD OF OPERATION

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Claims priority, application Germany Dec. 3, 1956

20 Claims. (Cl. 13—31)

The present invention relates to new improvements in vacuum smelting furnaces.

Such furnaces are now being used increasingly in preference to furnaces of the conventional types which do not operate under a vacuum since it has been found that metals, particularly those having a high melting point, when molten under a vacuum either oxidize less easily or that the gases are more easily released from the molten material and the properties thereof are thus considerably improved. Particularly, the methods of smelting such metals under a vacuum in an electric arc furnace by means of consumable electrodes or in a furnace, for example, an induction furnace, in which the material is first melted and subsequently cast under a vacuum have proved to be very successful and of considerable advantage.

However, particularly when smelting easily reacting metals, these types of furnaces have proved to be rather uneconomical. Such metals, when in a hot condition will easily oxidize and should therefore not come into any contact with air. Therefore, prior to this invention, when the actual smelting process was completed, and before the vacuum in the furnace could be released and the furnace opened, it was always necessary first to allow the consumable electrode and the ingot to cool sufficiently so as to prevent the oxidation thereof which would ruin either of them. Such cooling period usually required at least as much time and often a much longer time than the actual smelting process. Such cooling period was even very long if the crucibles were water-cooled, since the ingot shrinks while cooling and thereby loosens and separates from the walls of the crucible so that a direct heat transmission from the ingot to the cooling walls of the crucible will no longer occur. Consequently, in the known types of vacuum furnaces, it was not possible to use the furnace during this cooling period and the furnace had to stand idle for a long time. Obviously, such dead time rendered the furnace uneconomical and increased the cost of the ingots.

It is the principal object of the present invention to provide a vacuum smelting furnace which operates much more economically than previous vacuum furnaces and permits a considerable increase in its ingot output.

More specifically it is an object of the invention to provide such revolutionizing improvements in vacuum smelting furnaces and in the method of operating the same that the ingot output attained thereby is twice or even more of the output as previously attained.

These objects are attained according to the invention by hermetically sealing the crucible or cast ingot therein under a vacuum while it is still hot. It is thus possible to release the vacuum in the furnace proper and to admit air into the same without bringing the hot ingot into any contact with the air whereby the ingot would be ruined. The crucible or ingot mold may then be removed from the vacuum furnace and set aside to cool while another crucible or ingot mold is attached to the furnace for the next smelting or casting process.

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Although the different types of vacuum furnaces as known in the art require certain modifications of the invention, the general principles thereof are equally applicable to all. Since vacuum arc furnaces and induction furnaces are the types most prominently used at the present time, the invention will be subsequently described in its application to these types of furnaces.

In a vacuum arc furnace, the ingot is produced directly in the crucible. The smelting process itself is accompanied by considerable spurting and spattering of the molten metal.

Therefore, the sealing surface or sealing elements at the upper edge of the crucible will be considerably soiled by such spattered metal, particularly toward the end of the smelting process when the upper surface of the ingot reaches close to the upper edge of the crucible.

It is therefore a further object of the invention to provide a cover ring which is placed upon the sealing surface or sealing elements on the crucible, and further to provide means for removing such cover ring from the crucible or its sealing means when the crucible while still under a vacuum is to be sealed hermetically by means of a full cover. Such protective ring will, however, not be required if the sealing surface is spaced a considerable distance from the highest level of the ingot in the crucible, or if an intermediate gate is provided between the upper edge of the crucible and the actual sealing surface, which gate can be easily cleaned after the crucible has been removed from the furnace.

If two smelting processes are to be carried out in immediate succession of each other, the ingot of the first smelting process may serve as a consumable electrode in the second process. For this purpose, the ingot of the first process may be fused to the head of the electrode or to the remainder thereof from the first process and, after cooling sufficiently, it may be lifted out of the crucible into the upper part of the furnace. The exchange of the first crucible for that in which the final smelting is carried out, that is, usually one of a larger diameter, will be considerably accelerated by the present invention. Whereas prior to the invention it was necessary to wait until the preliminary ingot had cooled, it is now possible according to the present invention also to close the upper furnace part hermetically while the vacuum in the lower part is released by the admission of air, the first crucible exchanged for another, and the lower part of the furnace, including the new crucible, is again evacuated. The preliminary ingot which is retained in the upper evacuated furnace part while still in a hot condition and without danger of oxidizing may then be used immediately as a consumable electrode for producing the final ingot. According to another feature of the invention, the lower furnace part, to the lower end of which the exchangeable crucible is attached, is for this purpose provided with a vacuum-release valve and with means for separately evacuating such lower part. Since the crucible is to be removed from the furnace to be set aside for cooling while its inside is still under a vacuum, it should also be provided with a vacuum release valve to permit the cover to be removed.

In a vacuum induction furnace, the smelting process is carried out in a crucible which is located at the inside of the induction coil. After the molten metal is poured into an ingot mold either by tilting the crucible or preferably by melting a plug of metal within an outlet channel therefrom, the present invention provides a vacuum-tight cover either for this ingot mold itself or for a chamber containing the mold so that the latter with the hot ingot therein may be removed from the furnace in a closed condition while still under a vacuum, and be set aside to cool while a new empty ingot mold is attached to the furnace for the next evacuation and casting operation.

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Since in the vacuum induction furnace the hot crucible remains in the furnace chamber, it is advisable also to seal this chamber hermetically by a cover while the ingot molds are being exchanged. It is then possible by means of a suitable gate mechanism again to fill the crucible in the furnace chamber while still under a vacuum, and to start the next smelting process without first cooling the ceramic crucible to a temperature below the transformation point of the respective material. A cover ring for protecting the sealing elements is usually not required in a vacuum induction furnace since the molten metal will hardly ever spatter thereon.

As already indicated, such modification of the known vacuum furnaces and the method of operating the same will double or even triple the ingot output of such furnaces.

Further objects, features, and advantages of the present invention will be apparent from the following detailed description thereof, particularly when read with reference to the accompanying diagrammatical drawings, in which—

Fig. 1 shows a vertical cross section through a vacuum arc furnace according to the invention while in the process of smelting;

Fig. 2 shows the same furnace with the crucible being hermetically locked after the smelting process is completed;

Fig. 3 shows a vertical cross section of a modification of the invention with a different type of sealing mechanism;

Fig. 4 shows a cross section taken along line IV—IV of Fig. 3;

Fig. 5 shows a front view, partly in cross section, of a vacuum induction furnace according to the invention with covers for hermetically sealing both the main furnace chamber and also the ingot mold; while

Figure 6 shows a simple means for gripping and lifting the cover from a crucible and for releasing the same thereon;

Fig. 7 is a view taken on line VII—VII of Fig. 3;

Fig. 8 is a view taken on line VIII—VIII of Fig. 3;

Fig. 9 is an enlarged side elevation view, partly broken away, of the T-shaped head for holding the covers utilized in the furnace arrangement of Fig. 1;

Fig. 10 is a side elevation view of a modification of the T-shaped head of Figs. 1 and 9; and

Fig. 11 is an enlarged side elevation view of a magnetic cover supporting member that may be used in the invention.

Referring to the drawings, Figs. 1 and 2 show a vacuum arc furnace which essentially comprises an upper furnace chamber 1 which is provided with a socket 2 through which the furnace is evacuated and a vacuum release valve 2', and a central chamber 3 which is separated from the upper chamber 1 by suitable electric insulating means 4 and has a lateral extension chamber 5 at one side from which it is partly separated by partitions 6 and 7 leaving an intermediate opening 8. The bottom flange 9 of central chamber 3 has removably secured thereto a lower chamber 10 which forms the crucible in which the ingot 11 is formed. All three chambers 1, 3, and 10, are substantially surrounded by water-cooling jackets 12. The upper furnace chamber 1 has a head 13 with a guide bushing 14 thereon through which the connecting rod 15 of an electrode 16 is slidably passed. Bushing 14 seals chamber 1 toward the outside and may, if desired, also be evacuated. The means for lowering the electrode 16 within the furnace and into crucible 10, as well as the electric means for operating the furnace, are not shown in the drawings since they are essentially well known in the art.

While the smelting of electrode 16 in crucible 10 is in progress, as shown in Fig. 1, the sealing ring 17 at the upper edge of crucible 10 is preferably to be covered and protected from the spattering molten metal in cru-

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cible 10 by means of removable conical cover ring 18 which is set from the inside of chamber 3 upon this sealing ring 17. Partitions 6 and 7 serve a similar purpose, namely, to shield the inside of extension chamber 5 from any molten metal spattering from electrode 16 or out of crucible 10. After the smelting operation is completed, cover ring 18 is to be removed and replaced by a cover 19 which is likewise set from the inside of chamber 3 upon sealing ring 17.

The lateral extension chamber 5 serves as an airtight container for holding an operating mechanism 20 for alternately placing covers 18 and 19 upon crucible 10 or removing them therefrom, and for withdrawing the unused cover 18 or 19 from the central chamber 3 so as not to interfere in the operation of the furnace proper. According to the invention, all of these procedures are carried out without requiring the vacuum in the furnace to be released.

This operating mechanism 20 essentially comprises a horizontal supporting bar 21 which is slidably guided within one or more vacuum-tight bushings 22 on the end wall 23 of extension chamber 5 and extends toward the outside thereof. Similar to bushing 14, bushing 22 may also be evacuated. On its inner end, supporting bar 21 carries a substantially T-shaped head 24 which contains a pair of hydraulic pistons 110 and 111 slidable within cylinders 112 and 113 which are connected through passages 25 in bar 21 with connecting sockets 26 or the like at the other end thereof for connecting the cylinders to a hydraulic pump and control mechanism (not shown). The chambers which are above and below the pistons 110 and 111 are accessible through lines 114 and 115 as is shown in Figure 9. These hydraulic pistons are mounted on two arms 27 and 28 which carry suitable means for picking up and releasing covers 18 and 19, respectively. The means for picking up and releasing the annular cover 18 for example may consist of a permanent magnet 30 such as that shown in the Figure 11 or a spring controlled catch or lock arrangement such as shown in Figure 6 and described in more detail later. The means for picking up and releasing cover 19 may likewise consist of a suitable permanent magnet or a spring controlled catch or lock arrangement such as that described with respect to the gripping member 29 so as directly to pick up or release cover 19.

The outer end of supporting bar 21 is rotatably mounted within a housing 31 and adapted to be turned at an angle of 180° about its axis by a motor 32 and a gearing (not shown) in housing 31. Housing 31 further carries a rack 33 which is driven by a motor 34 through a pinion 35 to move the entire operating mechanism 20 from extension chamber 5 into the main chamber 3 or vice versa.

In the operation of the furnace, after an empty crucible 10 with its cover 19 thereon is attached to the lower end of furnace chamber 3 and while the entire furnace is being evacuated, the operating mechanism 20 with annular cover 18 attached to its gripping member 29 is moved from extension chamber 5 through opening 8 into chamber 3 to the position shown in Fig. 2. Thereupon, the hydraulic piston on arm 28 is actuated to move downwardly so that the gripping member 30 will engage with and be connected to cover 19, whereupon arm 28 with cover 19 thereon is retracted and lifted from crucible 10. Motor 32 is then turned on to turn the T-shaped head 24 about an angle of 180° whereby the position of the two covers 18 and 19 will be reversed so that the annular cover 18 now faces toward crucible 10. The hydraulic piston on arm 27 is then moved outwardly to set cover 18 upon sealing ring 17 on crucible 10, that is, into the position as shown in Fig. 1, so that in the subsequent smelting operation sealing ring 17 will be protected from any material spraying out of crucible 10. The gripping mechanism 29 is then released from cover 18 and arm 27 retracted, whereupon operating mechanism 20 with cover

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19 thereon is retracted through opening 8 into extension chamber 5. In order to protect the sealing surface of cover 19 from any material spraying out of crucible 10 through opening 8 into extension chamber 5, the hydraulic piston on arm 28 should then be moved outwardly to place the sealing surface of cover 19 into engagement with the wall of chamber 5, as shown in Fig. 1. For the same reason, it is also advisable at the same time, to move arm 27 outwardly so that gripping member 29 will be protected. The entire furnace including crucible 10 is then completely evacuated and electrode 16 lowered into crucible 10 to start the smelting operation.

At the end of the smelting process, the stump of electrode 16 is withdrawn in the upper chamber 1, as shown in Fig. 2, whereupon operating mechanism 30 is again moved into chamber 3 and arm 27 extended to place the magnetic gripping member 29 into engagement with annular cover 18. Member 29 is then energized to grip cover 18, whereupon the latter is lifted off sealing ring 17. Head 24 is then again swiveled with both covers thereon, and arm 28 is extended to set and press cover 19 upon sealing ring 17. The vacuum in chambers 1, 3, and 5 is then released by opening valve 2' or similar valves 2' on chambers 3 and 5.

If gripping member 30 is a permanent magnet or a mechanical spring-controlled device such as shown, for example, in Fig. 6, the gripping strength thereof is calculated so as to be weaker than the pressure difference between the still evacuated crucible 10 and the inside of furnace chambers 1, 3, and 5 which is then under atmospheric pressure. Thus, such atmospheric pressure forces cover 18 upon sealing ring 17 and closes crucible 10 hermetically. Crucible 10 may then be removed from chamber 3 and set aside to cool. When cooled sufficiently, a vacuum release valve 36 on cover 19 or on any other suitable part of crucible 10 may then be opened to permit the cover to be lifted and ingot 11 to be removed from crucible 10. If electrode 16 has been consumed, the stump thereof is removed and another electrode inserted through the open bottom of chamber 3 and attached to suspension rod 15. While the first ingot is still cooling in its evacuated crucible 10, another empty crucible with its cover 19 thereon may be attached to the bottom flange 9 of chamber 3, whereupon the operation of the furnace may be repeated in the same manner as described above.

A further improvement in the furnace as shown in Figs. 1 and 2 may be attained by utilizing the ingot produced in the first smelting process to serve as the electrode for a second smelting process. For this purpose, the ingot, after cooling sufficiently, is fused to the stump of the first electrode 16 and withdrawn under a vacuum from the crucible into the upper furnace chamber 1, so that such first crucible may then be exchanged for one of a larger size in which the final ingot is then produced. In order to protect such hot ingot electrode from oxidizing by a contact with the air during the exchange of crucibles, head 24 of operating mechanism 20 may be provided with another hydraulic cylinder 119 and piston arm 120 operating in a direction at a right angle to arms 27 and 28, that is, in a direction vertical to the plane of Figs. 1 and 2 see Figure 10. The outer end of the piston arm 120 may carry a cover 121 similar to cover 19. Thus, after cover 19 has been set upon sealing ring 17 on crucible 10 by the gripping mechanism 19, head 24 is swiveled 90° so that the other full cover faces toward flange 37. By operation of its hydraulic piston, the arm 120 carrying this cover 121 is then moved upwardly and into engagement with flange 37 so as to close the opening into chamber 1. Of course, either this cover 121 or flange 37 may carry a sealing ring such as the ring 122 to effect a hermetic sealing of chamber 1 when the vacuum in chambers 3 and 5 is then released by opening the previously-mentioned vacuum release valve on chamber 3 or 5. The atmospheric pressure in chambers 3 and 5

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then presses both covers simultaneously upon crucible 10 and flange 37, and these covers hermetically seal crucible 10 and chamber 1 which will thus remain under a vacuum. Crucible 10 may then be removed from chamber 3 and set aside to cool, while a new crucible is attached to the furnace. After this crucible and chambers 3 and 5 have then been evacuated, the second cover may be removed from flange 37 and the ingot electrode be lowered into the empty crucible to carry out the second smelting process.

Another embodiment of the invention for closing the crucible or for covering its upper edge is shown in Figs. 3 and 4. The central chamber 38 of this vacuum furnace has a lateral extension 39 which projects toward both sides, as shown in Fig. 4, and contains a shaft 40 which is rotatably mounted in chamber 38 and one end of which extends through a stuffing box or the like 41 to the outside and has a crank or handwheel 42 secured thereto. A cover ring 43 and a cover 44 are mounted by means of arms 45 and 46 on two tubular members 47 and 48, respectively, surrounding shaft 40. Members 47 and 48 are connected by a coupling 49 so as to be rotatable relative to each other but slidable together along shaft 40. Shaft 40 carries a key 40A in a position in front of the opening into chamber 38, and tubular members 47 and 48 have a continuous internal longitudinal groove 47A therein which fits slidably over the key 40A, as may best be seen in Figure 8. This key 40A also serves as a stop which is adapted to engage with one or the other end of the groove 47A in members 47 and 48 to determine the central position of cover 43 or cover 44, respectively, relative to the opening of crucible 50. Thus, if one or the other cover 43 or 44 faces centrally toward the opening into chamber 38, and handwheel 42 is then turned about an angle of approximately 90°, this rotary motion is transmitted by the key 40A on shaft 40 to such cover to pivot the same downwardly upon crucible 50 so as either to cover the sealing ring 51 or to close the opening of crucible 50. Since the two sleeves are rotatable relative to each other by means of coupling 49, such rotation of shaft 40 will not affect the other tubular member 47 or 48 or the respective cover thereon which is then positioned at one side or the other of the opening into chamber 38. For shifting covers 43 and 44 laterally to exchange their position relative to the center of the opening of crucible 50, a tubular rack 52 is slidably mounted on shaft 40 and connected by a coupling 53 to the end of tubular member 48 so as to permit the latter to rotate relative to rack 52. A pinion 54 in mesh with rack 52 is mounted on a shaft 55 which extends through a stuffing box 56 in a wall of chamber 39 to a motor 57. When motor 57 rotates shaft 55 in one direction or the other, pinion 54 will move rack 52 so that both tubular members 47 and 48 with covers 43 and 44 thereon and tilted upwardly are then moved along shaft 40 until the key on shaft 40 engages with one end or the other of the groove in members 47 and 48 and the position of the covers relative to the opening of crucible 50 will thus be reversed.

Fig. 5 illustrates an induction furnace with a sealing mechanism according to the invention. The furnace chamber 60 as such is surrounded by a water-cooled jacket 60A and contains the crucible 61 which is surrounded by an induction coil 62. The water-cooled jacket 60A is provided with inlet conduits 60B and 60C and outlet conduits 60D and 60E which may be connected to a suitable source of water (not shown). A socket 63 on chamber 60 is connected to a pump unit 63A which is adapted to evacuate the furnace. The bottom of crucible 61 has an outlet or pouring channel 64 in which during the melting process a metallic plug will form which may be melted by means of a second induction coil 65 surrounding the pouring channel 64. Underneath furnace chamber 60 the central chamber 66 and the mold chamber 67 are mounted. The outer walls of central chamber 66, which is eccentrically disposed relative to chambers 60 and 67 are hermetically connected to the body of cham-

ber 60. Central chamber 66 is also provided with means such as bolts 66A and nuts 66B for removably securing mold chamber 67 thereto. Chamber 66 contains two covers 68 and 69 for closing the bottom opening of furnace chamber 60 and the top opening of mold chamber 67, respectively. These two covers are mounted on an arm 70 which is rotatable about a shaft 71 which extends through an airtight bushing or the like 72 to the outside of chamber 67 where its outer end is connected by a gearing 73 to a motor 74. Covers 68 and 69 are thus pivotable about the axis of shaft 71 completely away from the openings of chambers 60 and 67 or back to a position directly in front of such openings. Covers 68 and 69 may then be pressed hydraulically upon the two chambers by means of pistons 75 and 76, which are supplied with a pressure fluid through one or a pair of channels indicated generally at 76A which are provided in arm 70 on shaft 71 and are connected to a pump and control mechanism 77B by one or a pair of sockets 77. The central chamber 66 is also provided with a vacuum-release valve 78 for admitting air into chamber 66 to press covers 68 and 69 hermetically upon their seats on chambers 60 and 67, and also with a socket 79 for evacuating chamber 66.

Mold chamber 67 contains an elevating mechanism of any suitable type, the drive shaft 80 of which may be passed through an airtight bushing or the like 81 from chamber 67 to a motor 82 for raising or lowering the ingot mold 83. A simple mechanism of this type may, for example, consist of a pair of sprocket wheels 84 on shaft 80 which are connected by chains 85 passing over another pair of sprocket wheels 86 in chamber 67 to a platform 87 which supports ingot mold 83.

The top 88 of the main furnace chamber 60 has an opening which is adapted to be closed by a cover 89 which is pivotable horizontally about the vertical axis of an angularly bent shaft 90 within another chamber 91 which is hermetically connected to top 88. Shaft 90 passing through an airtight bushing 92, which, if desired, may be evacuated, is connected by a gearing 93 to a motor 94. By driving the shaft of motor 94 in one direction or the other, cover 89 may be opened or closed within chamber 91 in a similar manner as covers 68 and 69 are opened or closed in chamber 66. Chamber 91 has connected to its upper end a chamber 95 forming a dispenser containing a supply of metal which, after cover 89 has been opened, may be dropped into crucible 61 to fill the same. Chamber 95 has a cover 96 which may be opened from the outside in order to fill the raw material into the same and may thereafter be closed hermetically. Chamber 91 also has a socket 97 for evacuating the same and a vacuum-release valve 98 for admitting air into the chamber.

In the operation of the furnace as shown in Fig. 5, an initial charge of raw material is first filled from the dispenser 79 through the uncovered opening in top 88 into crucible 61. Cover 89 is then closed. A mold chamber 67 with an empty ingot mold 83 therein having been attached to central chamber 66, covers 68 and 69 are opened and all three chambers 60, 66, and 67 are evacuated. Valve 98 is then opened to press cover 89 by atmospheric pressure upon its seat. The electric current is then turned on to heat induction coil 62 and melt the charge in crucible 61. The ingot mold 83 is then elevated on its platform 87 so that its upper part passes through the opposite open ends of chambers 67 and 60 into chamber 60 to the position indicated in Fig. 5 in dotted lines. The metal plug in pouring channel 64 is then melted by heating of induction coil 65 so that the molten metal can flow through channel 64 into ingot mold 83. The casting process being thus completed, mold 83 is again lowered to its former position. Covers 68 and 69 are then pivoted inwardly and pressed hydraulically upon chambers 67 and 60. Valve 78 is then opened to release the vacuum in central chamber 66 so that the atmospheric pressure in chamber 66 will

then press covers 68 and 69 firmly upon their seats, thus permitting hydraulic pistons 75 and 76 to be released. Mold chamber 67 with the filled ingot mold 83 therein may then be detached and removed from central chamber 66 and set aside for cooling and subsequent removal of the ingot mold 83 for an empty mold after vacuum release valve 79 has been opened to permit the removal of cover 69. Mold chamber 67 is then again attached to central chamber 66. Since the upper furnace chamber 60 remained under a vacuum, a new smelting process may be carried out during the removal and replacement of mold chamber 67. Provided there is still a sufficient supply of raw material in dispenser 79, top chamber 91 is then evacuated and thereafter cover 89 opened. The dispensing mechanism is then actuated to drop a new charge of raw material into crucible 61. Cover 89 is then again closed. Since the main furnace chamber 60 is still under a vacuum, only the central and mold chambers 66 and 67 need now be evacuated while the charge in crucible 61 is melted. For this purpose only the lower hydraulic piston 76 is then actuated to connect with cover 69, whereupon shaft 71 is turned about its axis to pivot cover 69 away from the opening of mold chamber 67. Then, after chambers 66 and 67 have been evacuated, shaft 71 with cover 69 on arm 70 is pivoted back to the closing position so that the other hydraulic piston 75 can now also be operated to connect with cover 68, whereupon both covers 68 and 69 are opened so that the empty ingot mold 83 may be elevated into chamber 60 for the next casting process.

Since in the operation of all of the furnaces according to the invention, the mold or mold chamber with the molten ingot therein is removed from the furnace with its cover thereon, it is necessary to remove such cover from its retaining means. As already indicated, these means, for example, the gripping member 30 as shown in Figs. 1 and 2, may consist of a permanent magnet or an electromagnet which directly retains or releases the cover, or of a mechanical clamping or tripping mechanism which is operated by such electromagnet. However, since the vacuum in the central furnace chamber has to be released before the covered mold or crucible can be removed therefrom, and since the cover is thereby pressed under a high atmospheric pressure upon the mold or crucible, such gripping member may consist merely of a spring-controlled catch or lock, as illustrated in Fig. 6 in which cover 19 is provided with a ball 100 which is held within a socket 101 on arm 28 by means of a snap lock 102. If cover 19 is forced upon crucible 10 by a high atmospheric pressure, it will overcome the retaining spring pressure of snap lock 102 and slip out of socket 101.

Although the invention has been illustrated and described with reference to the preferred embodiments thereof, it is to be understood that it is in no way limited to the details of such embodiments but is capable of numerous modifications within the scope of the appended claims. Thus, for example, the new method and apparatus prescribed by the invention for removing the hot ingot from the furnace while still under a vacuum is not limited to vacuum arc furnaces or vacuum induction furnaces but may likewise be applied to vacuum resistance or annealing or sintering furnaces in order to speed up the output of such furnaces and render them much more economical than was possible prior to the invention. Also, it is to be understood that the various elements of the different embodiments of the invention may be exchanged for one another.

The invention having thus been fully disclosed, what is being claimed as new is:

1. A vacuum smelting furnace comprising at least one chamber having a bottom opening, an open container constructed and arranged to be connected to said bottom opening, means for evacuating said chamber and container, means for releasing said vacuum in said chamber,

means for hermetically closing said container within said furnace, and means at the outside of said furnace for operating said closing means within the evacuated furnace so as to permit said container to be removed from said chamber at the end of a smelting operation in a closed condition with its inside still being under a vacuum.

2. A vacuum smelting furnace comprising at least one chamber having a bottom opening, a container having a top opening, a cover for closing said top opening, means for connecting said container with its cover thereon to said bottom opening of said chamber, operating means within said chamber for removing said cover from said container after it has been connected to said chamber, means for evacuating said chamber and said attached open container, said operating means also being constructed and arranged to replace said cover upon said container at the end of the smelting process and while said chamber and container are still under a vacuum, means at the outside of said furnace for manipulating said operating means within said furnace, and means for releasing said vacuum in said chamber so as to permit said covered container to be removed from said chamber with its inside still being under a vacuum.

3. A vacuum smelting furnace comprising at least one chamber having a bottom opening, a lateral extension chamber connected to said first chamber, said two chambers having an intermediate side opening into each other, a container having a top opening, a cover for closing said top opening, means for connecting said container with its cover thereon to said bottom opening of said first chamber, an electrode within said first chamber, operating means within at least one of said chambers for removing said cover from said container after it has been connected to said first chamber and for withdrawing said cover from said first chamber into said extension chamber, means for evacuating said chambers and said attached open container, means for lowering said electrode into said container to carry out a smelting process therein and for retracting said electrode at the end of said smelting process from said container, said operating means also being constructed and arranged to return said cover from said extension chamber into said first chamber and upon said container at the end of said smelting process and after said electrode has been retracted, means at the outside of said furnace for manipulating said operating means within said furnace, means for then releasing said vacuum in said chambers so as to permit said covered container to be removed from said first chamber with the inside of said container still being under a vacuum, and means on said container for releasing the vacuum therein after its removal from said chamber.

4. A vacuum smelting furnace comprising an upper chamber, a lower chamber connected to said upper chamber, said upper chamber having a bottom opening constructed and arranged to communicate with said lower chamber, a lateral extension chamber connected to said lower chamber, said lower chamber and said extension chamber having an intermediate side opening into each other, said lower chamber also having a bottom opening, a container having a top opening, a pair of covers for closing said bottom opening of said upper chamber and said top opening of said container, means for connecting said container with its cover thereon to said bottom opening of said lower chamber, operating means within at least said extension chamber for removing said covers from said upper chamber and said container and for then withdrawing said covers from said lower chamber into said extension chamber, means for evacuating said upper chamber, means for evacuating said lower and extension chambers and said container after said cover on said container has been removed, said operating means also being constructed and arranged to return said covers from said extension cham-

ber into said lower chamber and upon said upper chamber and said container, means on said lower chamber for releasing the vacuum therein when said covers on said upper chamber and said container are closed, means at the outside of said furnace for manipulating said operating means within said furnace, and means for releasing the vacuum in said container at the end of the smelting process and after the container has been removed from said furnace for removing the cover from said container.

5. A vacuum smelting furnace comprising an upper chamber, a lower chamber connected to said upper chamber, said upper chamber having a bottom opening constructed and arranged to communicate with said lower chamber, a lateral extension chamber connected to said lower chamber, said lower chamber and said extension chamber having an intermediate side opening into each other, said lower chamber also having a bottom opening, a container having a top opening, a pair of covers for closing said bottom opening of said upper chamber and said top opening of said container, means for connecting said container with its cover thereon to said bottom opening of said lower chamber, operating means within at least said extension chamber for removing said covers from said upper chamber and said container and for then withdrawing said covers from said lower chamber into said extension chamber, means for evacuating all of said chambers and said container after said covers have been removed from said upper chamber and said container, an electrode at least within said upper chamber, means for lowering said electrode into said container to carry out a smelting process therein and for retracting said electrode at the end of said smelting process from said container into said upper chamber, said operating means also being constructed and arranged to return said covers from said extension chamber into said lower chamber and upon said upper chamber and said container at the end of said smelting process and after said electrode has been retracted into said upper chamber, means at the outside of said furnace for manipulating said operating means within said furnace, means on said lower chamber for releasing the vacuum therein at the end of said smelting process after said electrode has been retracted into said upper chamber and said covers have been closed so as to retain the vacuum within said upper chamber to protect said electrode and to permit said container with its cover thereon to be removed from said lower chamber with the inside of said container still being under a vacuum, and means on said container for releasing the vacuum therein after its removal from said lower chamber.

6. A vacuum smelting furnace comprising at least one chamber having a bottom opening, a lateral extension chamber connected to said first chamber, said two chambers having an intermediate side opening into each other, a container having a top opening, a cover for closing said top opening, a sealing ring interposed between the rim of said container and said cover, means for connecting said container with its cover thereon to said bottom opening of said first chamber, an electrode within said first chamber, operating means within at least said extension chamber for removing said cover from said container after it has been connected to said first chamber and for withdrawing said cover from said first chamber into said extension chamber, an annular cover, operating means within at least said extension chamber for setting said annular cover upon said container after said cover has been removed therefrom so as to protect said sealing ring from being soiled during the smelting process and for lifting said annular cover from said container after the completion of the smelting process, means for lowering said electrode into said container to carry out the smelting process therein and to retract said electrode at the end of said smelting process from said container into said chamber, said operating means also being con-

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structed and arranged to return said cover from said extension chamber into said first chamber and upon said container at the end of said smelting process and after said electrode has been retracted and said annular cover has been lifted from said container, means at the outside of said furnace for manipulating said operating means within said furnace, means for then releasing said vacuum in said chambers so as to permit said covered container to be removed from said first chamber with the inside of said container still being under a vacuum, and means on said container for releasing the vacuum therein after its removal from said chamber.

7. A vacuum smelting furnace comprising a chamber, a crucible within said chamber, an electric induction coil within said chamber and surrounding said crucible, a second chamber underneath said first chamber and disposed eccentrically thereto and connected thereto, said first chamber having a bottom opening into said second chamber, said second chamber having a lower opening, a container having a top opening, a pair of covers for closing said top and bottom openings of said container and said first chamber, respectively, means for connecting said container with its cover thereon to said lower opening of said second chamber, operating means pivotable about a vertical axis within said second chamber for removing said covers from said first chamber and said container after said container has been connected to said second chamber and for pivoting said covers within said second chamber away from said top and bottom openings, means for evacuating said chambers and said attached open container, said operating means also being constructed and arranged to return said covers upon said top and bottom openings at the end of a smelting process so as to maintain the vacuum in said first chamber and said container, means at the outside of said furnace for manipulating said operating means within said second chamber, means for releasing the vacuum in said second chamber at the end of the smelting process after said covers are closed so as to permit said container with its cover thereon and its inside still under a vacuum to be removed from said second chamber while said first chamber remains closed and under a vacuum, and means on said container for releasing the vacuum therein after its removal from said second chamber.

8. A vacuum smelting furnace as defined in claim 7, further comprising a pouring channel at the lower end of said crucible, and a second induction coil within said first chamber and surrounding said pouring channel for melting a metal plug formed within said channel.

9. A vacuum smelting furnace as defined in claim 7, further comprising another chamber at the upper end of said first chamber and means within said last chamber for supplying a charge of metal into said crucible without releasing the vacuum therein.

10. A vacuum smelting furnace as defined in claim 2, including an annular cover and wherein said manipulating means comprise a bushing on one wall of said chamber, a shaft extending hermetically through said bushing from the inside of said chamber to the outside thereof, said operating means mounted on the inner end of said shaft, and means connected to the outer end of said shaft for sliding said shaft with said operating means thereon toward the opposite wall of said chamber and back toward said first wall and means also connected to the outer end of said shaft for turning said shaft about its axis for swiveling said operating means so that one of said operating means first removes said full cover from said container and the other operating means then sets said annular cover upon said container.

11. A vacuum smelting furnace as defined in claim 2, wherein said operating means for said full cover comprise an arm, said manipulating means connected to one end of said arm for moving the same toward and away from said bottom opening of said chamber, a ball and socket mounted on the other end of said arm and on said full

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cover, respectively, and constructed and arranged to engage with each other, and a spring lock on said socket for securing said ball within said socket and for automatically releasing said ball from said socket and for thus separating said full cover from said arm when the vacuum in said chamber is released.

12. A vacuum smelting furnace as defined in claim 2, wherein said operating means comprise a tubular arm, at least one cylinder mounted on one end of said arm, a piston slidable within said cylinder and having a shaft extending from said cylinder, and gripping means on the outer end of said shaft constructed and arranged to grip and release said cover, said manipulating means connected to the other end of said arm for moving said arm with said cylinder and gripping means toward and away from said bottom opening of said chamber, said manipulating means including means for passing a pressure fluid from the outside of said furnace through said tubular arm to said cylinder for operating said piston to move said gripping means into engagement with said cover to lift said cover from said container and subsequently to replace said cover on said container.

13. A vacuum smelting furnace as defined in claim 6, wherein said operating means comprise a shaft extending through the end wall of said extension chamber and being slidably and rotatably mounted in said end wall for movement centrally through said extension chamber and at a right angle to the vertical axis of said first chamber and said container when connected to said first chamber, a head member mounted on the inner end of said shaft having a pair of hydraulic pistons therein, said shaft having passages therein, hydraulic pump and control means at the outside of said furnace and connected to said passages at the outer end of said shaft, gripping means secured to each of said pistons constructed and arranged to engage and grip each of said covers and to disengage therefrom, said pistons being constructed and arranged to lift said covers from said container and to set them upon said container, means at the outer end of said shaft for turning the same together with said head member about an angle of 180°, and means at the outer end of said shaft for sliding said shaft with said head member from one of said chambers into the other.

14. A vacuum smelting furnace as defined in claim 4, further comprising a sealing ring on the upper open end of said container, and an angular cover adapted to be placed within said lower chamber upon said container to protect said sealing ring, said operating means comprising a shaft extending through the end wall of said extension chamber and being slidably and rotatably mounted in said end wall for movement centrally through said extension chamber and at a right angle to the vertical axis of said first chamber and said container when connected to said first chamber, a head member mounted on the inner end of said shaft having three hydraulic pistons therein, said shaft having passages therein, hydraulic pump and control means at the outside of said furnace and connected to said passages at the outer end of said shaft, gripping means secured to each of said pistons constructed and arranged to engage and grip each of said three covers, respectively, and to disengage therefrom, said pistons being constructed and arranged to set said covers upon said container and the bottom opening of said upper chamber and to lift them therefrom, said operating means also being constructed and arranged to exchange one of said full covers and said annular cover on said container, means at the outer end of said shaft for turning the same together with said head member intermittently at least about an angle of 90° so as to bring said covers in register with the openings of said container and said upper chamber, respectively, and means at the outer end of said shaft for sliding said shaft with said head member from said lower chamber into said extension chamber and vice versa.

15. A vacuum smelting furnace as defined in claim 6,

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wherein said extension chamber extends transversely to said first chamber, said operating means comprising a horizontal shaft extending through said extension chamber and rotatably mounted at the outer ends of said chamber, said shaft having one outer end extending hermetically through an end wall of said extension chamber, a pair of tubular members slidably mounted on said shaft, each of said tubular members having an arm, said annular cover mounted at the outer end of one of said arms, gripping means mounted at the outer end of the other arm for gripping said full cover, coupling means connecting said tubular members so as to permit said members to rotate relative to each other but to slide together along said shaft, a rack secured to one end of one of said tubular members, a pinion meshing with said rack, means at the outside of said extension chamber for rotating said pinion for sliding said tubular members along said shaft, and means on said outer end of said shaft for turning said shaft about its axis whereby the respective arm which is moved by said rack to a position centrally in front of said first chamber is pivoted into said first chamber to place said annular cover upon said container and to lift it therefrom or to place said gripping means into engagement with said full cover on said container to lift said cover and to return said cover upon said container.

16. A vacuum smelting furnace as defined in claim 15, wherein said horizontal shaft has a projection thereon at a point in front of the opening between said first chamber and said extension chamber, both of said tubular members having a longitudinal groove therein engaging over said projection on said shaft and slidable thereon longitudinally, an end stop in said groove in each tubular member constructed and arranged to engage with said projection to limit the sliding movement of said members in opposite directions so that when both of said tubular members are moved in one direction along said shaft until one of said end stops engages with said projection, one of said covers is located centrally in front of

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said first chamber, while when they are moved in the other direction until the other end stop engages with said projection, the other cover is located centrally in front of said first chamber.

17. A vacuum smelting furnace as defined in claim 1, wherein said cover when removed from said container is held in a position in which its sealing surface is protected from being soiled by material spraying out of said container.

18. A vacuum smelting furnace as defined in claim 7, wherein said container encloses an ingot mold and elevating means for raising said ingot mold within said container and its upper end through the uncovered openings of said container and through said second chamber and the uncovered opening of said first chamber to a point within said first chamber underneath said crucible for receiving a charge of molten metal from said crucible and for subsequently lowering said ingot mold into said container, and means at the outside of said container for operating said elevating means within said container without releasing the vacuum therein.

19. The method of operating a vacuum smelting furnace which comprises positioning a consumable electrode into engagement with an ingot in a crucible, welding the electrode to the ingot, and retracting the electrode and the ingot from the crucible to form a composite electrode including the ingot.

20. The method of claim 19 in which the ingot is formed in a first crucible, and including the further step of replacing the first crucible with a larger crucible for melting the electrode including the ingot.

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