Sept. 25, 1956 S. A. HERRES 2,763,903

APPARATUS FOR MELTING AND CASTING REFRACTORY MATERIAL

Filed July 9, 1953

4 Sheets-Sheet 1

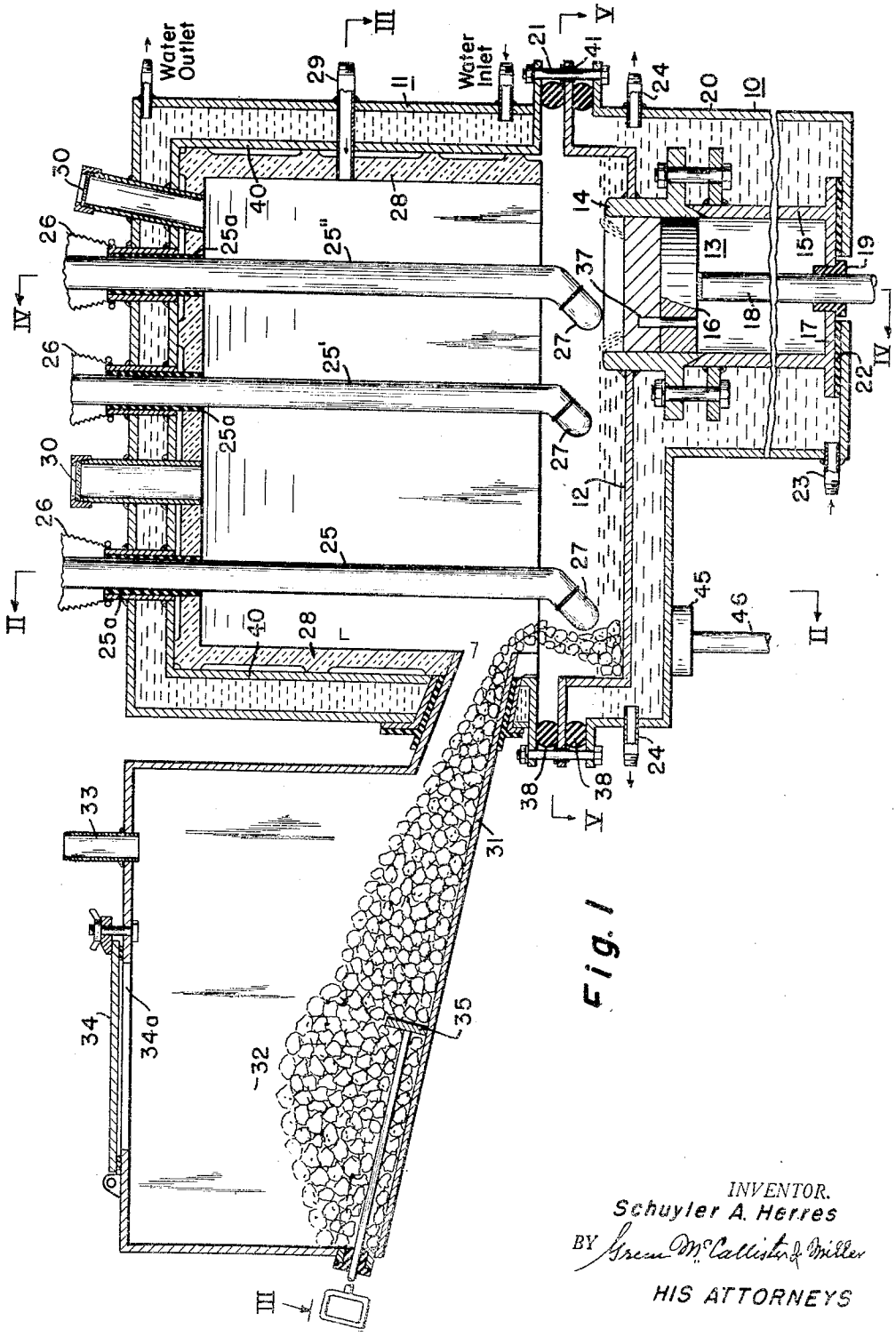


Fig. 1

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4 Sheets-Sheet 2

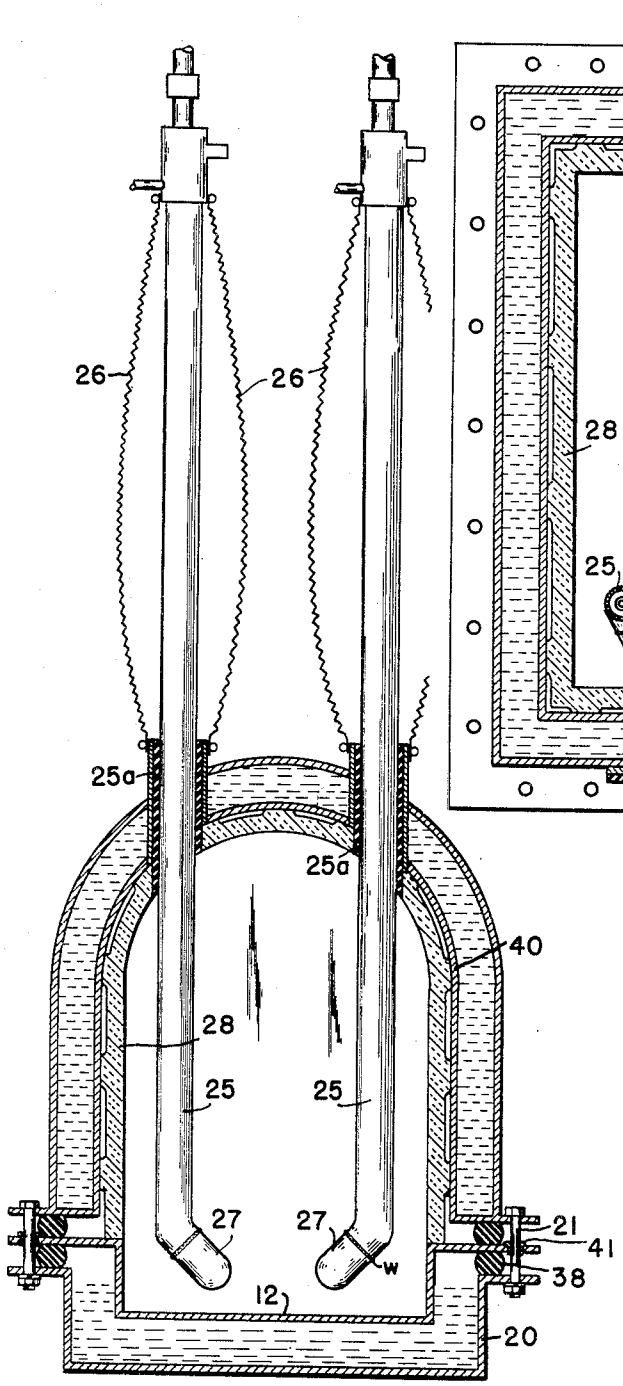


Fig. 2

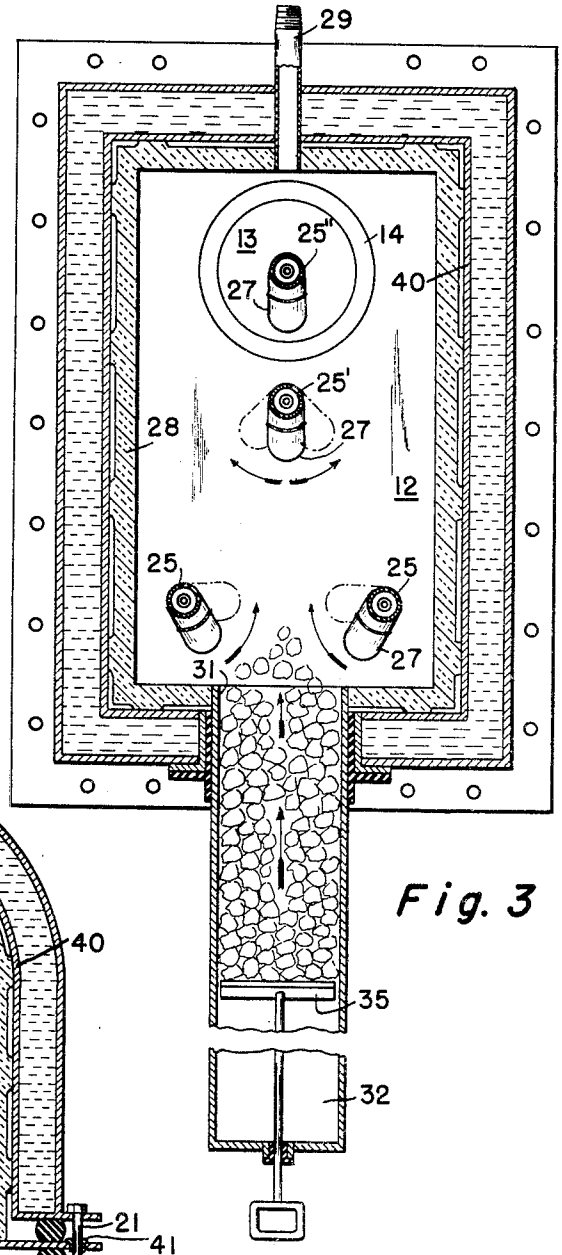


Fig. 3

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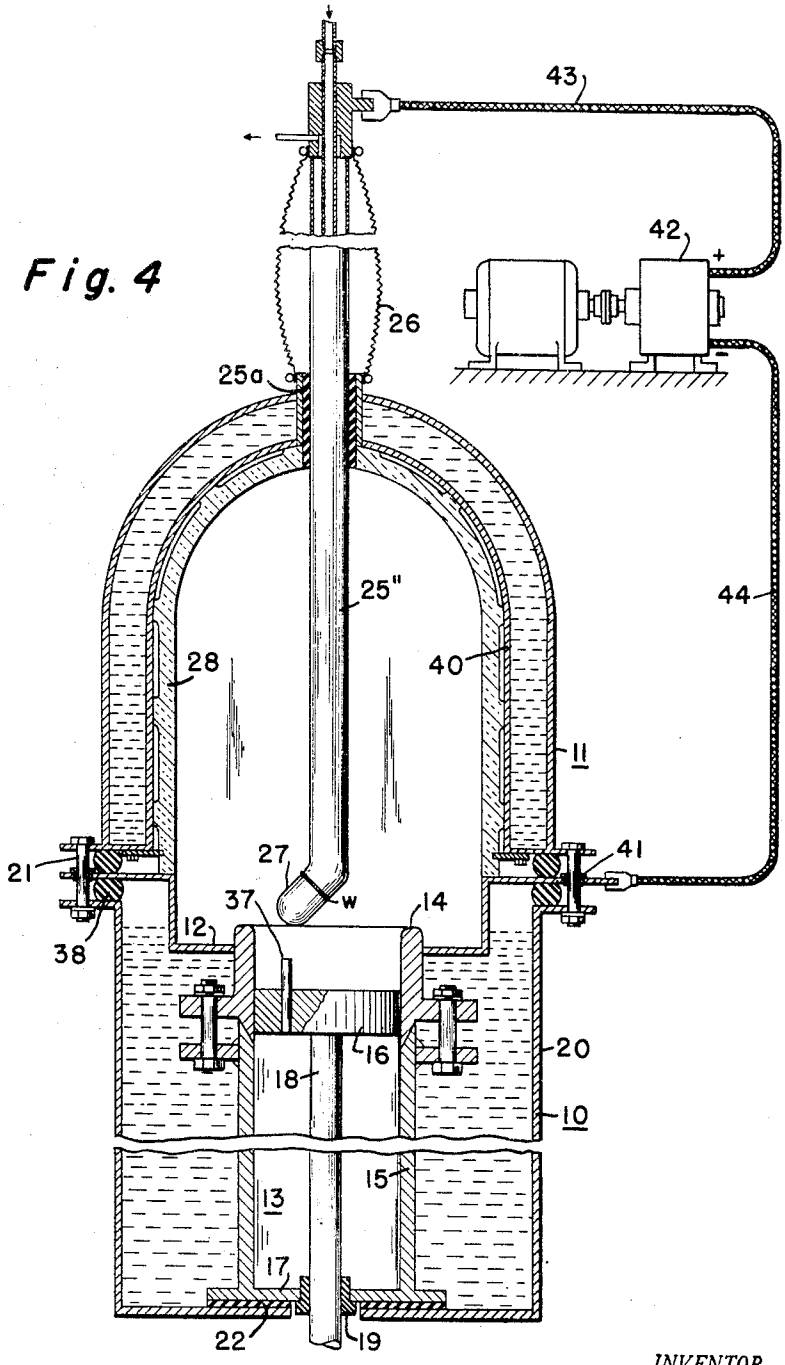
Sept. 25, 1956 S. A. HERRES 2,763,903

APPARATUS FOR MELTING AND CASTING REFRACTORY MATERIAL

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4 Sheets-Sheet 3

Fig. 4



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APPARATUS FOR MELTING AND CASTING REFRACTORY MATERIAL

Filed July 9, 1953 4 Sheets-Sheet 4

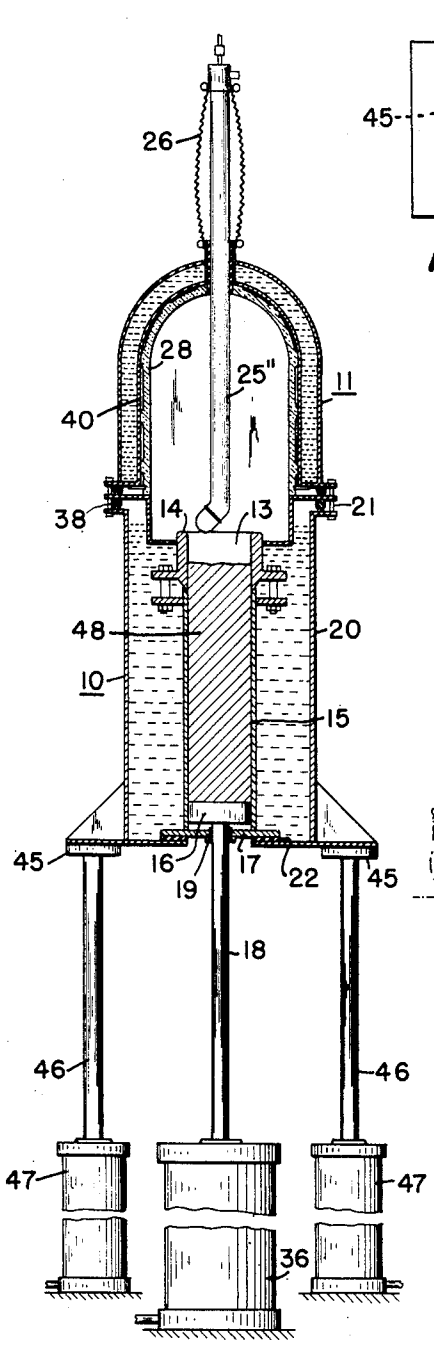


Fig. 6

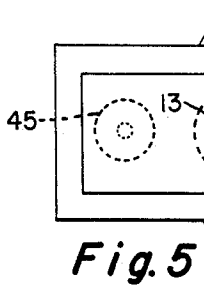
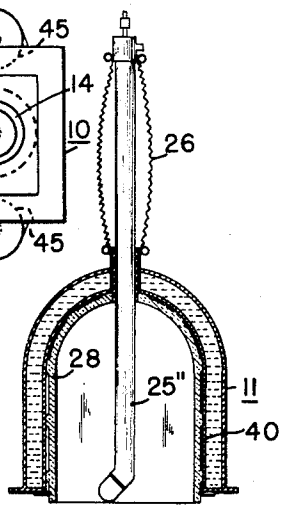


Fig. 5



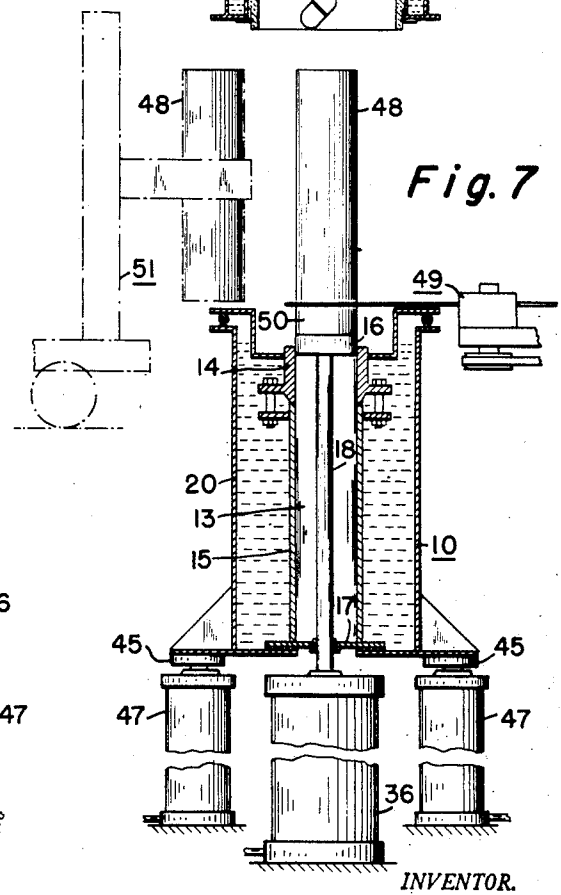


Fig. 7

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United States Patent Office 2,763,903 Patented Sept. 25, 1956

2,763,903

APPARATUS FOR MELTING AND CASTING REFRACTORY MATERIAL

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Application July 9, 1953, Serial No. 366,965

11 Claims. (Cl. 22—57)

This invention relates generally to melting means for refractory material such as titanium, zirconium, chromium, molybdenum, tungsten, the carbides, oxides and other compounds of such metals, and more particularly to electric furnaces for melting and processing such materials.

An object of the invention is to produce an improved melting furnace which includes an arrangement of electrodes such as contribute to the rapid melting of refractory material such, for example, as titanium, and which also is effective in refining such metal after the same is melted.

A further object is to produce highly effective means for producing an ingot of substantially pure titanium or similar metals, under conditions such that the ingot when produced is substantially free of non-metallic inclusions, voids, seams, fissures and other defects encountered in ingots.

A further and more specific object is to produce ingot-forming apparatus which is capable of being readily manipulated for the purpose of freeing the ingot after it is formed.

These and other objects which will be made more apparent throughout the further description of the invention are attained by means of apparatus illustrated in the accompanying drawings.

In the drawings,

Figure 1 is a longitudinal, sectional view of apparatus embodying my invention.

Figure 2 is a transverse sectional view as if taken along the line II—II of Figure 1 but illustrating a preferred arrangement of what may be termed the forward electrode arrangement, and to that extent differing from the electrode arrangement illustrated in Figure 1.

Figure 3 is a sectional view as if taken on the broken line III—III of Figure 1, the preferred arrangement of forward electrodes is, however, illustrated. Figure 4 is a sectional view taken along the line IV—IV of Figure 1 and shown in connection with a diagrammatic view of a motor generator set for delivering electric current to at least one of the electrodes of the furnace illustrated.

Figure 5 is a view on a reduced scale taken along the line V—V of Figure 1 for the purpose of illustrating a suggested arrangement of movable supports for the hearth structure forming a part of the illustrated apparatus.

Figure 6 is a transverse sectional view on a somewhat reduced scale, taken along the line IV—IV of Figure 1, and diagrammatically illustrating hydraulically or pneumatically actuated means for separately supporting both the hearth structure and the movable bottom of the ingot-forming well which constitutes a structural feature of my invention.

Figure 7 is a view corresponding to Figure 6 but showing the hearth structure of the illustrated apparatus lowered away from the roof structure of such apparatus so that a completed or partially completed ingot is accessible for removal from the furnace structure. The view of Figure 7 is shown in connection with a diagrammatic illustration of means for severing the major portion of the ingot from the movable bottom of the ingot-forming well and of means for engaging and removing the severed portion of the ingot.

The apparatus illustrated is capable of being employed in the operation of melting and refining various refractory materials such as have been previously designated and, while the invention is described as if employed for the melting and refining of titanium metal, it will be understood that such a limitation is for convenience of description only, and that there is no intention to limit the use of the apparatus or such procedural steps as are defined, to the processing of any particular metal or material. It is also noted that many of the structural features of the apparatus illustrated are disclosed and described in applications heretofore filed by me which are still pending in the Patent Office. For that reason some such strtuctural features are not here explicitly described or even fully illustrated. The apparatus illustrated as an embodiment of my present invention, while employing some such structural features, is not to be construed as limited to the use of the same except in so far as they, or equivalents thereof, contribute to the effectiveness of the apparatus or the procedure employed.

The invention broadly consists in producing a highly effective electric furnace for melting and processing refractory material such as previously referred to, and particularly for the melting and processing of metallic titanium. One of the features of the invention is the preferred arrangement of electrodes illustrated in Figures 2, 3 and 4 of the drawings, whereby metallic values, on being received in the furnace, are quickly and effectively melted and then maintained at a temperature high enough and for a period long enough to refine the same before the molten metal is delivered tto an ingot-forming well which is illustrated as part of the illustrated embodiment of my invention and as a feature of the invention.

Another feature of the invention is the correlation of at least one of the electrodes with the ingot-forming well so as to produce ingots which are free from defects often encountered in such structures. An additional and important feature of the invention involves tthe means employed for mounting the hearth structure, forming a part of the furnace, so that it can be readily and quickly disassociated from the roof structure of the furnace and in this way, provide easy access to completed ingots for the purpose of removing the same.

In Figure 1, I have illustrated the furnace structure in association with a sealed bin which is adapted to contain titanium metal particles such as initially formed titanium metal and/or titanium scrap, and is so arranged that from time to time measured or controlled amounts of the metal may be delivered to the furnace and onto the melting hearth portion thereof during a melting and processing operation. The furnace structure illustrated, consists essentially of a hearth structure **10**, a roof strtucture **11** and electrodes projecting into the enclosure formed by the two structures. The hearth structure **10** and the roof structure **11** are separately formed and separately supported although they are adapted to be secured together during the operation of melting and processing refractory material, and are secured together in such a way as to accomplish the melting and processing in a vacuum or in the presence of an inert atmosphere.

The hearth portion includes a metal floor **12** such as is normally employed in the melting of titanium metal and similar materials. A feature of my invention, however, is that an ingot-forming well **13** forms a part of the hearth structure and is so located and arranged that molten metal from the floor **12** flows into the well during the operation of melting and processing the same. The well **13** is illus-

trated with the opening thereof formed in the floor 12. The floor and the well are water jacketed or otherwise cooled, the arrangement being such in the illustrated embodiment of the invention that one cooling compartment is employed in connection with both the melting floor 12 and the well. The opening into the well is provided with a metallic bounding flange 14 which projects upwardly through the floor to a point above the surface thereof but somewhat below, although adjacent to the normal level of molten material included on the floor during the operation of melting and processing such material. As shown, the flange is annular, is secured to the floor 12 and is secured to the cylindrical wall 15 of the well in such manner that the inner surface thereof registers with and forms a snug fit with and, in effect, is a continuation of the inner cylindrical surface of the wall 15. As illustrated the well is provided with a movable bottom 16 which is shown as a piston, snugly fitted and movable along the inner cylindrical wall 15. At least the flange 14 of the well is formed of the same metal as the floor 12. The well is also provided with a fixed bottom 17 which may be integrally formed with the cylindrical wall 15 and which forms a support and guide for a rod-like support 18 for the movable bottom 16. The fixed bottom 17 is shown as provided with a bushing 19 which surrounds and snugly fits the rod-like support 18 and constitutes a guide for that support and also performs the function of a gasket, thus sealing the interior of the well against the leakage of air into the well.

The cooling compartment for the hearth floor 12 and the cylindrical wall of the well 13, is enclosed within a casing 20 which is secured to the hearth structure by a series of bolts 21 but is electrically insulated therefrom as will be later described. A gasket 22 is shown located between the fixed wall 17 of the well and the casing 20 for the purpose of preventing leakage from the cooling compartment into and around the bottom of the well and also for the purpose of electrically insulating the shell 20.

While it is apparent that any cooling fluid may be employed within the casing 20, I have shown a water inlet 23 near the bottom of the casing and two water outlets 24 near the upper portion of the casing. With such an arrangement an adequate flow of cooling fluid is provided for around the wall 15 of the well and along the floor 12 of the hearth portion.

Many of the structural features of the roof structure 11 are similar to structural features described and illustrated in my prior application Serial No. 209,994 filed February 8, 1951, now Patent No. 2,734,244. The roof structure is mounted on immovable supports (not shown) and is so connected to the hearth structure 10 that the space enclosed by the two structures is sealed so that an inert atmosphere or even a vacuum may be maintained therein. The roof structure constitutes a support for electrodes 25, each of which is similar in some respects to electrodes disclosed in my earlier application. Each electrode of the present application is formed with a gooseneck at its lower end so that the arcing tip secured thereto is inclined at a substantial angle to the axis of the major portion of the shell of the electrode. Each electrode is also adjustable toward and away from the hearth portion and each is capable of being turned to different positions about its axis for the purpose of changing the position of the inclined tip thereof relatively to adjacent portions of the hearth structure. These adjustments are preferably mechanically accomplished and the devices for accomplishing the adjustments may be electrically controlled, but they are not directly involved by the present invention except for the purpose of accomplishing adjustments and manipulating the electrodes in a manner herein described.

The aperture in the roof structure through which each such electrode projects, is provided with a guiding and bearing sleeve 25*a* which may be formed of dielectric

and heat insulating material such as Micarta. Each such electrode is also provided with a bellows-like sealing sleeve 26, one end of which is secured to the housing of the associated sleeve bearing 25*a* of the electrode and the other end of which is secured to the electrode adjacent the current-receiving end thereof. These bellows-like sleeves are preferably formed of heat-resistant, flexible insulating material and are adapted to permit longitudinal as well as some rotary movement of the associated electrode without the danger of venting the interior of the furnace to the atmosphere through the sleeve bearing or its supporting structure. Similar sleeves are illustrated and described in said prior application. The inner or "gooseneck" end of each electrode carries a special tip 27 formed of suitable high temperature metal or material such as tungsten or tungsten alloy, which does not contaminate titanium or similar metals when subjected to high temperatures such as those attained within the furnace structure during the melting and processing of materials such as are here involved.

As clearly shown in Figures 2, 4, 6 and 7, the roof structure is arc shape transversely of the length of the hearth structure. It is also water jacketed, or to state it more broadly, is surrounded by a cooling chamber to which cooling fluid is delivered and which is provided with at least one fluid inlet and one fluid outlet so arranged as to provide adequate circulation of the cooling medium adjacent all surfaces to be cooled. It is also shown as provided with a ceramic lining 28 through which each of the sleeve bearings 25*a* of the electrodes project and through which a gas delivery pipe or passage 29 also projects. The passage 29 is employed for the purpose of delivering argon gas or some similar fluid to the furnace chamber for the purpose of maintaining an inert atmosphere within the furnace structure. As shown, the roof structure is also provided with observation apertures 30 which are so located and arranged that the hearth structure and the molten metal contained thereon, may be observed during the operation of melting and processing titanium or similar material. Structural features similar to those here mentioned, are illustrated and described in said prior filed application.

In the illustrated embodiment of the invention, titanium or similar metal is delivered to the melting floor 12 of the hearth structure through a chute 31 which projects through an opening formed in one end wall of the roof structure 11 and opens into the space enclosed by that structure and the hearth structure. As illustrated in Figures 1 and 3 of the drawings, the chute 31 forms a part of a container 32 which communicates with the furnace chamber and, except for a vent pipe or passage 33, may be hermetically sealed. It is adapted to contain a supply of titanium metal or similar material intended for delivery onto the melting floor 12 of the hearth structure. As shown, the container 32 is provided with a hinged door 34 for closing a loading aperture 34*a*, and which is capable of being locked in the closed position. A sealing gasket surrounds the opening 34*a* and seals the door 34 when it is closed. The container is also shown as provided with a pusher rod and pusher 35 for moving material from the container along the chute and into the interior of the furnace.

The present invention is not directly concerned with the apparatus last illustrated except for the fact that it is sealed against the admission of air although the vent pipe 33 is provided for the purpose of venting such gases as may be given off by the metal within the container as that metal receives heat from the furnace. The delivery end of the pipe 33 may be pressure-controlled in such a way as to prevent a reverse flow therethrough into the container 32, or the pressure of the inert atmosphere within the furnace chamber may be maintained at such a point as to prevent a reverse flow from the receptacle 32 and into the furnace chamber.

While many of the structural features of the apparatus

here under consideration are not directly involved as a part of the present invention, it is, however, to be understood that the preferred arrangement of the electrodes here disclosed and the manner of operating or manipulating those electrodes, contributes to the effectiveness of the furnace structure here illustrated and to that extent at least, constitutes a part of the present invention. As shown in Figures 2 and 3, the preferred arrangement of the electrodes **25** involves two such electrodes located adjacent to the delivery port through which material from the chute **31** enters the furnace chamber. One such electrode is located on one side of the path of travel of such material as it enters the furnace, and the other is located on the other side of such path. As indicated by full and dotted lines in Figure 3, the rotary movement of the gooseneck electrodes located at the chute end of the furnace, is such as to turn the tips **27** of such electrodes toward the material delivery port formed in the roof structure and to then turn the tips to the positions shown in dotted lines in which they extend more or less into the path of travel of the material as it is melted and moves along the floor **12** of the hearth portion. As indicated by the arc shaped arrow in Figure 3, each of the end positioned electrodes are oscillated through an arc of about 60° during the melting and the processing of material on the floor **12**. This oscillatory movement is periodic and is preferably timed with relation to similar movements of the other electrodes.

For convenience of description I have designated an intermediate electrode by the reference character **25'**. This electrode is shown as located between the end electrodes **25** and the ingot-forming well **13**. In addition, the intermediate electrode **25'** is shown as located substantially centrally with relation to the floor **12** and, consequently, in the path of travel of melting or molten material moving toward the well **13**. The arc shaped arrows associated with the electrode **25'** indicate a periodic oscillatory movement of the tip portion **27** of that electrode from a central position to one side of the central longitudinal axis of the melting floor **12**, then back to the central position as a preliminary to a further and similar movement on the other side of the axis of the floor. As indicated by the arrows, the tip **27** of electrode **25'** is moved through an arc of about 45° from a central position first to one side and then to the other side of the central longitudinal axis of the floor.

One of the important features of the present invention is the location of, and manner of operating or manipulating the fourth electrode, clearly illustrated in Figures 3, 4 and 6 and to which the reference character **25''** is applied. As shown in the drawings, this electrode projects vertically through the roof structure and through the furnace chamber to a point above the well **13**. It is located substantially coaxially with the well **13**. The tip **27** thereof is inclined with relation to the axis of the major portion of the electrode and the axis of the well, and the electrode is so positioned that its tip **27** is spaced from the annular flange **14** but is directed toward that flange, or more properly stated, is directed toward the flow of molten material cascading over the flange in its passage from the floor **12** into the well **13**.

The electrode **25''** is, like all the other electrodes, adjustable vertically, but it is adapted to be rotated first in one direction and then in the other so that its tip portion moves in a clockwise direction through an arc of approximately 360° and then back in a counterclockwise direction through a 360° arc. With this arrangement the metal in and the metal entering the well **13** is subjected to the heating effect of the arc maintained at the tip end of the electrode **25''**. As a result, the surface of the metal located within the well and the metal entering the well, is subjected to the direct heat of the arc throughout the entire operation of completing the ingot within the well, and is maintained at a temperature sufficient to promote the production of a homogeneous ingot, i. e., one which is free from non-metallic inclusions, seams, voids and other defects often encounted in ingots.

As previously described, the well **13** is provided with a piston-like movable bottom **16**. This bottom is pneumatically or hydraulically supported through the agency of the rod **18**, by a hydraulic or pneumatic cylinder **36** such as diagrammatically shown in Figures 6 and 7 of the drawings. The cylinder **36** and its piston (not shown) is so controlled during the operation of melting and processing material within the furnace structure, that the level of molten material within the well is maintained substantially constant throughout the entire processing operation. That is to say, the movable bottom **16** of the well **13** is moved downwardly either continuously or periodically by short steps, but in such a way as to substantially maintain the surface of the molten material within the well at a predetermined position with relation to the upper edge of the flange **14**. The intent is to maintain a flow of molten material across the entire upper edge of the flange **12** and into the well throughout substantially the entire melting and processing operation taking place within the furnace chamber.

A reference to Figure 1 of the drawings will disclose that the normal vertical adjustment of each electrode may differ from that of every other electrode. Thus as shown in Figure 1, the electrode or electrodes **25** located adjacent to the material-receiving end of the melting floor **12**, may be adjusted to a position such that it is relatively close to the floor **12**. The intermediate electrode **25'** is preferably adjusted to a vertical position close to, but above, the normal level of the melting and/or molten material moving toward the well **13**. As previously indicated the vertical adjustment of the electrode **25''** is such that the tip **27** thereof is so located that the heat of the arc is particularly effective in connection with the molten metal entering, and the molten metal within the well. In Figures 1 and 4 I have shown the movable bottom **16** of the well **13** provided with an upwardly projecting finger **37** formed of the metal being melted within the furnace chamber, and adapted to form a connection between the bottom **16** and the metal within the well as that metal solidifies on cooling.

As illustrated, the hearth portion **10** is electrically insulated from the roof portion by means of heat-resistant dielectric gaskets **38—38** shown in the drawings as located on opposite sides of the laterally and horizontally projecting flange which forms a part of the melting floor **12**. As shown, each of these gaskets is in the form of two cylindrical members and each extends along the entire length of the flange of the floor **12**, one being located between the floor **12** and the water jacket casing **20**, and the other located between the floor and the inner metallic shell or case of the roof structure.

I have also illustrated a more or less usual form of construction in connection with the bolts **21** for securing the roof structure and the floor structure together. As shown, each such bolt passes through a separate aperture formed in the lateral flange of the floor structure **12**, and is electrically insulated from that flange by means of a heat resistant, dielectric sleeve **41**. That is to say, the use of electric insulation is such that the electric circuits employed are limited to the electrodes and the floor structure **12** (including the well **13**) and exclude other structural parts of the apparatus.

It will be apparent that various means or circuits may be employed for delivering current to the different electrodes of the furnance. However, in Figure 4 I have illustrated the electrode **25''** as electrically connected to the generator **42** of a motor generator set, by means of a lead **43** which is indicated as the positive lead. The other lead **44**, indicated as the negative lead, is shown connected to a projecting portion of the melting floor **12**. Thus it is apparent that the generator **42**, is a direct

current generator. This, however, is not essential since either direct or alternating current may be employed. It will also be apparent to those skilled in the art that each electrode may be connected to a separate source of electric current or that the electrodes may be grouped, with each group connected to a separate source of current. In this way the distribution of current and the intensity of the current delivered to different portions of the hearth portion may be controlled to suit conditions encountered.

It will also be understood that each of the electrodes is water or otherwise cooled and in some of the views of the drawings I have more or less diagrammatically illustrated the water inlet of the electrode as positioned centrally with relation to the cylindrical shell portion of the electrode and the water outlet communicating with the annular chamber within the electrode shell which surrounds the water inlet tube. This is a more or less conventional method of cooling electrodes and the structural details disclosed do not constitute a part of the present invention.

It will be apparent that the movable floor **16** of the well **13** is moved from a position adjacent the upper edge of the flange **14** to a position such as illustrated in Figure 6, during the melting and processing operation. Thus the well **13** is finally substantially filled with metal received from the melting floor **12** and under conditions such that as the movable bottom **16** moves downwardly, metal within the well is moved away from the high temperature region within the furnace and is subjected to the cooling direct effect of the cooling medium or fluid included within the jacket **20**. The movement of the solidified and the cooling molten metal within the well may be accomplished by the support device for the bottom **16**, i. e., the movable bottom **16** of the well may, in effect, pull the solidified metal, within the well, downwardly as it is lowered by its support device.

At the end of each melting and processing operation the heating current is shut off and the furnace remains inoperative for a short period which may be termed the cooling period. During this interval, molten metal in the well and also on the floor **12** below the level of the upper edge of the well flange **14**, is subjected to the cooling action of the fluid within the jacket **20** and the inert atmosphere within the furnace chamber is maintained under conditions such as to prevent the leakage of air into that chamber. After the cooling period, i. e., after the molten metal has solidified, the hearth structure **10** is disconnected from the roof structure **11** by removing the bolts **21**. In order to provide for the movement of the hearth structure independently of the roof structure, I separately support the hearth structure either hydraulically or pneumatically so that it can be readily dropped away from the separately supported roof structure for the purpose of removing the formed ingot from the well structure. In Figures 5, 6 and 7, I have more or less diagrammatically illustrated the floor structure as carried by piston-like supports **45**, each of which is carried by what may be termed a piston rod **46** equipped with a piston (not shown) which is located within one of the hydraulic or pneumatic cylinders **47**.

As a preliminary to the operation of removing an ingot it will be apparent that the movable bottom **16** of the ingot-forming well will be located below the flange **14** and preferably adjacent the fixed bottom **17** of the well. See, for example, the position of the bottom **16** as illustrated in Figure 6. After the cooling period the bolts **21** are removed and the supports **45** of the hearth structure **10** are lowered while the movable bottom **16** of the well **13** is held in its final position. It will be apparent that all portions of the hearth structure must be uniformly and simultaneously moved and that the direction of this movement must be parallel to the axis of the well **13**. The result of such a movement is illustrated in Figure 7 wherein an ingot **48** supported by the bottom **16** projects beyond the confines of the well and is accessible for removal. In view of the fact that the movement of the hearth structure must be a controlled movement, I note that it is desirable to provide rigid guides for the hearth which limit its up and down movements to movements in a direction parallel to the axis of the well.

It will be apparent that various means may be employed for removing ingots as they are formed and made accessible, but in Figure 7 of the drawings I have diagrammatically illustrated apparatus such, for example, as a familiar type of mechanically-actuated saw **49** which may be employed for severing the major portion of the ingot **48** while leaving a stump **50** on and secured to the movable bottom **16**. With such an arrangement the stump **50** may be employed as a starting piece for the formation of another ingot. I have also shown in association with Figure 7 of the drawings, a very diagrammatic representation of apparatus **51** for engaging and removing the ingot. This is to indicate that mechanical means of one type or another may be employed for engaging and removing the formed ingot while it still exists at a high temperature.

As a preliminary to the production of another ingot, both the hearth structure **10** and the movable bottom **16** of the well **13** are moved upwardly to the positions shown in Figures 1 and 3. The bolts **21** are again employed in coupling the hearth structure to the fixed or immovably mounted roof structure **11**. During this operation the dielectric gaskets **38** are placed under compression so as to seal the interior of the furnace. An inert fluid is again delivered to the furnace chamber and in quantities such as will purge that chamber of air and other gases. Current is then delivered to at least some of the electrodes of the furnace for the purpose of melting at least the upper portion of the solidified value metal on the melting floor **12**. As a matter of practical operation, the metal forming the floor **12** is preferably continuously coated with at least a solidified film of the value metal being melted and processed within the furnace. After a substantial portion of the metal on the floor of the hearth is melted, metal (the material being melted) is again delivered to the floor of the hearth through the chute **31**. As the delivery of such metal continues molten metal will flow over the flange **14** and enter the well **13**. As soon as the flow of metal into the well is well established, current may be delivered to the electrode **25''** and that electrode will be manipulated in such a way as to initiate arcing at its tip and also to move first in one direction and then in the other around the upper portion of the well, all as previously described.

It will be apparent to those skilled in the art that the flange **14** must be formed of the same metal as the melting floor **12** and that it should be so formed that it in fact constitutes the upper portion of the cylindrical wall of the well. The lower portion of the wall **15** of the well may be formed of some other metal, but it must be borne in mind that that portion of the well which normally contains molten metal must be formed of metal or material which will not contaminate the molten metal. The wall of that portion of the well which surrounds the cooled and solidified metal may be formed of various metals since under such conditions the chances of contaminating the metal of the ingot are greatly minimized.

While I have illustrated and described but one embodiment of my invention, it will be apparent that various changes, additions and omissions may be made in the apparatus illustrated, and also that some changes may be made in procedural steps here defined, without departing from the spirit and scope of my invention as defined by the appended claims.

What I claim is:

1. A melting furnace for refractory material comprising a hearth structure including a metallic floor and water jacketing therefor; a separately supported roof structure for said hearth structure located above and removably

secured to said hearth structure; at least one electrode carried by said roof structure and terminating within the space normally enclosed thereby; a molten-metal-receiving well with the opening thereof formed in said floor and with the vertically extending wall structure thereof secured to said hearth structure and to the floor thereof, and included within the water jacket of said hearth structure; a piston located within said well movable along the wall structure thereof and constituting a movable bottom for said well; a movable support for said hearth structure; a movable support for said piston; and separate means for varying the positions of said supports.

2. A melting furnace for refractory material, comprising a separately formed hearth structure including a metallic floor, a molten-metal-receiving well with the opening thereof formed in the floor of said hearth structure and with the vertically extending wall structure thereof secured to said hearth structure; a piston located in said well movable along the vertical wall structure thereof and constituting a movable bottom for said well; a separately formed and separately supported roof structure enclosing the floor of said hearth structure located above such floor; a fixed support for said roof structure; means for removably securing said hearth structure to said roof structure; at least one electrode carried by said roof structure and terminating within the space normally enclosed thereby; a movable support for said hearth structure; and a separate movable support for said piston.

3. A melting furnace for refractory material, comprising a separately formed hearth structure including a metallic floor, a molten-metal-receiving well with the opening thereof formed in the floor of said hearth structure and with the vertically extending wall structure thereof secured to said hearth structure; a piston located in said well movable along the vertical wall structure thereof and constituting a movable bottom for said well; a separately formed and separately supported roof structure enclosing the floor of said hearth structure located above such floor; a fixed support for said roof structure; means for removably securing said hearth structure to said roof structure; at least one electrode carried by said roof structure and terminating within the space normally enclosed thereby; a movable support for said hearth structure; a separate movable support for said piston; and separate means for raising and lowering said supports.

4. A melting furnace for refractory material, comprising a separately formed hearth portion having a metallic melting floor; a well for receiving molten material from said floor having the opening thereof formed in said floor; a movable bottom for said well; a movable support for said hearth portion; a separate movable support for said bottom; a roof structure for said hearth portion enclosing said melting floor; a fixed support for said roof structure; and separate means for raising and lowering said movable supports.

5. A melting furnace for refractory material, comprising a separately formed and separately supported hearth structure including a metallic hearth floor and cooling means therefor; a molten-metal-receiving well, with the opening thereof formed in said floor and the vertically extending wall structure thereof secured to said hearth structure; a movable bottom for said well, movable to different positions along the vertical wall structure thereof; a separately formed and separately supported roof structure for said hearth structure; means for removably securing said hearth structure to said roof structure; at least one electrode carried by said roof structure and terminating within the space normally enclosed thereby and above said opening; movable means for supporting said hearth structure; separate movable means for supporting said bottom; and separate means for varying the relative positions of said movable support means.

6. A melting furnace for refractory material such as titanium, zirconium, chromium, molybdenum and tungsten comprising, a melting hearth; an enclosing structure therefor; an open top well located below said hearth and receiving molten metal therefrom, with the bounding wall thereof projecting through the floor of said hearth intermediate the ends and the lateral edges of such floor; an electrode projecting through said structure and extending to a point above and adjacent to the open top of said well; and means for maintaining a non-contaminating atmosphere in the space enclosed by said structure and the floor of said hearth.

7. A melting furnace of refractory material which comprises a melting hearth; an enclosing structure for said hearth having a material delivery port formed therein above said hearth; an open top well located below said hearth and receiving molten metal therefrom; a metallic flange bounding the open top of said well and projecting through the floor of said hearth; an electrode extending through said enclosure, with the arcing tip thereof located adjacent said flange; a source of electric current; separate means for connecting said electrode and said flange to said source; and means for maintaining a non-contaminating atmosphere within the space enclosed by said structure and the floor of said hearth.

8. A melting furnace for refractory material comprising a hearth; an enclosing structure therefor; an open top well located below said hearth and receiving molten metal therefrom; a metallic, annular flange surrounding the open top of said well projecting through the floor of said hearth at a point intermediate the ends and the lateral edges thereof; an electrode projecting through said structure with the arcing tip thereof located immediately above said well and adjacent the bounding flange thereof; a source of electric current; separate means connecting said source to said electrode and said flange and means for moving said electrode so that the tip thereof moves relatively to said flange without increasing the distance between said flange and said tip; and means for maintaining a selected atmosphere within the space enclosed by said structure and said hearth floor.

9. A melting furnace for refractory material comprising a melting hearth having a metallic floor; an enclosing structure for said hearth; a delivery port formed within said structure above said hearth; a plurality of electrodes projecting through said structure and extending toward the floor structure of said hearth; an open top well located below said hearth; an annular metal flange surrounding the open top of said well, projecting through the floor of said hearth at a point intermediate the ends and the edges thereof and secured to said floor, the arcing tip of one of said electrodes being located above said well and in arcing relationship with said flange; a source of electric current connected to said electrodes and the floor of said hearth; and means for maintaining a selected atmosphere within the space enclosed by said structure and said hearth floor.

10. A melting furnace for refractory material comprising a melting hearth having a metallic floor; an enclosing structure for said hearth; an open top well located below said hearth and receiving molten metal therefrom; an annular metallic flange surrounding the open top of said well, secured to said floor and projecting therethrough at a point intermediate the ends and the lateral edges thereof and across which molten metal flows from said hearth into said well; an electrode projecting through said structure and extending to a point adjacent said flange with the arcing tip thereof so located that metal entering said well from said hearth intervenes between said tip and said flange; a source of electric current connected to said flange and to said electrode; means for water cooling the floor of said hearth and said flange; and means for maintaining a selected atmosphere within the space enclosed by said structure and said hearth.

11. A melting furnace for refractory material including a hearth having a metallic floor; an enclosing structure for said hearth; an open top well below said hearth receiving molten metal therefrom; an annular metallic flange surrounding the open top of said well, projecting through

the floor of said hearth and secured thereto; a plurality of electrodes projecting through said structure and into the space enclosed thereby with one such electrode located immediately above said well with the arcing tip thereof adjacent said flange; separate means for delivering electric current to said electrode and to said flange; means for water cooling the floor of said hearth and the wall of said well including said flange; and means for maintaining a selected atmosphere within the space enclosed by said structure and the floor of said hearth.

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