July 20, 1948. R. K. HOPKINS 2,445,670

APPARATUS FOR PRODUCING CAST METAL BODIES

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FIG. 1.

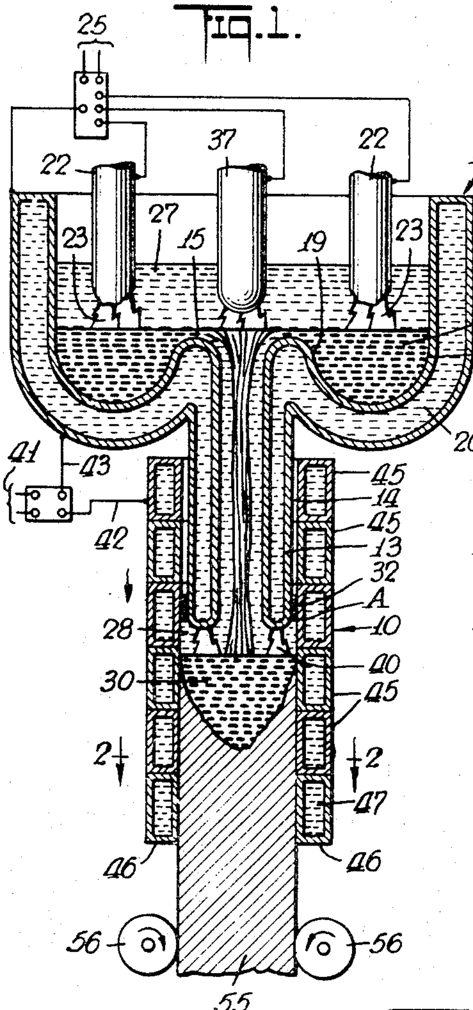


FIG. 3.

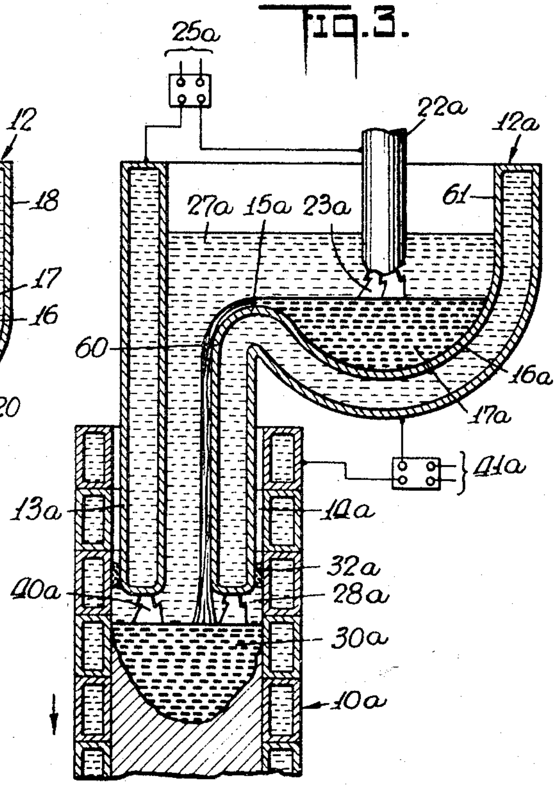
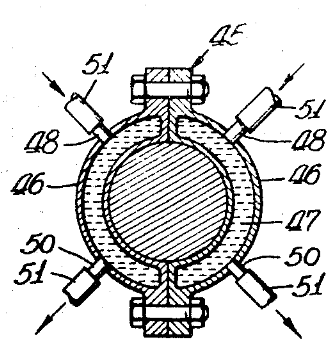


FIG. 2.



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APPARATUS FOR PRODUCING CAST METAL BODIES

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2 Claims. (Cl. 22—57.2)

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The present invention relates to the art of producing cast metal bodies.

In the electric fusion method of producing cast metal bodies, such as ingots, current is discharged from an electrode through a flux submerged gap separating said electrode from the body of deposited molten metal, to create a metal fusing zone in and around said gap. At the same time, solid ingredients of the metal to be produced are fed into this fusing zone at controlled rates. The electrode may be of consumable hollow construction, and may contain some of the metal ingredients of the ingot to be produced, while the other ingredients may be delivered into the metal fusing zone in the fluent form of granules, pellets, powders or the like, through the hollow of said electrode. Some of the particles from these fluent metal ingredients having high fusion points may pass through the metal fusing zone and may settle towards the bottom of the deposited molten metal without being completely fused. These solid unfused particles imbedded in the casting will produce therein so-called "bright spots" which adversely affect the soundness of the casting.

One object of the present invention is to provide a new and improved apparatus for producing and depositing metal in a mold in a manner to assure fusion of the metal ingredients.

Another object of the present invention is to provide a new and improved apparatus for producing metal in a highly fluid highly superheated condition and depositing said metal in a mold at substantially said temperature without allowing the molten metal to come in contact with the air.

Another object is to provide a new and improved apparatus for producing molten metal and depositing it free from atmospheric contamination and at high temperature into a mold having a cavity with a cross-section too restricted to permit effective use of a metal producing furnace therein.

Another object is to provide a new and improved continuous apparatus by which molten metal is produced and deposited free from atmospheric contamination and at high temperature, while the solidified ingot is withdrawn with respect to said mold.

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

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Fig. 1 shows somewhat diagrammatically partly in vertical section and partly in front elevation one form of apparatus which embodies the structural features of the present invention;

Fig. 2 is a transverse section taken on line 2—2 of Fig. 1; and

Fig. 3 shows somewhat diagrammatically partly in vertical section and partly in front elevation another form of apparatus which embodies the structural features of the present invention.

In the form of the invention shown in Figs. 1 and 2, there is provided a mold 10 which may be of any suitable shape according to the desired shape of the metal to be produced, and which for the purpose of illustration is shown cylindrical for the casting of ingots. As far as certain aspects of the invention are concerned, this mold 10 may be of unitary structure, but for continuous casting operations it is desirably of split sectional construction as will be more fully described hereinafter.

For producing metal of the desired analysis, there is provided outside the mold 10 a furnace 12 in the form of a wide mouth vessel having a lower contracted desirably cylindrical spout or nozzle 13 extending into the upper end of said mold, and spaced from the inner periphery of said mold by an annular clearance 14. Spout 13 connects into the furnace 12 by an overflow gate 15 raised a substantial distance above the bottom of said furnace to form therein a reservoir cavity or chamber 16 adapted to hold a substantial body of molten metal 17.

In the form of the invention shown in Fig. 1, the furnace 12 has concentric circular peripheral walls 18 and 19 integrally or otherwise rigidly connected together at the bottom. The reservoir furnace chamber 16 formed between these furnace walls 18 and 19 is annular in horizontal section and bowl-shaped in vertical radial section.

The walls of the furnace 12 and spout 13 are hollow to form a jacket 20 through which a suitable cooling liquid is circulated, and are made of a metal having high heat conductive capacity, as for example copper. The cooling liquid is circulated through this jacket 20 by inlet and outlet pipes (not shown) connected into said jacket and arranged in any suitable manner.

The metal is produced and deposited in the furnace 12 by the use of an electrode device which may be of the general type shown in my U. S. Patents Nos. 2,191,479 and 2,191,481. For that purpose, there is provided one or more consumable electrodes 22, two being shown, disposed in furnace 12 directly over its annular reservoir chamber 16. Electrodes 22 contain the base ingredients of the metal to be produced and deposited, and are desirably of hollow construction. Other constituents of the deposited metal may be furnished in the fluent form of granules, pellets, powders or the like through the hollows of the electrodes 22, so that these constituents in conjunction with said electrodes when fused produce a metal in the furnace 12 having the required analysis.

For creating a zone hot enough to fuse the metal as it is fed therein, the electrodes 22 are spaced by respective gaps 23 from the pool of deposited metal 17 in the furnace chamber 16, and current of sufficient intensity is discharged across said gaps to create a metal fusing zone in and around each of said gaps. For creating metal fusing current discharges across gaps 23, the electrodes 22 and the deposited metal 17 in the furnace chamber 16 are electrically connected in the same circuit from a suitable source 25 of electric power. The electrical connection to the deposited metal 17 in the furnace chamber 16 may be made from source of power 25 through the metal walls of said chamber.

The electrodes 22 and the granular metal constituents are fed at controlled rates towards the current discharge gaps 23 by suitable means, as for example that shown in my aforesaid Patent No. 2,191,479, to produce metal of the desired analysis, and to maintain said gaps substantially constant in length. The controlled downward feeding of the electrodes 22 may be effected by one or more feed motors regulated automatically in a suitable manner, as for example by the voltage drop across the current discharge gaps 23.

The hollow electrodes 22 may be continuously shaped from metal strips or skelps as shown in the aforesaid Patent No. 2,191,479, as said electrodes are fed continuously into the metal fusing zones in and around the current discharge gaps 23. The granular metal constituents may be delivered through the hollows of electrodes 22 and into the current discharge gaps 23 at controlled rates and in desired proportions by means of metering devices (not shown) similar to those indicated in U. S. Patent No. 2,260,259. A number of these metering devices may be provided and arranged to feed the granular metal constituents at the desired rate to funnels leading into respective electrodes 22.

The furnace 12 contains a floating layer or blanket of flux 27 extending to a level above the inlet of the overflow gate 15. The lower ends of the electrodes 22 extend into flux 27, so that the current discharge gaps 23 are entirely submerged. Flux 27 fills the spout 13 through the overflow gate 15 and forms a protective blanket 28 over the surface of the molten metal 30 deposited in the mold 10. On the outside of spout 13 in the annular clearance space 14, the protective flux blanket 28 extends above the lower end of said spout up to an approximate level A. Due to the heat conductive action of the mold 10, especially when liquid cooled, the flux in the annular clearance space 14 is frozen or solidified a comparatively short distance above the lower end of the spout 13 and forms thereby a solid seal 32. This solid flux seal 32 resists the static pressure of the flux in the furnace 12 and prevents said flux from rising upwardly in the annular space 14.

The flux 27 arranged and distributed as described, maintains the molten metal from the time it is produced in the furnace 12 to the time it is deposited in the mold 10 out of contact with the air, so that this metal is effectively protected against air contamination while in the molten state. Flux 27 also serves as a heat insulating blanket around the metal from the time it is produced in the furnace 12 to the time it is deposited in the mold 10, thereby allowing the use of extremely high temperatures in said furnace and effecting deposit of the molten metal at substantially the same high temperatures in mold 10.

The flux 27 also refines the metal, and comprises any suitable material having chemical and metallurgical properties necessary to carry out the method of the present invention. Silicates or components of silicates, such as magnesium silicate, calcium silicate, aluminum silicate and glass are suitable for the purpose.

Highly fluid superheated metal is continuously produced in furnace chamber 16 from the electrodes 22 and from the other metal ingredients delivered in fluent form. After the molten metal deposited in furnace chamber 16 reaches the level of pouring gate 15, it overflows the gate and discharges into the spout 13. The discharged molten metal flows thereafter as a continuous stream through the body of flux 27 in the spout 13, and is deposited in the mold 10 underneath the flux layer 28 as pool 30, the metal from the time it is produced to the time it is solidified is maintained by the protective action of the flux out of contact with the air. The molten metal overflows the furnace chamber 16 and is discharged into the mold 10 at a rate which is substantially equal to the rate of its production.

Any solid particles which are not fused in the metal fusing zones in and around current discharge gaps 23 will eventually become fused before overflowing the gate 15. The unfused particles will sink towards the bottom of chamber 16 and, if they do not fuse as they sink, will settle at the bottom of chamber 16. As the unfused particles accumulate they will form piles that eventually will reach the level where the intense heat generated by the electrodes 22 will fuse the particles. Delivery of molten metal to the mold 10 free from unfused particles is thereby assured.

A heating electrode 37 is desirably disposed directly over the pouring gate 15 to maintain the overflowing metal highly fluid as it is discharged through said gate, and to prevent thereby freezing of the metal in said gate. Heating electrode 37 is desirably non-consumable, and for that purpose may be of copper hollowed to allow circulation of a cooling medium therethrough. Heating electrode 37 and the body of deposited metal 17 are connected in the same electric circuit to effect a current discharge from the lower end of said electrode to the metal overflowing the gate 15. For that purpose, electrode 37 may be connected to the source 25 of electric power.

As the molten metal overflows the pouring gate 15, the level of the deposited metal in mold 10 rises. At the same time, the metal deposited in the mold 10 solidifies progressively upwardly and inwardly as shown in the drawings.

In order to promote progressive solidification of the metal upwardly and to assure the maintenance of a body 30 of highly fluid superheated metal in mold 10 to serve as a shrinkage feeder for the solidifying metal below, heat is desirably transmitted continuously to the upper portion of the metal deposited in said mold. In the specific form shown, the pouring spout 13 serves as the electrode to discharge heating current across the annular gap 40 intervening between the lower end of said spout and the surface of molten metal 30. Electrical connections from a source 41 of electric power to the furnace 12 and the mold 10 through leads 42 and 43, provide the necessary electrical tie-up for discharging current across the gap 40. The current discharge across the gap 40 generates enough heat to maintain a supernatant body of highly fluid highly superheated metal 30, which feeds the shrinking solidifying metal below and thereby substantially eliminates shrink holes, cavities or pipes, floats out segregated impurities, and avoids the formation of cleavage planes. This so-called "hot-topping" operation is carried out continuously and progressively upwardly, so that substantially the full length of the casting will be free from the defects indicated.

The heat input and the heat outgo of the operation are balanced to effect solidification of the metal in mold 10 at a rate substantially equal to the rate at which the metal is produced in the furnace 12.

In the operation so far described, as the cast metal is poured in the mold 10 and the level of the deposited metal rises therein the mold is moved gradually downwardly at a substantially uniform rate to maintain the current discharge gap 40 substantially constant in length.

As far as certain aspects of the invention are concerned, the process described may be applied to either still casting or continuous casting. By "still casting" is meant a process in which the deposited metal in the mold is completely solidified before it is withdrawn from the mold. By continuous casting is intended a process in which the solidified metal is removed or withdrawn from the mold while the upper portion of the deposited metal is still in molten condition to form a casting of either finite or infinite length.

For still casting, the mold 10 may be supported on a platform which is movable downwardly at a substantially constant rate during metal producing operations, as for example by means of a screw feed drive.

In the specific form shown, the apparatus is employed to carry out a continuous casting operation. For that purpose, the mold 10 is desirably of split sectional construction as shown, and comprises a series of mold sections 45 tubularly stacked and diametrically split into complemental segments 46. As far as certain aspects of the invention are concerned, these mold sections 45 may be of refractory material, and may be of solid construction. However, it is desirable to have these mold sections 45 of metal and of hollow construction to permit liquid cooling thereof. For that purpose, the mold segments 46 are of a metal having high heat conductivity such as copper, and are provided with respective jackets 47. The cooling liquid is circulated through each of these jackets 47 by means of an inlet 48 and an outlet 50 connected into each of said jackets. Inlets 48 and outlets 50 may be connected to respective hose or tubings 51 for circulating the cooling medium to and from the jackets 47. The hose or tubings 51 may be flexible to permit movement of the mold segments 46 in a manner to be described, and may be detachably secured to the connections 48 and 50 on the mold segments.

The solid ingot 55 formed by the casting operation described is continuously withdrawn from the mold 10 during metal producing, depositing and hot-topping operations at a rate which is substantially equal to the rate of solidification of the metal in said mold, and which is correlated with the rate of metal production and deposition to maintain the spout 13 in constant positional relationship with respect to the surface of the molten metal 30. The continuous withdrawal of the solid ingot 55 may be effected by means of pinch rollers 56 having drive engagement with the ingot 55, and driven at substantially constant speed by any suitable means, and for instance from the motor and gear drive to one of said rollers.

To make the casting operations prolonged or continuous, the mold 10 is moved downwardly with the solidified ingot 55 during metal producing, depositing and hot-topping operations, and when the part of the solid cast metal embraced by the lower mold section 45 is cooled to the desired extent, this mold section is removed from the ingot and the same mold section or another mold section is mounted on top of the tubular mold stack.

The frictional attachment between the ingot 55 and the mold 10 is sufficient to hold said mold against downward relative gravitational movement with respect to said ingot. However, if the mold 10 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 said mold, then suitable mold supporting means may be provided to prevent slippage of said mold along the ingot.

At the beginning of operations, the electrical connection 42 from the source 41 of electric power may be attached to one of the upper mold segments 46. The connection 42 from the mold 10 to the power source 41 is long enough and flexible enough to permit movement of the mold segment 46 attached thereto from the top of the mold stack to the bottom. If the casting operation proceeds to the point where the mold segment 46 having this electrical connection 42 reaches the bottom of the mold stack and must be removed from the solidified ingot 55 in order to continue the casting operations, this electrical connection may be removed from this bottom mold segment and readily attached to the upper mold segment without interrupting operations. For that purpose, there may be connected to the power source 41 branch leads, one of which may be attached to the upper mold segment 46 before the other lead is disconnected from the bottom mold segment.

If desired, after a solidified portion of the ingot 55 has been withdrawn from mold 10, electrical connection can be continuously maintained between the bottom of the spout 13 and the body of molten metal 30 by attaching an electrical connection directly to the solidified ingot by means of a stationary contact shoe in slide engagement with said ingot.

If desired, the opposed mold segments 46 instead of being bolted together as shown, may be secured to a pair of opposed conveyors, and the opposed mold segments may be brought together into tubular relationship at the top and separated at the bottom successively and progressively by said conveyors as shown in my copending application Serial No. 485,956 filed May 5, 1943.

As the mold 10 is moved downwardly with respect to the spout 13, it is moved with respect to the solid flux seal 32 without destroying the pressure resisting function of this seal, so that flux is prevented from overflowing the top of said mold.

It is seen that with the furnace construction of Figs. 1 and 2, it is possible to make a casting having a cross-section much smaller than that of the smallest furnace which can be efficiently employed. The use of a furnace constructed and arranged with respect to the mold **10** as described, effects the continuous production and deposit of the metal in the furnace **12** and simultaneous continuous transfer of the metal from said furnace to said mold at a rate substantially equal to the rate of production of the metal in said furnace, while maintaining said metal free from atmospheric contamination, and substantially at the high temperature at which it is produced. At the same time, the furnace chamber **16** serves as a trap to prevent unfused particles of metal from being deposited in the mold **10** and forming "bright" spots in the casting.

In Fig. 3 is shown another form of apparatus which embodies the features of the present invention. In this form of the invention, the furnace **12***a* is circular in cross-section, and instead of having an annular furnace chamber with a central overflow gate connecting into a depending spout as in the construction of Fig. 1, it is formed with an overflow gate **15***a* on one side of the chamber merging into a depending spout **13***a* circular in cross-section. Overflow gate **15***a* is formed by a dam **60** constituting an upper extension of a portion of the circular wall of the spout **13***a*, and defining a reservoir furnace chamber **16***a* between said dam **60** and the outer peripheral circular wall section **61** of the furnace **12***a*. This furnace chamber **16***a* is approximately crescentic in horizontal section, and approximately bowl-shaped in vertical radial section, and has sufficient capacity to hold back a substantial amount of molten metal **17***a* before said metal starts to overflow the gate **15***a*.

The walls of the furnace **12***a* and spout **13***a* are desirably of copper, and are hollowed as in the construction of Fig. 1, to permit the circulation of a cooling medium in heat exchange relationship with said walls.

The metal is produced and deposited in the furnace **12***a* by the use of an electrode device similar to that employed in the method and construction of Fig. 1. For that purpose, a hollow consumable electrode **22***a* containing the base ingredients of the metal to be produced and deposited extends directly over and substantially centrally of the furnace chamber **16***a*, and has its lower end submerged in a layer of flux **27***a* covering the deposited metal **17***a* in said chamber. Although only one consumable electrode **22***a* is shown, any number of these may be provided according to the size of the furnace **12***a*.

The other constituents of the deposited metal may be furnished in the fluent form of granules, pellets, powders or the like through the hollow of the electrode **22***a*, so that these constituents in conjunction with said electrode when fused, produce a metal in the furnace **12***a* having the required analysis. The electrode **22***a* is spaced from the upper surface of the deposited metal **17***a* by a gap **23***a*, and current of sufficient intensity is discharged through said gap to create a metal fusing zone as in the construction of Fig. 1. The electrode **22***a* and the body of metal **17***a* in the furnace **12***a* are connected in the same circuit by connections to the power source **25***a* to effect the necessary current discharge across the gap **23***a*.

The flux **27***a* forms a protective cover or blanket over the deposited metal **17***a* in the furnace chamber **16***a*, fills the spout **13***a*, and forms in the mold **10***a* a protective flux blanket **28***a* over the surface of said metal. The lower end of the spout **13***a* is submerged in this flux blanket **28***a*, and the solidification of the flux in the annular clearance space **14***a* between said spout and said mold **10***a* forms a solid seal **32***a* which serves as in the construction of Fig. 1 to resist the static pressure of the flux in the furnace **12***a*, and thereby to prevent said flux from overflowing the upper end of the mold **10***a*.

The deposited metal **30***a* in the mold **10***a* is heated to promote progressive solidification in said mold and to effect continuous hot-topping operations. For that purpose, heating current is discharged across the gap **40***a* intervening between the lower end of the spout **13***a* and the upper surface of the deposited metal **30***a*. The furnace **12***a* and the mold **10***a* may be connected to a suitable current source **41***a* to effect the necessary current discharge across the gap **40***a*.

The mold **10***a* is constructed as described in connection with the apparatus of Fig. 1, and is moved and progressively assembled and disassembled in a manner already made apparent in the description of said apparatus. The operation of the construction of Fig. 3 is in all respects the same as that described in connection with the construction of Figs. 1 and 2.

As many changes can be made in the above 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 drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An apparatus for casting metal comprising a mold, a furnace outside said mold having a reservoir trap chamber and an overflow gate, a layer of flux over said chamber, a layer of flux in said mold, a spout connected to said gate and extending into said mold with its lower end submerged in the flux layer in said mold, said spout affording communication between the two flux layers, means for producing metal in said furnace under the protective action of the flux layer therein and depositing it in said furnace chamber under said latter flux layer, whereby the overflow from said furnace chamber passes over said gate through said spout and into said mold free from air contamination, while unfused particles of metal ingredients are trapped in said chamber, and means for solidifying the flux between said spout and the peripheral wall of said mold to form a substantially solid seal, whereby the flux is prevented from overflowing the upper end of the mold.

2. An apparatus for casting metal comprising a mold, a furnace outside said mold having a reservoir trap chamber and an overflow gate, a layer of flux over said chamber, a layer of flux in said mold, a spout connected to said gate and extending into said mold with its lower end submerged in the flux layer in said mold, said spout affording communication between the two flux layers, means for producing metal in said furnace under the protective action of the flux layer therein and depositing it in said furnace cham-

ber under said latter flux layer, whereby the overflow from said furnace chamber passes over said gate through said spout and into said mold free from air contamination, while unfused particles of metal ingredients are trapped in said chamber, means for liquid cooling said mold, and means for liquid cooling said spout, the flux between said spout and the peripheral wall of said mold being solidified by both of said liquid cooling means and forming a solid seal to prevent overflow of the flux from the upper end of said mold.

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