July 10, 1945. R. K. HOPKINS 2,380,238

METHOD AND APPARATUS FOR PRODUCING CAST METAL BODIES

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FIG. 1.

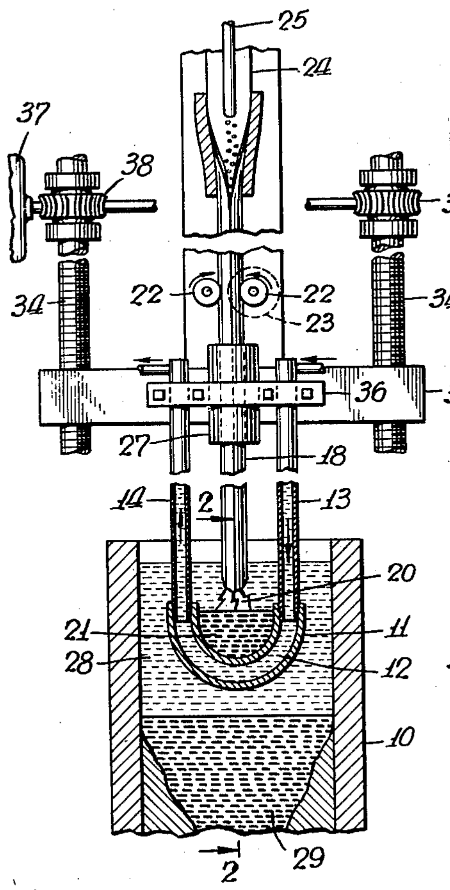

FIG. 3.

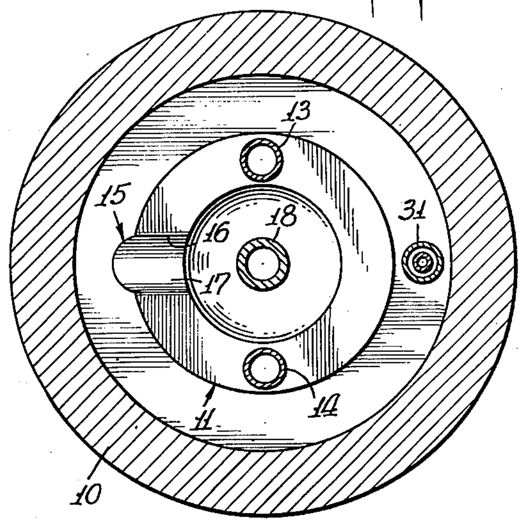

FIG. 2.

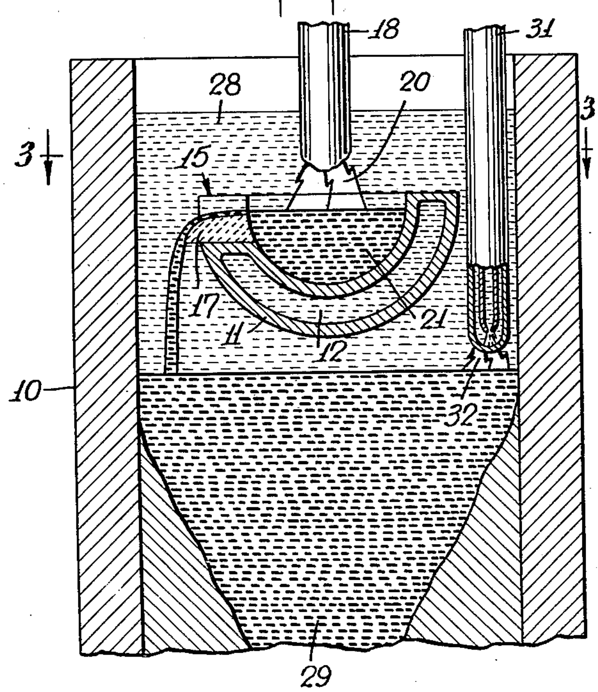

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FIG. 4.

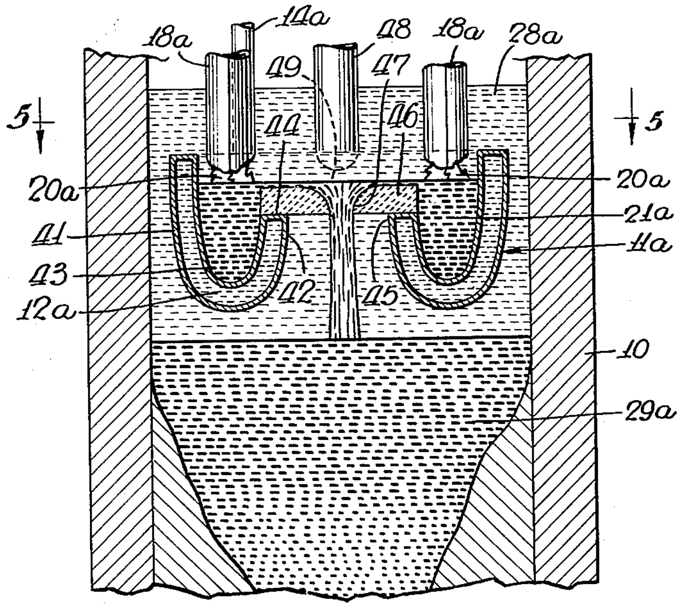
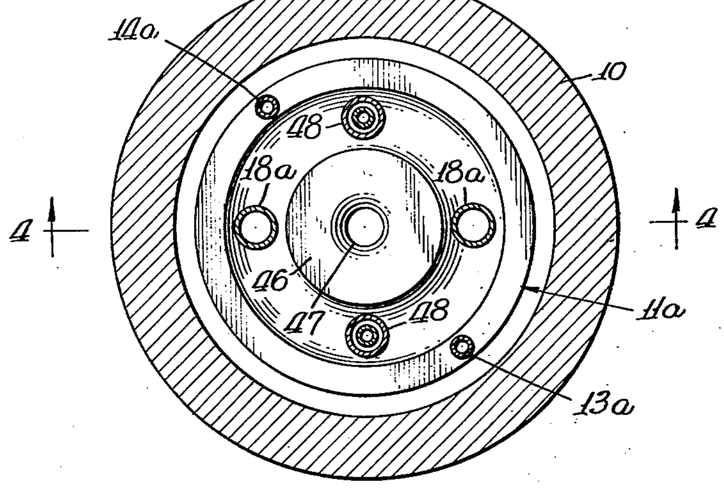


FIG. 5.



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METHOD AND APPARATUS FOR PRODUCING CAST METAL BODIES

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Application January 21, 1944, Serial No. 519,230

9 Claims. (Cl. 22—61)

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 method and apparatus for producing and depositing metal in a mold in a manner to assure complete fusion of the metal ingredients deposited in said mold.

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

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:

Fig. 1 shows somewhat diagrammatically partly in vertical section and partly in front elevation one form of apparatus which may be employed to carry out the method of the present invention, and which embodies the structural features of the present invention;

Fig. 2 is a vertical section taken on the line 2—2 of Fig. 1, but on a larger scale;

Fig. 3 is a horizontal section taken on line 3—3 of Fig. 2;

Fig. 4 shows somewhat diagrammatically in vertical section another form of apparatus which may be employed to carry out the method of the present invention, and which embodies the structural features of the present invention; and

Fig. 5 is a horizontal section taken on line 5—5 of Fig. 4.

In the form of the invention shown in Figs. 1 to 3, there is provided a mold 10 which may be of any suitable shape, according to the desired shape of the metal body to be produced, and which for the purpose of illustration, is shown cylindrical. Mold 10 may be of any suitable material such as cast iron, and is constructed and dimensioned to effect solidification of the deposited metal progressively upwardly and inwardly therein in the manner well-known in the art. Mold 10 is closed at its bottom end, as for example by means of a stool of suitable material, such as cast iron.

For producing metal in the interior of the mold 10, there is provided therein a vessel 11 serving as a furnace or crucible. This crucible 11 may be of any suitable shape, and is shown cup-shaped and specifically in the form of a bowl with a substantially hemispherical cavity. The walls of crucible 11 are hollowed to form a jacket 12 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 the jacket 12 of the crucible wall by an inlet pipe 13 and an outlet pipe 14. These pipes 13 and 14 are desirably diametrically or otherwise symmetrically disposed with respect to the cricible 11, and are connected into said jacket by any suitable means, as for example by threading or welding, or both. The crucible 11 is advantageously suspended and supported in the mold 10 through the medium of these pipes 13 and 14, in a manner to be made apparent.

The crucible 11 is provided with an overflow pouring gate 15 comprising a substantially radial channel 16 in the wall of said crucible, and a runner 17 in said channel desirably of refractory material. When the molten metal deposited in the crucible 11 reaches a predetermined level therein, it overflows through the pouring gate 15 and into the mold 10.

The metal is produced and deposited in the crucible 11 by the use of an electrode device which may be of the general type shown in my U. S. Patents 2,191,479 and 2,191,481. For that purpose, there may be provided a consumable electrode 18 extending in the mold 10 directly above the crucible 11, and containing ingredients of the metal to be produced and deposited in said mold. 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 18, so that these other constituents in conjunction with said electrode produce a metal in the crucible 11 having the required analysis. The electrode 18 and the granular metal constituents are fed at controlled rates to the current discharge gap 20 between the end of said electrode and the pool of molten metal 21 in said crucible by suitable means, as for instance that shown in my Patent No. 2,191,479 above referred to, to produce metal of the desired analysis, and to maintain said gap substantially constant in length.

The controlled downward feeding of the electrode 18 may be effected through a pair of feed wheels 22 on opposite sides of said electrode and in frictional engagement therewith. At least one of these feed wheels 22 is driven from a motor 23 through a suitable reduction gearing, while the other wheel may be positively driven from said motor or may be merely an idler serving as a guide for the electrode 18. This motor 23 may be regulated automatically by the voltage drop across the current discharge gap 20 in any well-known manner, so that the feed wheels 22 are automatically operated and controlled to feed the electrode 18 downwardly as it is continuously consumed. The current discharge gap 20 is thereby maintained substantially constant in length.

The hollow electrode 18 may be continuously shaped from a metal strip or skelp 24 as shown in the aforesaid Patent No. 2,191,479 as said electrode is fed continuously into the metal fusing zone.

The granular metal constituents may be delivered through the hollow of the electrode 18 and into the current discharge gap 20 at controlled rates and at desired proportions by means of metering devices (not shown) that feed it at the desired rate to a funnel tube 25 leading into the electrode 18 as it is formed.

The electrode 18 and the deposited metal 21 in the crucible 11 are electrically connected in the same circuit, so that current as it is discharged from said electrode, passes through the gap 20, and thereby creates a high temperature zone in which the solid metal ingredients are readily fused. The electrical connection to the electrode 18 may be effected, as for example, through a contact nozzle 27, connected to a suitable source of current and embracing said electrode with a snug slide fit loose enough to permit the feeding of said electrode through said nozzle, but tight enough to maintain electrical contact between said nozzle and said electrode.

The electrical connection of the deposited metal 21 into the circuit of the contact nozzle 27 may be effected by grounding the metal walls of the crucible 11 through the water circulating pipes 13 and/or 14.

During metal producing and depositing operations, the crucible 11 is entirely submerged in a floating layer or blanket of flux 28 of any suitable composition, and the lower end of the electrode 18 is submerged in this flux, so that the current discharge gap 20 is also entirely submerged in this flux. Flux 28 refines the metal as it is produced, promotes fusion, and maintains the molten metal from the time it is produced to the time it is deposited in the mold 10 out of contact with the air. Flux 28 also serves as a heat insulating blanket around the crucible 11 and the metal being produced and deposited in the mold 10, thereby allowing the use of extremely high temperatures in the crucible 11 and effecting deposit of the molten metal at this high temperature in the mold 10. For that purpose, this flux may comprise silicates or components of silicates, such as magnesium silicate, calcium silicate, aluminum silicate, glass, or any other composition having the necessary properties to produce the desired effects for carrying out the method of the present invention.

Highly superheated molten metal is continuously produced from the electrode 18 and the other metal ingredients delivered in fluent state into the metal fusing zone in and around the current discharge gap 20; this metal is continuously deposited in the crucible 11. After the metal in the crucible 11 reaches the level of the pouring gate 15 it overflows into the mold 10 as a steady continuous stream under the protective action of the encompassing flux 28, to form the pool of molten metal 29. The molten metal overflows into the mold 10 at a rate substantially equal to its rate of production.

Any solid particles supplied to the current discharge gap 20 which are not fused therein, and which are deposited in the crucible 11 in unfused condition will eventually become fused because of the intense heat concentrated in the comparatively restricted space afforded by the crucible cavity. These unfused particles will not overflow into the mold 10, but will sink towards the bottom of crucible 11. If these particles do not all fuse as they sink in the crucible 11, they will settle and accumulate at the bottom of said crucible to form a pile whose peak will eventually reach a level where the intense heat generated by the electrode 18 will fuse the particles. Delivery of molten metal to the mold 10 free from unfused particles is thereby assured.

As the molten metal overflows the crucible 11, and is deposited in the mold 10, the level of the deposited metal in the mold rises and 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 substantial body of molten metal 29 in the upper portion of the deposited metal in the mold 10 to serve as a shrinkage feeder for the solidifying metal below, heat is continuously transmitted to the upper portion of the deposited metal. In the specific form shown, this heating of the upper portion of the deposited metal 29 is carried out by means of an electrode device comprising an electrode 31 extending into the mold 10 with its lower end submerged in the flux 28, but spaced from the surface of metal 29 by a current discharge gap 32. Electrode 31 is desirably non-consumable, and for that purpose may be of copper hollowed to allow circulation of a cooling medium therethrough, whereby the temperature of said electrode is maintained below its fusion point.

The electrode 31 and the body of deposited metal 29 in the mold 10 are connected in the same circuit to effect a current discharge across the gas 32 of sufficient intensity to maintain said metal fluid for the purpose indicated, and to promote progressive solidification. Non-consumable electrode 31 is desirably disposed diametrically opposite the pouring gate 15 to promote equalization of the temperature of metal 29 and solidification of the metal in the mold 10 substantially symmetrically with respect to the vertical axis of said mold.

The rate of input of heat into the mold metal 29 through the medium of the electrode 31 is desirably so controlled and correlated with respect to the rate of production and deposition of metal in the crucible 11, as to effect progressive solidification of the metal in the mold 10 at a rate substantially equal to said rate of metal production and deposition.

Although only one heating electrode 31 is shown, as far as certain aspects of the invention are concerned, any number of these electrodes can be provided according to the size of the mold 10, and these may be distributed over the surface of the deposited metal 29 in the mold 10 according to any desired pattern.

As the metal producing operation progresses, the level of the deposited metal 29 in the mold 10 gradually rises. It is therefore necessary to move the crucible 11 and the two electrodes 18 and 31 relatively with respect to the mold 10 to maintain a constant positional relationship between said crucible and electrodes on the one hand, and the upper surface of the deposited metal 29 in the mold 10 on the other hand. This relative movement may be effected either by moving the mold 10 continuously downwardly while the crucible 11 and electrodes 18 and 31 are held stationary, or by maintaining the mold 10 fixed in position while said crucible and electrodes are moved continuously upwardly as a unit. In Fig. 1 there is shown for the purpose of illustration means which may be employed to effect the desired relative movement, and which comprise a hoist 35 to which the contact nozzle 27 and the water circulating pipes 13 and 14 for the crucible jacket 12 are fastened, as for example by a clamp 36, and to which the electrode 31 may be similarly fastened. Hoist 35 may be moved vertically by any suitable means, as for example that shown in my U. S. Patent 2,191,478, or may be moved in the manner indicated in the drawings through a pair of vertical feed screws 34 threaded therein and journalled in suitable fixed bearings (not shown) arranged to hold these feed screws against axial movement. The two feed screws 34 are driven in unison and in the same direction through a motor 37, and a speed reducing transmission between said motor and said feed screws. This transmission may comprise worm wheels 38 keyed or otherwise fixed to the feed screws 34 respectively for rotation therewith, and meshing with respective worm wheels on the shaft of the motor 37.

The motor 37 is desirably automatically controlled, to maintain a constant positional relationship between the crucible 11 and electrodes 18 and 31 on the one hand, and the surface of the deposited metal 29 in the mold 10 on the other hand. For that purpose, this motor 37 may be automatically controlled in accordance with the voltage drop across the current discharge gap 32.

The feed device 22 and 23 for the electrode 18 may, if desired, be supported on the hoist 35 as shown. With this construction, the electrode 18 will be moved upwardly with its contact nozzle 27, but will still be subject to the control of the feed wheels 22 according to the voltage drop across the gap 20, or according to any other regulating factor selected, so that the length of this gap will be kept substantially constant.

The use of the crucible 11 permits the production of metal at extremely high temperatures. This highly fluid highly superheated metal as fast as it is produced is deposited as a continuous stream into the mold 10, and during its transfer from the crucible 11 to said mold 10 is maintained under the protective action of the flux 28. The metal, during its transfer to the mold 10, is further refined by the flux 28 and as a result of the heat insulating action of said flux, is added to the pool of molten metal 29 in said mold at substantially the same high temperature it had in the crucible 11. At the same time, the transfer is effected without atmospheric contamination. The metal deposited in the mold 10 is maintained free from air contact during its solidification.

At the beginning of casting operations, the crucible 11 may be empty of metal and submerged in the flux 28 near the bottom of the mold 10. Under these conditions, the metal producing operation in the crucible 11 may be initiated with the electrode 18 sufficiently close to the bottom of said crucible to produce the necessary metal fusing heat. During this initial metal producing stage, the crucible 11 and the mold 10 are kept in fixed relative positions until the molten metal deposited in the crucible 11 begins to overflow the pouring gate 15. During this initial metal producing stage, the feed of the electrode 18 may be under manual control, or may be under the automatic control described. After the overflow of metal from the crucible 11 begins, said crucible can be moved at a controlled rate with respect to the mold 10, as the level of the metal deposited in said mold rises in a manner already described.

If desired, instead of initiating the metal producing operation with the crucible 11 empty of metal and near the bottom of the mold 10, the operation may be initiated with the crucible 11 out of the mold and in the presence of a protective layer of flux in said crucible. When metal to the desired level has been produced in the crucible 11, it may be lowered with its protective layer of flux into and relatively with respect to the mold 10, and the metal producing operation continued with the crucible in said mold.

Where a number of molds are being filled in succession with molten metal, the crucible 11 containing this metal is raised with respect to and out of the filled mold, and may be lowered relatively into the next mold to be filled. As crucible 11 is so raised out of the mold, it carries with it a layer of flux which protects the metal in said crucible against atmospheric contamination while said crucible is being transferred into the next flux containing mold.

In Figs. 4 and 5 is shown another form of apparatus which may be employed to carry out the method of the present invention, and which comprises an endless or annular crucible or furnace 11*a*, desirably of circular shape and disposed in the mold 10. This crucible 11*a* has a circular outer peripheral wall 41 and a circular inner peripheral wall 42 integrally or otherwise rigidly connected concentrically together at the bottom, and forming therebetween an annular cavity 43 substantially bowl-shaped in radial section. The top of the inner crucible wall 42 extends below the top of the outer crucible wall 41, and defines a substantially horizontal circular seat 44 around a central circular opening 45. Resting on and secured to this seat 44 is a circular runner 46, which is desirably of refractory material, and which has a central funnel-shaped discharge opening 47 of circular horizontal section defining a pouring gate for the crucible 11*a*. The upper surface of this runner 46 is below the top of the outer crucible wall 41, so that the molten metal deposited in the crucible 11*a* will overflow the brim of said runner 46 and discharge into the opening 47 when the level of this metal reaches the top of said runner. This overflow metal from the crucible 11a is deposited substantially centrally in the mold 10, so that all the advantages inherent in pouring the metal in said mold in a stream substantially equidistant from all sides of the mold walls is obtained.

The crucible 11a is made of suitable metal of high heat conductivity, such as copper, and its walls are hollowed to define a jacket 12a through which a cooling medium is circulated. This circulation of the cooling medium through the jacket 12a may be effected by means of an inlet pipe 13a and an outlet pipe 14a threaded, welded, or otherwise connected to the crucible walls at diametrically opposite sides thereof.

Molten metal of the required analysis is produced in the crucible 11a desirably by the use of an electrode device similar to that described in connection with the construction of Figs. 1 to 3. For that purpose, one or more consumable electrodes 18a are provided, two being shown, diametrically disposed directly over the crucible cavity 43, and spaced by current discharge gaps 20a above the surface of the deposited metal 21a in the crucible 11a. These electrodes 18a which are connected into the circuit of the molten metal 21a as in the construction of Figs. 1 to 3, contain at least some of the ingredients of the metal to be produced, and are desirably hollow. Other metal ingredients in the fluent form of granules, pellets or powders, are delivered to the metal fusing zones created by the current discharge across the gaps 20a, as for example through the hollows of the electrodes 18a.

The feeding of the electrodes 18a and the fluent metal ingredients into the metal fusing zone may be effected at controlled rates in a manner already indicated in connection with the construction of Figs. 1 to 3.

The molten metal 21a in the crucible 11a, besides being heated by the consumable electrodes 18a, may be further heated by the use of one or more electrodes 48, two being shown diametrically disposed directly over the surface of the deposited metal 21a in quadrant relationship with the electrodes 18a, and spaced from said surface by current discharge gaps 49. These electrodes 48, which are connected into the circuit of the crucible metal 21a, are desirably non-consumable, and are constructed like the electrodes 31 of Figs. 1 to 3.

Instead of employing the heating electrodes 48 in the position shown, as far as certain aspects of the invention are concerned, a single heating electrode may be used, disposed directly over the pouring hole 47 to maintain the overflowing metal highly fluid as it is discharged through said hole, and to prevent thereby freezing of said metal in said hole. This single central heating electrode may replace the two heating electrodes 48 shown, or may supplement the heating action of these latter electrodes.

Also, if desired, as far as certain aspects of the invention are concerned, if the clearance between the crucible 11a and the mold walls permits, one or more non-consumable heating electrodes may be employed between said crucible and said mold walls directly over the metal 29a deposited in the mold 10 to serve the same purpose as the heating electrodes 31 in the construction of Figs. 1 to 3.

The crucible 11a and the lower ends of the electrodes 18a and 48 are submerged in the flux 28a in the manner and for the purpose indicated in connection with the construction of Figs. 1 to 3, and these members are supported for movement in unison with respect to the mold 10a as shown in said construction.

The process illustrated in Figs. 4 and 5 is carried out in the manner already made apparent in connection with the method shown in Figs. 1 to 3, the molten metal being deposited in the mold 10 from crucible 11a at a rate which is substantially equal to the rate of production and deposition of the metal in said crucible.

In the two constructions of Figs. 1 to 5, the furnace or crucible 11 or 11a is disposed in the mold 10. However, as far as certain aspects of the invention are concerned, the furnace or crucible may have its metal producing section outside of the mold 10, and the metal may be transferred from said furnace section to the mold continuously while the metal is being produced in said furnace section. This transfer would be effected at a rate substantially equal to the rate of metal production in said furnace while the metal being transferred is maintained out of contact with the air. Such a construction is shown in my copending application, Serial No. 534,829, filed May 9, 1944.

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 drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A method of casting metal which comprises the steps of producing and depositing metal in a furnace immersed in a layer of flux in a mold, and simultaneously discharging molten metal from said furnace through said layer of flux and into said mold.

2. A method of casting metal which comprises the steps of continuously depositing metal in a crucible immersed in a layer of flux in a mold, and simultaneously overflowing metal from said crucible through said layer of flux and into said mold when the level of metal in said crucible reaches a substantial distance about the bottom of said crucible.

3. A method of casting metal which comprises the steps of continuously depositing metal in a crucible immersed in a layer of flux in a mold, overflowing metal from said crucible through said layer of flux and into said mold, and simultaneously moving said mold and said crucible relatively apart as the level of deposited metal in said mold rises, to maintain a substantial constant positional relationship between said crucible and the surface of said latter metal.

4. An apparatus for casting metal comprising a mold, flux in said mold, a crucible immersed in said flux, means for producing and depositing metal in said crucible below a layer of said flux, and means for discharging metal from said crucible through said flux and into said mold below said flux.

5. An apparatus for casting metal comprising a mold, flux in said mold, a crucible immersed in said flux, and means for continuously producing and depositing metal in said crucible, said crucible having an overflow pouring gate disposed a substantial distance above the bottom thereof, whereby metal deposited in said crucible as it reaches the level of said pouring gate overflows

said gate and discharges through said flux and into said mold below said flux.

6. An apparatus for casting metal comprising a mold, flux in said mold, a crucible immersed in said flux, current discharge electrode means for continuously producing metal under a layer of said flux and depositing it in said crucible, and means for discharging metal from said crucible through said flux and into said mold below said flux.

7. An apparatus for casting metal comprising a mold, flux in said mold, a crucible immersed in said flux, means for continuously producing metal under a layer of said flux and depositing it in said crucible, means for overflowing metal from said crucible through said flux and into said mold below said flux while metal is being produced and deposited in said crucible, and means for moving said mold and said crucible relatively while said metal is being discharged into said mold to maintain said crucible in constant positional relationship with respect to the rising surface of the metal in said mold.

8. An apparatus for casting metal comprising a mold, flux in said mold, a cup-shaped crucible immersed in said flux and having an overflow pouring gate on one side thereof, and means for continuously producing metal in said flux and depositing it in said crucible.

9. An apparatus for casting metal comprising a mold, flux in said mold, an annular crucible immersed in said flux and having an overflow gate positioned substantially centrally of its outer wall a substantial distance above the bottom of said crucible, and means for producing metal in said flux and depositing it in said crucible.

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