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METHOD AND APPARATUS FOR CASTING METAL BODIES

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FIG. 1.

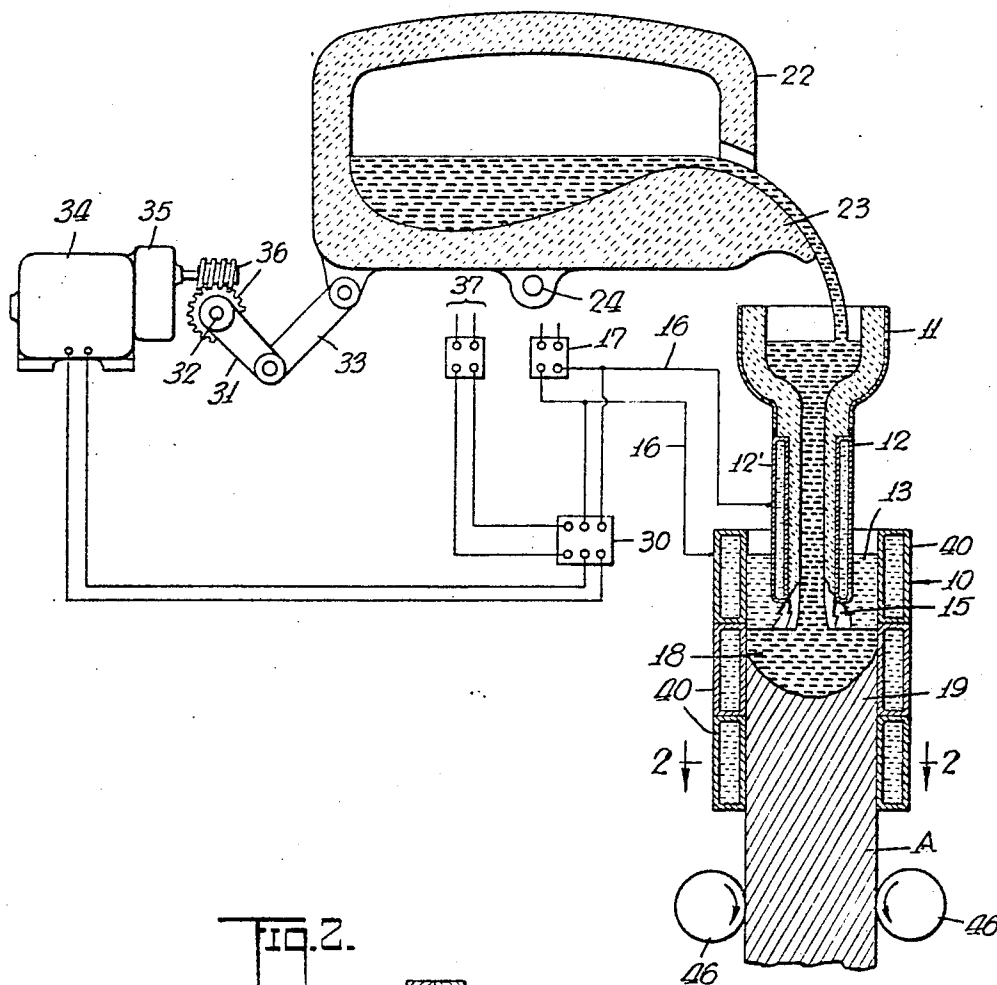
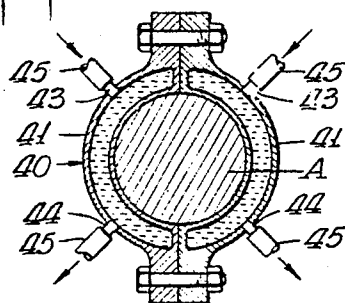


FIG. 2.



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METHOD AND APPARATUS FOR CASTING
METAL BODIES

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14 Claims. (Cl. 22—57.2)

The present invention relates to the art of casting metals.

One object of the present invention is to provide a new and improved method and apparatus for producing a sound, dense casting.

Another object is to provide a new and improved method and apparatus for promoting progressive solidification of the cast metal in a mold.

A further object is to provide a new and improved method and apparatus for controlling the rate of deposition of cast metal in a mold.

Another object is to provide a new and improved method and apparatus for continuously hot-topping cast metal in a mold. The term "hot-topping" is applied to the procedure in which a comparatively small pool of the deposited metal is maintained in highly fluid superheated condition on the solidifying metal beneath it so that said pool of metal will readily feed the shrinking metal below it to prevent shrinkage defects and, furthermore, since crystallization takes place from a comparatively small volume of molten metal, segregation will not take place, also, the presence of said pool of metal prevents or relieves all shrinkage stresses.

As another feature, the rate of pouring of the cast metal into the mold through the nozzle is automatically controlled to render said rate substantially uniform, and substantially equal to the rate of solidification of the metal in said mold.

As another feature, while the molten metal is teeming into the mold, the deposited metal and the current discharge nozzle, or other electrode which may be employed, are moved relatively apart substantially at uniform rate to maintain the intervening current discharge gap substantially constant in length, and the rate with which the molten metal is deposited into the mold is automatically controlled in accordance with variations in the length of said gap to maintain said gap substantially constant in length and to assure flow of molten metal in said mold at substantially constant rate.

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

Fig. 1 is a vertical section somewhat diagrammatic showing an apparatus which embodies the present invention, and which may be employed to carry out the method of the present invention; and

Fig. 2 is a transverse section of the mold taken on line 2—2 of Fig. 1.

Referring to the drawing, there is provided a

mold 10 which may be of refractory material, but which is shown of suitable metal such as copper, jacketed to permit circulation of a cooling liquid in heat exchange relationship therewith. This

5 mold 10 has a cross-sectional shape corresponding to the desired cross-sectional shape of the article to be cast, and is shown for the purpose of illustration cylindrical to form ingot of corresponding shape. The molten metal to be cast is poured into the mold 10 through a basin 11 which has a nozzle 12 extending into the mold. Basin 11 and nozzle 12 are preferably refractory lined as shown. The lower portion of nozzle 12 includes an annular member 12' from whose end the electric current is discharged. Member 12' is preferably made of copper and hollowed as shown for circulation of a cooling medium there-
10 through to prevent its destruction in use. The electric current connection is made directly to member 12', as shown, and an insulation ring is interposed between the upper end of member 12' and the lower end of the metal lining of basin 11 to electrically separate them. The refractory lining of nozzle 12 extends substantially to the end of member 12' to electrically separate mem-
15 ber 12' from the teeming metal. A floating layer of flux 13 is desirably maintained in the mold 10, and the lower discharge end of the pouring nozzle 12' is submerged in said flux layer above the surface of the deposited metal.

The flux 13 may be of suitable composition which has the proper electrical and refining characteristics. Flux comprising silicates or components of silicates, such as manganese silicate, calcium silicate, aluminum silicate, glass and the like, has been found suitable for this purpose. This flux 13 serves to refine the deposited material in the mold, protect it against at-
20 mospheric contamination and also serves to prevent rapid dissipation of the heat from the top surface of the deposited metal.

As the cast metal is teemed into the mold 10, the upper portion of the deposited metal is maintained in highly fluid superheated condition by the heating action of an electrode. In accordance with certain aspects of the present invention, member 12' of the pouring nozzle 12 serves as the electrode to discharge heating current across a gap 15 intervening between the lower discharge end of member 12' and the upper surface of the deposited metal. Connections 16 to member 12', as above explained, and for example to the metal mold 10 from a power source 17, provide the necessary electrical tie-up to dis-
25 charge current across the gap 15. The current

discharged is so chosen that the heat generated by it when correlated with the heat input from the molten metal poured into the mold and the heat removed from the mold by all causes, will be proper to continuously maintain a comparatively small pool 18 of highly fluid superheated metal on the solidifying metal below it. The pouring rate will also be so adjusted that it is substantially equal to the rate of solidification. With these conditions established and maintained, the poured metal will solidify progressively upwards and because of pool 18, continuous hot-topping will take place and all defects due to shrinkage, segregation and stresses obviated.

In the operation of the apparatus so far described, the metal, as above stated, is poured in the mold 10 at a rate substantially equal to the rate of solidification of the deposited metal in said mold. As the cast metal is poured in the mold 10, and the level of the deposited metal rises in the mold, said mold is moved gradually downwardly at a substantially uniform rate to maintain the current discharge gap 15 substantially constant in length and characteristics. The current discharge across the gap 15 generates enough heat to maintain the supernatant body 18 of highly fluid superheated metal substantially constant in volume throughout substantially the entire mold pouring operation.

The cast metal is poured into the basin 11 from a suitable receptacle, such as a conventional furnace 22 having a discharge spout 23. If desired, the furnace 22 may supply the base metal in molten condition, and alloying materials may be added to this base metal in solid or molten form in the upper larger end of the basin 11. Also, if desired, deoxidizing materials may be added to the metal in the upper receiving end of the basin 11.

The molten metal is teemed from the furnace 22 at a controlled rate to deposit metal in the mold 10 through the nozzle 12 at a substantially constant rate equal substantially to the rate of solidification of the deposited metal. In accordance with certain aspects of the present invention, this control is effected automatically in accordance with the length of the current discharge gap 15, to maintain said gap substantially constant in length. For that purpose, the voltage drop across this gap 15 is employed as a control factor and the furnace 22 has a pivot support 24 or may have trunnion support, and is automatically tilted about this support according to this voltage drop.

When the rate of deposition of the cast metal in the mold 10 is reduced beyond a predetermined amount, this rate reduction is reflected in the lengthening of the gap 15, and in an increase in voltage drop across said gap. This change in voltage drop is automatically translated into pivotal movement of the furnace 22 clockwise (Fig. 1) about its pivotal support 24. This increases the rate of discharge from the furnace 22, and the resulting increase in the static head of the molten metal in the basin 11 causes an increase in the rate of deposition of the metal in the mold 10.

When the rate of deposition of the cast metal in the mold is increased beyond a predetermined amount, the corresponding shortening of the gap 15 causes decrease in voltage drop across said gap and tilting of the furnace 22 counterclockwise (Fig. 1) about its pivot support 24. This reduces the rate of discharge from furnace 22 and there-

by reduces the rate of deposition of cast metal in the mold 10.

By the control operations described, the rate of deposition of cast metal in the mold 10 is maintained substantially constant and substantially equal to the rate of solidification of the deposited metal in said mold, the current discharge gap 15 is maintained substantially constant in length, and the volume of molten supernatant feeder metal 18 is maintained substantially constant.

The furnace 22 may be tiltably controlled automatically in any suitable manner from a control device 30. For example, a crank 31 may be provided fixed at one end on a crank shaft 32, and pivotally connected at its other end to a link 33 pivotally secured to the furnace 22. A reversible motor 34 drives the crank shaft 32 by means of a reduction gearing 35 and a worm and worm wheel drive 36. This motor 34 is controlled from the device 30 to cause rotation of said motor in either direction according to the voltage drop across the gap 15.

The control device 30 may be of any suitable type, the arc control devices used to control the feed of electrode feed motors in the arc welding and electric furnace arts are suitable. These devices are well known and need not be described here. As shown, the power leads from a source of power 37, for motor 34, pass to device 30; power leads pass from device 30 to motor 34. Leads are also shown leading from basin 11 to device 30 and from mold 10 to device 30.

Instead of controlling discharge into the basin 11 by tilting the furnace 22, as far as certain aspects of the invention are concerned, flow from the furnace or any other reservoir which may be employed may be controlled by means of a valve or stopper regulating flow from said reservoir.

The casting method 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 indefinite length.

For still casting, the mold 10 may be supported on a stool, which in turn is supported on a platform, and the mold may be moved downwardly at substantially constant rate during pouring operations, as for example by means of a screw feed drive to said platform operated from a constant speed motor.

In the specific form shown, the apparatus is employed to carry out a continuous casting process. For that purpose, the mold 10 may be of split sectional construction as shown, and may comprise a series of mold sections 40 tubularly stacked and diametrically split into complementary segments 41. These mold segments 41 may be of refractory material or of metal construction as shown, and may be solid or hollow. If liquid-cooled metal mold segments 41 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, each of the mold segments 41 is of hollow metal construction, and has an inlet 43 and an outlet 44 for the cooling medium. This inlet 43 and outlet 44 may be connected to respective hose or tubings 45 for circulating

the cooling medium to and from the mold segments 41. These hose or tubings 45 may be flexible to permit movement of the mold sections 40, and may be detachably secured to the connections 43 and 44 on the mold segments 41.

The ingot A formed by the casting operation described can be continuously withdrawn away from the mold 10 during pouring and hot-topping operations by means of pinch rolls 46 engaging said ingot and driven at substantially constant speed by any suitable means, as for instance from a motor and gear drive to one of said rolls.

To make the casting operations prolonged or continuous, the mold 10 is moved downwardly with the solidified ingot during pouring and when the solid cast metal embraced by the lower mold section 40 is cooled to the desired extent, this section 40 is removed from the ingot A, and this same mold section or another mold section is mounted on top of the tubular mold stack.

The frictional attachment between the ingot A 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.

The electrical connection 16 may be attached to one of the upper mold segments 41 as shown and this connection moved to other segments as required. However, in practice it would be preferred to employ a contact arrangement that will maintain all of the segments that are in mold forming position constantly in the electric circuit.

If desired, the opposed mold segments 41 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 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. A method of casting which comprises depositing molten metal into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion, and discharging current across a gap between said lower portion and the upper surface of the deposited metal while metal is being deposited in said mold, to heat the upper portion of the deposited metal and maintain it continuously in fluid condition to feed the solidifying metal below.

2. A method of casting which comprises depositing molten metal into a mold through a substantially non-conductive nozzle having a conductive external lower discharge end submerged in a floating layer of flux in said mold, and discharging current across a gap between said discharge end and the upper surface of the deposited metal while metal is being deposited in said mold, to heat the upper portion of the deposited

metal and maintain it sufficiently fluid to feed continuously the solidifying metal below.

3. A method of casting which comprises depositing molten metal into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion and at a rate substantially equal to the rate of solidification of the deposited metal in said mold, and discharging current across a gap between said lower portion and the deposited metal while metal is teeming from said nozzle to heat the top portion of the deposited metal and maintain it sufficiently molten to progressively hot-top the deposited metal continuously as its level rises with respect to the mold.

4. A method of casting which comprises depositing molten metal into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion and at a rate substantially equal to the rate of solidification of the deposited metal in said mold while said conductive lower portion is submerged in a floating layer of flux in said mold, and discharging current across a gap between said conductive lower portion and the deposited metal while metal is teeming from said nozzle to heat the top portion of the deposited metal and maintain it sufficiently molten to progressively hot-top the deposited metal continuously as its level rises with respect to the mold.

5. A method of casting which comprises depositing molten metal into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion, discharging current across a gap between said lower portion and the deposited metal while metal is teeming from said nozzle to maintain the top portion of the deposited metal in molten state, moving the nozzle and the body of deposited metal relatively apart while metal is being deposited in said mold, and simultaneously controlling the rate of discharge of the metal from said nozzle to maintain said gap substantially constant in length.

6. A method of casting which comprises depositing molten metal into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion, discharging current across a gap between said lower portion and the deposited metal while metal is teeming from said nozzle to maintain the top portion of the deposited metal in molten state, moving the nozzle and the body of deposited metal relatively apart while metal is being deposited in said mold, and simultaneously controlling the rate of discharge of the metal from said nozzle in accordance with the voltage drop across said gap to maintain said gap substantially constant in length.

7. A method of continuous casting which comprises continuously depositing molten metal into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion, withdrawing the solidified metal from said mold, and discharging current across a gap between said conductive lower portion and the deposited metal while metal is teeming from said nozzle to maintain the top portion of the deposited metal in molten state as the solidified metal is being withdrawn from said mold.

8. A method of continuous casting which comprises continuously depositing molten metal into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion, withdrawing the solidified metal from

said mold, discharging current across a gap between said conductive lower portion and the deposited metal while metal is teeming from said nozzle to maintain the top portion of the deposited metal in molten state as the solidified metal is being withdrawn from said mold, and simultaneously controlling the rate of discharge of the metal from said nozzle to maintain said gap substantially constant in length.

9. A method of continuous casting which comprises continuously depositing molten metal from an outside source into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion having its lower discharge end submerged in a floating layer of flux in said mold, withdrawing the solidified metal from said mold while the top portion of the deposited metal is still fluid, discharging current across a gap submerged in said flux between said conductive lower portion and the deposited metal while metal is teeming from said nozzle to maintain the top portion of the deposited metal in molten state, and simultaneously controlling the rate of discharge of the metal from said nozzle in accordance with the voltage drop across said gap to maintain said gap substantially constant in length.

10. A casting apparatus comprising a mold, a nozzle made of substantially non-conductive material extending into said mold to deposit cast metal in said mold, said nozzle including a metallic member encircling the lower end thereof, and means for discharging current across a gap between said metallic member and the body of deposited metal to heat the upper portion of said metal and maintain it in molten condition for feeder purposes.

11. A casting apparatus comprising a mold, a nozzle made of substantially non-conductive material extending into said mold to deposit cast metal in said mold, said nozzle including a metallic member encircling the lower end thereof, means for discharging current across a gap between said metallic member and the body of deposited metal to heat the upper portion of said metal and maintain it in molten condition for feeder purposes, means for moving said nozzle and the body of deposited metal relatively apart as metal is being deposited in said mold to maintain said gap substantially constant in length, and means for varying the rate of discharge from said nozzle automatically in accordance with changes in the length of said gap to maintain said gap substantially constant in length.

12. A casting apparatus comprising a mold, a

nozzle made of substantially non-conductive material extending into said mold to deposit cast metal in said mold, said nozzle including a metallic member encircling the lower end thereof, a receptacle for feeding cast metal into said nozzle, means for discharging current across a gap between said metallic member and the body of deposited metal to heat the upper portion of said metal and maintain it in molten condition, means for moving the body of deposited metal away from said nozzle as metal is being deposited into said mold to maintain said gap substantially constant in length, and means for varying the rate of discharge from said receptacle automatically in accordance with changes in the length of said gap to maintain said gap length substantially constant.

13. A method of casting which comprises depositing molten metal from a tiltable molten metal containing receptacle into a mold through a substantially non-conductive nozzle provided with a conductive external lower portion, discharging electric current across a gap between said conductive portion and the surface of the deposited metal while metal is teeming from the nozzle to maintain the top portion of the deposited metal in a highly heated condition, maintaining said gap and the deposited metal beneath the surface of a depth of protective flux, effecting relative movement between the nozzle and the deposited metal, and simultaneously controlling the tilting of said container in accordance with the voltage drop across said gap to maintain said gap substantially constant in length.

14. A casting apparatus comprising a mold, a nozzle made of substantially non-conductive material extending into said mold to deposit cast metal into said mold, said nozzle including a metallic member encircling the lower end thereof, a tiltable supported receptacle for feeding cast metal into said nozzle for passage into said mold, means for discharging electric current through a gap between said metallic member and the surface of the metal deposited in the mold to supply heat to the upper portion of the deposited metal, means for effecting relative movement between the metal in the mold and said nozzle to maintain said gap substantially constant, and automatic means for tilting said receptacle in accordance with changes in length of said gap to control the rate of discharge of metal from said receptacle as required to maintain the length of said gap substantially constant.

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