Feb. 13, 1945. R. K. HOPKINS 2,369,233

METHOD AND APPARATUS FOR PRODUCING METALS

Filed Jan. 26, 1943

FIG. 1.

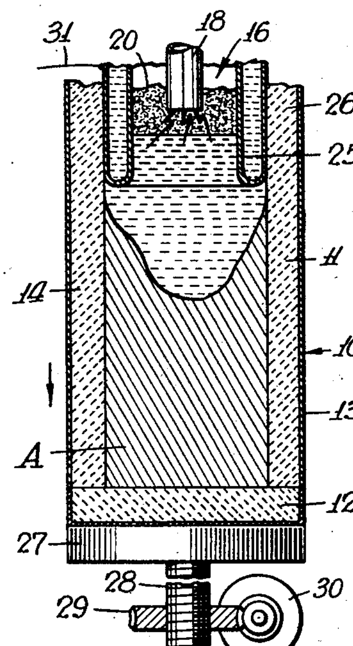


FIG. 3.

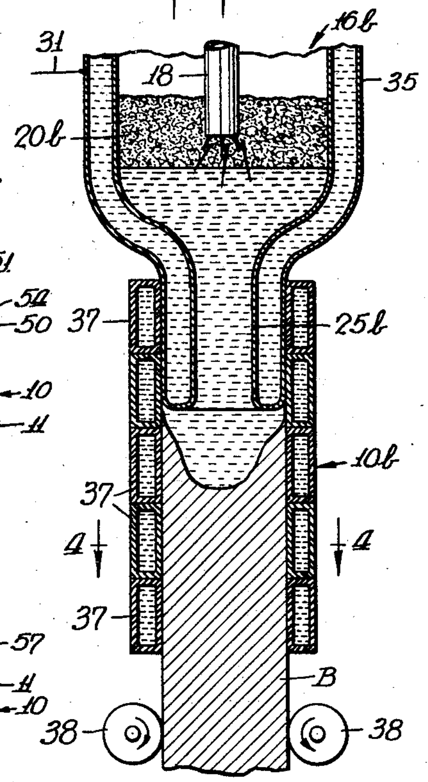


FIG. 6.

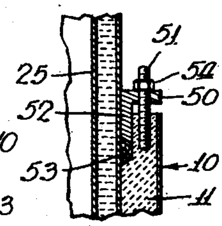


FIG. 7.

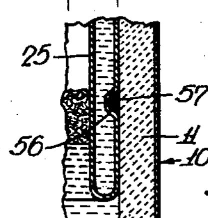


FIG. 2.

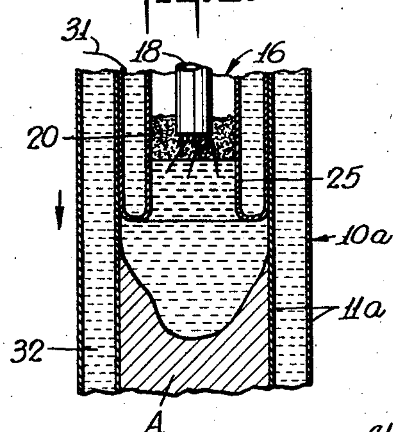


FIG. 5.

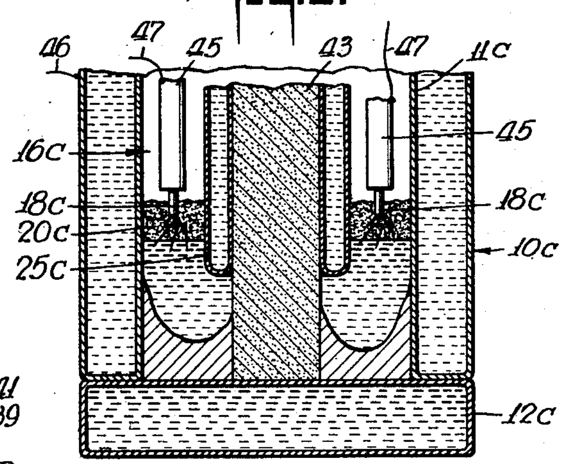
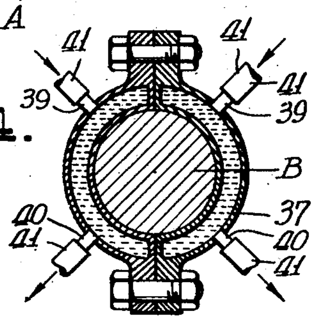


FIG. 4.



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METHOD AND APPARATUS FOR PRODUCING METAL

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7 Claims. (Cl. 22—57.2)

The present invention relates to the art of depositing and casting metals into predetermined shapes.

In certain methods of producing metals, as for instance by the use of a flux submerged electric current discharge, the fusing and casting operations are carried out simultaneously in a mold. In these operations where the mold walls are made of refractory materials, the action of the hot slag or flux on these materials causes corrosion of these walls and contamination of the slag or flux by the fused refractory material. Also with either metal or refractory molds, the flux or slag adheres to the mold walls and consequently affects the smoothness of the casting.

One object of the present invention is to provide a new and improved method and apparatus for casting metals.

Another object of the present invention is to provide a new method and apparatus in which molten metal is deposited in the presence of flux and cast, while said flux is maintained out of destructive or roughening contact with the mold walls or the surfaces of the solidifying metals.

As a feature of the present invention, a molten metal depository such as a furnace and a casting mold are arranged in superposed communication for direct gravity flow therebetween, and the furnace has a marginal wall separating said furnace from a mold wall and serving as a protective barrier to prevent the flux or slag in said furnace from coming in contact with said mold wall. Where the mold wall is of refractory material susceptible to the corrosive action of the flux or slag, this protective furnace wall prevents destructive fluxing and fusing of said mold wall and contamination of the flux.

As a further feature of the present invention, the depository for the molten metal and the mold are telescopically arranged in superposed relationship for relative slide movement, the overlapping portion of the depository wall protecting the contiguous mold wall against the action of the flux in said depository.

As another feature, the protective wall of the depository is tubular or annular in form, and has a snug overlapping conforming fit with a corresponding tubular or annular mold wall. By tubular or annular wall is intended a wall having an internal cavity of any suitable cross-sectional shape, and an outer periphery also of any suitable cross-sectional form.

As a further feature, the mold has a central core of refractory material to form a hollow casting, and the protective wall of the depository is in the form of a sleeve snugly embracing said core to prevent contamination of the flux by the fused refractory from said core.

As an additional feature, the mold is of sectional split construction, the various mold segments being detachable from the solidified metal during casting operations to permit either continuous or prolonged casting operations. In either case, the mold segments may be mounted successively into telescopic relationship with respect to the molten metal depository as the depositing and casting operations progress and the mold and depository are moved relatively apart. In the case of continuous casting operations, the lower mold segment is removed from the moving cast metal after the desired solidification and cooling has been achieved.

Various other objects, features and advantages of the invention will be apparent from the following particular description, and from an inspection of the accompanying drawing, in which

Figs. 1, 2 and 3 are respective fragmentary vertical sections of different forms of apparatus embodying the present invention;

Fig. 4 is a section taken on line 4—4 of Fig. 3;

Fig. 5 shows a fragmentary vertical section of still another form of apparatus embodying the present invention;

Fig. 6 is a fragmentary section of a form of device for sealing the mold against air contamination; and

Fig. 7 is a fragmentary section of another form of device for sealing the mold against air contamination.

Referring to Fig. 1 of the drawing, there is provided an ingot mold 10 which may be of any suitable hollow shape but which is shown in the form of an upright cylindrical tube 11 having a closure 12 at its lower end. In the specific form shown, this mold 10 has a metal shell 13 with an inner lining 14 of refractory material, and its tubular section may be either continuous as shown or transversely split.

A depository 16 for molten metal is arranged in the upper part of the mold 10. This depository 16, shown as a furnace, may be employed to carry out a melting operation desirably by the use of a flux submerged electrode device of the general type shown in my U. S. Patents No. 2,151,-914, issued March 28, 1939, and No. 2,191,476, issued February 27, 1940. For that purpose, there may be provided a consumable hollow electrode 18 extending in the furnace 16 and containing ingredients of the metal to be deposited in said furnace. The other constituents of the deposited metal may be furnished in the fluent form of granules, pellets, powders or the like through the hollow electrode 18. The electrode 18 and the granular metal are fed at controlled rates to the gap between the end of said electrode and the fused metal by suitable means, as for instance that shown in my Patent No. 2,191,476 above referred to. The hollow electrode 18 may be continuously shaped from a metal strip as shown in said patent.

The electrode 18 is submerged in a floating layer or blanket 20 of flux of any suitable composition which does not produce an objectionable amount of gas under the influence of an electric discharge, and which has the required refining effect on the fused metal. Flux comprising silicates or components of silicates, such as manganese silicate, iron silicate, calcium silicate, aluminum silicate, glass and the like, have been found suitable for this purpose. After start of operations, this flux 20 is fused by the heat in the furnace 16 and forms a molten layer. Although this flux is symbolized in the drawing as of semi-solid form to more clearly differentiate from the adjoining molten metal, it must be understood that this flux in the stage of operation shown in the drawing is actually in molten state.

Although the fusing operation is described as being carried out by the electrode method, as far as certain aspects of the present invention are concerned, this fusing operation may be carried out in the furnace 16 by any other suitable means. Also, as far as certain aspects of the invention are concerned, the metal may be produced in a separate chamber and deposited in molten state in the chamber 16.

Ordinarily, during melting operations, the flux combines with the refractory mold lining 14 and causes corrosion of said lining. Furthermore, fused refractory from this lining 14 becomes intermixed with the slag or flux 20 to cause undesirable contamination of said flux. Also, the flux or slag 20 may adhere to the mold lining 14 so that the casting may be rendered rough. To avoid these conditions, the furnace 16 is formed with a marginal wall 25 fitted in telescopic relationship with respect to the upper section 26 of the mold lining 14, and separating the fluxing zone of the furnace from said lining. This protective flux confining furnace wall 25 is of nonrefractory material inert to fluxing action. For that purpose the furnace wall 25 is made of a metal, preferably copper, and is formed with a jacket through which cooling medium such as water is circulated in any suitable manner. In cases where the ingot to be cast is solid as shown in Fig. 1, the protective furnace wall 25 is in the form of an annulus of any suitable cross-sectional shape, snugly engaging the inner periphery of the mold lining 14 to prevent the creeping of the fused metal upwardly between the mold lining 14 and the furnace wall 25, and the formation of cold "shuts." Where the mold lining 14 is cylindrical, the furnace wall 25 would be of corresponding annular shape.

The furnace wall 25 is mounted in fixed axial position with respect to the lower end of the electrode 18, so that if said electrode is supported on a vertically movable truck corresponding to the truck 21 in my prior Patent 2,191,476, said furnace wall 25 may also be carried by said truck.

The solidified cast metal A formed in mold 10 is moved with said mold relatively with respect to and away from the furnace 16 as the metal fusing and casting operations progress. To accomplish this, the mold 10 may be moved axially away from the furnace 16 by any suitable means as the mold fills up. In the form shown, the mold 10 is seated on a platform 27 connected to a feed screw 28 having a threaded engagement with a wheel, gear or sleeve 29 which is held against axial movement, and which is driven from a motor 30. The movement of the platform 27 would be synchronized with the melting operations in the furnace 16 to assure a substantially constant level of fused metal in said furnace.

Instead of a feed screw arrangement for moving the mold 10, the platform 27 may be moved in any well-known manner.

If desired, instead of moving the mold 10, this mold can be kept stationary, and the furnace 16 including the electrode 18 moved as the metal fusing and casting progresses.

In cases where the cast metal is withdrawn from its mold, fracturing of the surface of the casting may occur. The unisonal movement of the mold 10 and the cast metal with respect to the furnace 16 avoids this condition. Nevertheless, as far as certain aspects of the invention are concerned, the furnace 16 and the mold 10 can be kept in fixed relative position during the fusing and casting operations, and said mold can open at its lower end to permit the solidified cast ingot to be withdrawn from said mold end during these operations. This withdrawing of the casting from the mold 10 can be accomplished by any suitable means, such as the feed roller device shown in Fig. 3, and has the advantage of lending itself effectively to continuous casting operations. To avoid fracturing of the surface of the casting during this drawing operation, to reduce the drawing force to a minimum, and to improve the surface quality of the casting, a suitable lubricant such as graphite may be applied to the surface of the mold lining 14.

At the beginning of operations, the furnace 16 with its flux confining wall 25 and electrode 18 is lowered near the lower end of the mold 10, or if desired, said mold is telescopically raised over the lower end of said furnace. In either case, the electrode 18 is submerged in the flux blanket 20.

This electrode 18 is connected to one side of a source of current by any suitable means, while the other side is connected to a part of the apparatus in conductive relationship with respect to the fused metal. This other side of the current is shown diagrammatically for instance connected to the furnace wall 25 by a lead 31.

The current discharge from the electrode 18 is initiated by a suitable starter such as a ball of steel wool, a sliver of graphite or an iron nail, and said electrode progressively fused by the electric energy generated at the gap. As this electrode 18 is consumed, it is fed at a controlled rate to maintain an electric discharge of desired characteristics from said electrode. At the same time, the granular metal is fed through the hollow electrode 18 at a rate which is synchronized with that of the electrode feed according to the desired composition of the ultimate casting. As the metal is fused in the furnace 16, the fluid metal flows into the mold 10 and solidifies therein. While the filling of the mold 10 is progressing, said mold is lowered at a rate synchronized with the feeding of the electrode 18 and the granular metal to maintain the level of the fluid metal substantially constant with respect to the furnace wall 25. During these fusing and casting operations, the furnace wall 25 is maintained in protective position around the fusing and fluxing zone of the furnace 16, and the flux 20 thereby kept out of contact with the mold lining 14. Not only is the flux 20 kept away from the overlapping section 26 of the mold lining 14 around the flux confining wall 25, but is also kept away from the solidifying metal below said wall so that adhesion of the flux to the surface of the cast ingot is prevented.

In Fig. 2 is shown a form of apparatus which is similar to that shown in Fig. 1, except that the mold 10a is of non-refractory material inert to fluxing action. For that purpose, the tubular mold wall 11a is made of metal, desirably copper, and has a jacket 32 through which a cooling medium such as water may be circulated in any suitable manner. The furnace 16 with its flux confining wall 25 is arranged with respect to the mold 10a in a manner described with reference to the construction of Fig. 1 to prevent the molten flux 20 from reaching the mold wall 11a.

In Figs. 3 and 4 is shown another form of apparatus in which the furnace 16b comprises a wide mouthed vessel 35 having a lower contracted tubular portion 25b telescopically extending with a snug slide fit into the upper end of a tubular mold 10b. The furnace walls are desirably of metal such as copper, and are desirably hollowed to afford a cooling jacket. The contracted furnace wall 25b serves as a spout for the fluid metal in the furnace 16b. This construction permits the formation of a casting having a cross-section much smaller than that of the smallest furnace chamber which can be efficiently employed.

The mold 10b may be of solid form shown in Figs. 1 and 2, or may be of split sectional construction as shown in Figs. 3 and 4 with a series of mold segments 37 tubularly stacked and diametrically split to permit their clamping support around the furnace wall 25b. These mold segments 37 may be of refractory material or of metal construction, and may be solid or hollow. If liquid-cooled metal mold segments are employed, these may be jacketed to receive the cooling medium or may be solid, and the cooling medium circulated in any suitable manner in heat transfer relationship with the solid segments. In the specific form shown, these mold segments 37 are of hollow metal construction, and each segment part has an inlet 39 and outlet 40 for the cooling medium. This inlet 39 and outlet 40 may be connected to respective hose or tubings 41 for circulating the cooling medium to and from the mold segments 37. These hose or tubings 41 may be flexible to permit movement of the mold segments 37, and may be detachably secured to the connections 39 and 40 on the mold segments 37.

The cast ingot B formed by the molding operation can be continuously withdrawn away from the furnace 16b during fusing operations by means of pinch rolls 38 bearing against said ingot and driven by any suitable means, as for instance from a motor and gear drive to one of said rolls. The down feed of the ingot B would be synchronized with the fusing operation in the furnace 16b to maintain the level of the fluid metal in said furnace substantially constant.

The mold 10b may be held against axial movement during the ingot withdrawing operation described, but is desirably moved with the ingot during this operation. To make the fusing and casting operations prolonged or continuous, the mold 10b is moved downwardly with the ingot B, and when the solid metal embraced by the lower mold segment 37 is cooled to the desired extent, this segment is removed from the ingot and this same segment or another segment mounted on top of the tubular mold stack around the furnace wall 25b to maintain a substantially constant telescopic overlap between the mold 10b and said furnace wall as the fusing and casting progresses.

The frictional attachment between the ingot B and the mold 10b is sufficient to hold said mold against downward relative gravitational movement with respect to said ingot. However, if the mold 10b is too heavy to prevent this relative movement, or the cooling of the cast metal proceeds to a point where said metal is shrunk loose from the mold, then suitable mold supporting means may be provided to prevent slippage of said mold along the ingot, as for instance conveyor chains supporting the mold segments 37 and moving with said ingot.

If an internal metal core mold is employed for making hollow castings, the shrinkage of the solidifying metal around said core mold makes it difficult to remove said core mold. Although an easily collapsible refractory core such as one made of sand overcomes this defect, the action of the flux on said core becomes undesirable. In Fig. 5 is shown a construction for overcoming the fluxing of the sand core. In accordance with this form of the invention, there is provided a mold 10c having a tubular section 11c seated on a stool 12c. This mold 10c is desirably of metal, such as copper, and is jacketed to permit circulation of a cooling medium, such as water through the hollow mold walls.

A cylindrical sand core 43 is supported on the stool 12c and extends centrally in the mold 10c. The melting furnace 16c is telescoped in the mold 10c, and has a marginal wall 25c in the form of a cylindrical sleeve embracing the sand core 43 with a snug slide fit, and desirably hollowed or jacketed to permit circulation of a cooling medium such as water therethrough.

The electrode 18c may be of the hollow electrode type described in connection with the constructions of Figs. 1 to 4, or may constitute a solid electrode. This electrode 18c slides through a contact nozzle 45 and is fed downwardly as said electrode is consumed, as for instance in the manner shown in my U. S. Patent 2,191,478, issued February 27, 1940. A series of these electrodes 18c may be circularly arranged to fuse simultaneously in the annular space defined between the mold 10c and the sand core 43, and may be supported on a suitable carriage, such as that, for instance, shown in Patent No. 2,191,478. The marginal furnace wall 25c would also be mounted on this carriage, so that the electrodes 18c and the furnace wall 25c would be vertically moved in unison.

The metal fusing current across the electric furnace gap is shown diagrammatically supplied by leads 46 and 47 electrically connected to the mold section 11c and contact nozzles 45.

In the form of construction shown in Fig. 5, as the fusing and casting operations progress, the mold 10c with its central sand core 43 may be moved downwardly by any suitable means such as that shown in Fig. 1, or said mold and core may be held stationary while the electrodes 18c and the furnace wall 25c are progressively moved upwardly. In either case, during the relative movements of the furnace 16c and the mold 10c, the wall 25c is kept in protective position between the flux layer **20c** and the sand core **43**, so that said core is not subjected to fluxing action.

Although a single annular furnace wall **25c** is shown slidably embracing the sand core **43**, if desired and the size of the mold space permits, a second annular jacketed metal wall may be provided concentrically encircling said wall **25c** and snugly engaging the tubular mold wall **11c** with a slide fit to prevent the flux from adhering to said mold wall.

In Fig. 6 is shown a sealing device, which may be employed to prevent air from leaking between the overlapping furnace wall and the mold wall and contaminating the molten metal in the mold. This sealing device shown in the form of a stuffing box comprises a gland or follower **50**, secured to the upper end of the mold **10** by studs **51** affixed to the mold wall. This gland **50** has a tubular section **52** encircling the furnace wall **25** and bearing against a sealing ring **53** of suitable packing material. Nuts **54** on the studs **51** adjustably clamp the gland **50** against the packing ring **53**.

The fluid-tight stuffing box described prevents leakage of air into the mold **10** while permitting relative slide movement between the mold **10** and the furnace wall **25**, and is particularly applicable to the constructions of Figs. 1, 2 and 5. In Fig. 7 is shown a form of sealing device which is applicable to all of the forms shown. In this form the furnace wall **25** has a peripheral recess or channel **56** retaining a packing ring **57** forming a seal between said wall and the mold wall **11**. If desired, the packing ring **57** may be retained in a peripheral recess or channel of the mold wall **11**.

As many changes can be made in the above method and apparatus, and many apparently widely different embodiments of this invention can be made without departing from the scope of the claims, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An apparatus for producing and casting metals comprising a mold having an outer cylindrical casting wall, electrode means in said mold for depositing molten metal in the presence of a protective blanket of flux, a metal tubular jacketed member of cylindrical shape extending in the metal depositing zone of said electrode means and snugly engaging said wall to confine said flux above the casting section of said mold and thereby prevent said flux from finding its way to the outer surface of the solidifying metal below said tubular member, and means for withdrawing the metal relatively away from said electrode means and said tubular member as said metal solidifies below said tubular member.

2. An apparatus for producing and casting metals comprising a mold having an annular casting wall of refractory material susceptible to fluxing action, electrode means in said mold for depositing molten metal under a protective blanket of flux, an annular member of non-refractory material inert to the action of flux and extending in said mold in the metal depositing zone of said electrode means, said non-refractory wall being disposed in snug encircling relationship with said casting wall to protect said shaping wall against the action of said flux, and means for moving the cast metal relatively away from said electrode means and said annular member as the metal solidifies in said mold below said annular member.

3. An apparatus for producing and casting metals comprising a mold having a core of refractory material susceptible to fluxing action, electrode means in said mold for depositing molten metal in the presence of a protective blanket of flux, a sleeve of non-refractory material inert to the action of flux and extending in the metal depositing zone of said electrode means, said sleeve snugly embracing said core to protect said core against the action of said flux, and means for withdrawing the cast metal relatively away from said electrode means and said sleeve as the metal solidifies in said mold below said sleeve.

4. A method of casting metals which comprises depositing molten metal in a mold in the presence of a floating layer of flux, interposing a protective wall in the fluid metal zone between said flux and a mold wall during metal depositing operations, and moving the cast metal as it solidifies in said mold relatively away from the fluid metal zone during metal depositing operations while maintaining said first-mentioned wall in protective position with respect to said mold wall.

5. A method of producing and casting metals which comprises fusing metal in a mold including a refractory mold wall under the current discharge action of an electrode and in the presence of a floating layer of flux, interposing a protective non-refractory wall in the fusing zone between said flux and said refractory mold wall during fusing operations, whereby said refractory mold wall is protected against the corrosive action of said flux, and moving the cast metal relatively away from the fusing zone during fusing operations while maintaining said non-refractory wall in protective position with respect to said refractory mold wall.

6. A method of casting metals which comprises depositing molten metal in a chamber having a bottom opening and disposed directly over a horizontally sectioned casting mold telescoped over said chamber, whereby the molten metal flows from said chamber through said opening and into said mold for casting operations, moving the solidified metal and the mold in unison relatively away from said chamber during the metal depositing operation, and applying a mold segment to the top of said mold to maintain a telescopic relationship between said chamber and said mold during metal depositing and casting operations.

7. A method of casting metals which comprises depositing molten metal in a chamber having a bottom discharge opening and disposed directly over a casting mold telescoped over said chamber, whereby the molten metal flows from said chamber through said opening and into said mold for casting operations, moving the solidified metal and the mold in unison away from said chamber during the metal depositing operation, and removing the mold from the solidified casting while movement of said solidified metal is continued.

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