Nov. 9, 1926. 1,606,236

A. KADOW

PROCESS AND APPARATUS FOR CASTING LIQUID MOLTEN METAL

Filed March 15, 1926 3 Sheets-Sheet 1

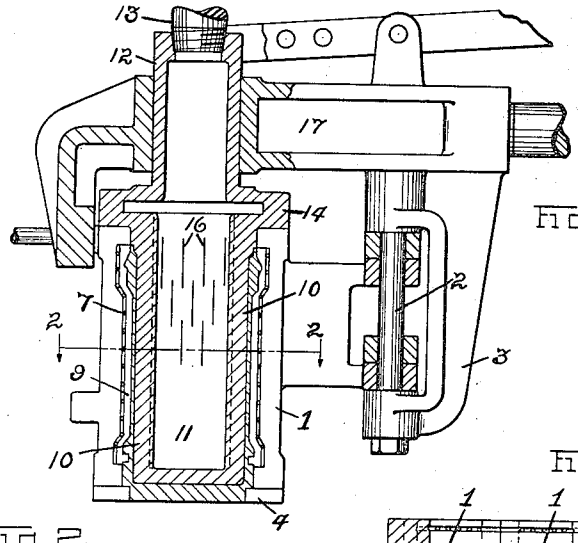


Fig. 1.

Fig. 2.

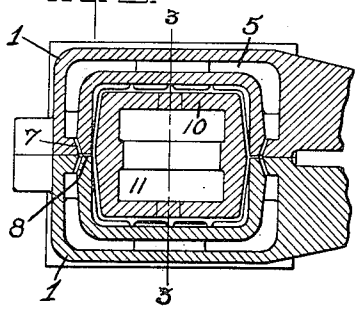


Fig. 3.

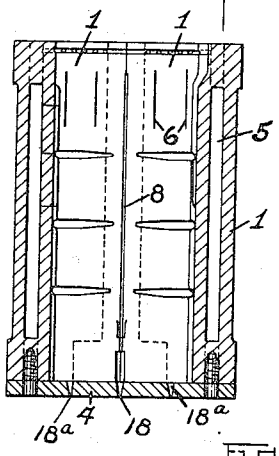


Fig. 4.

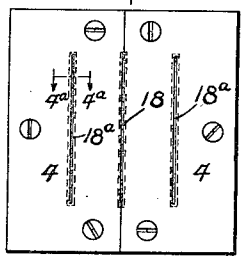


Fig. 4a.

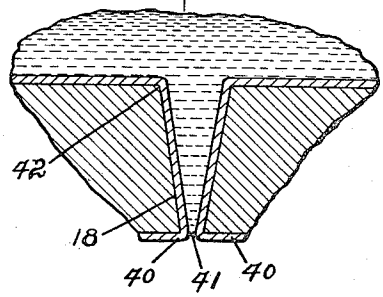
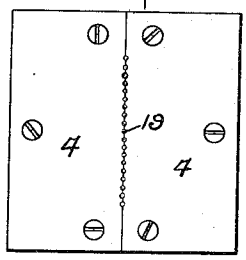


Fig. 5.



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Filed March 15, 1926 3 Sheets-Sheet 2

Fig. 6.

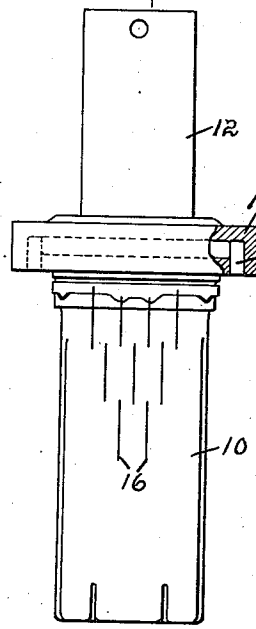


Fig. 7.

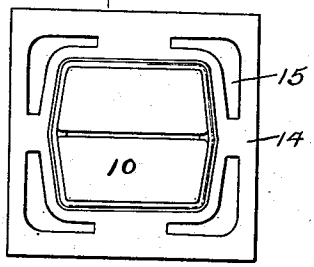


Fig. 9.

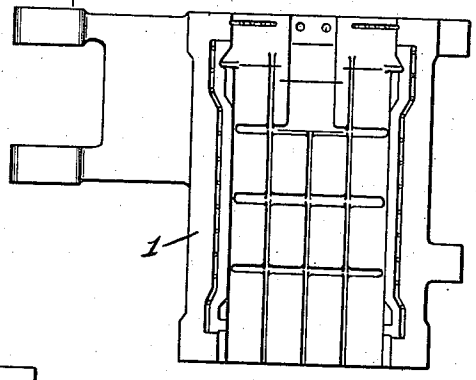


Fig. 8.

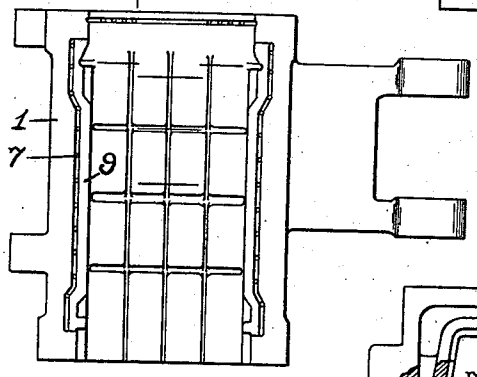
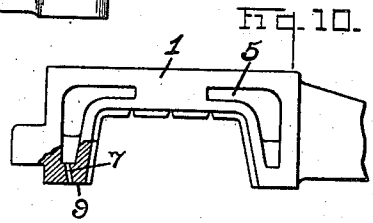


Fig. 10.



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Filed March 15, 1926 3 Sheets-Sheet 3

Fig. 11.

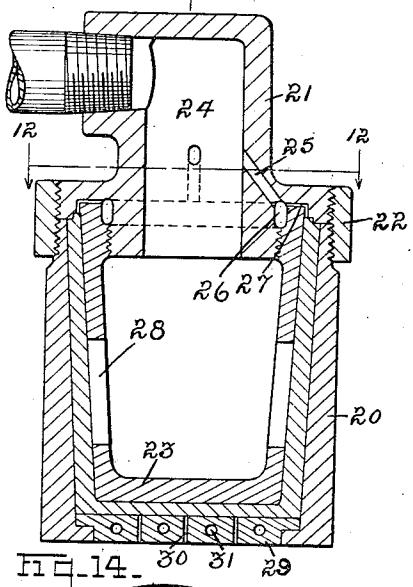


Fig. 12.

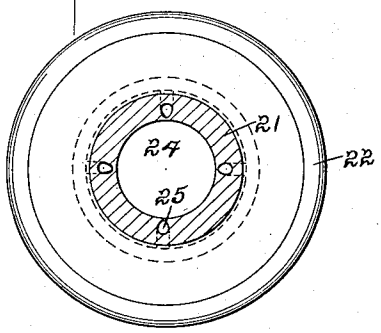


Fig. 13.

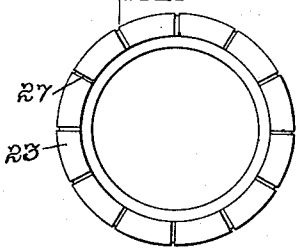


Fig. 14.

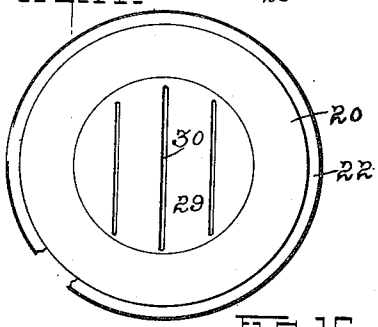


Fig. 15.

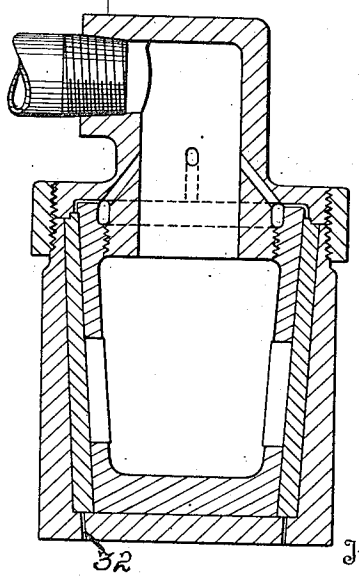
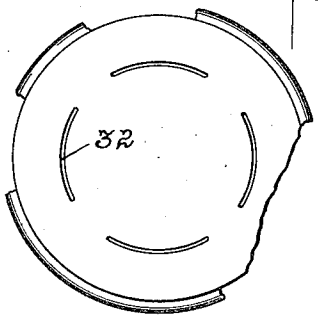


Fig. 16.



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Patented Nov. 9, 1926. 1,606,236

UNITED STATES PATENT OFFICE.

AUGUST KADOW, OF TOLEDO, OHIO, ASSIGNOR, BY DIRECT AND MESNE ASSIGNMENTS, TO THE VACUUM CASTING COMPANY, OF TOLEDO, OHIO, A CORPORATION OF OHIO.

PROCESS AND APPARATUS FOR CASTING LIQUID MOLTEN METAL.

Application filed March 15, 1926. Serial No. 94,712.

This invention relates to the molding of molten materials, and particularly to the molding of metals and other materials that are fluid at molding.

The object of my invention is the provision of simple and efficient means for casting materials of low viscosity at molding temperatures, whereby the material may be perfectly formed into the desired shapes and prevented from running back out of the mold.

It is old to fill a mold with molten glass by dipping the bottom of the mold, containing an inlet opening, in molten glass and exhausting the air from the mold cavity through openings or slits small enough to prevent the glass from passing out with the air, and molds so filled have been removed, immediately after filling, from the source of molten glass. Such a method has not, to my knowledge, been successfully applied to such materials as iron, copper, lead, tin and aluminum, or their alloys, which have low viscosity at the temperatures at which they must be cast or molded.

My invention therefore relates more especially to the casting of metals that are liquid at their casting or molding temperatures, and is particularly directed to the casting or molding of such metals by immersing the inlet opening of the mold in the molten metal and filling the mold by lowering the pressure within the mold cavity below atmospheric pressure, which method I shall hereinafter refer to as the "vacuum method."

I have found by experiment that molds that are suitable for forming glass articles by the vacuum methods are not suitable for forming similar articles of metals having low viscosity at casting temperatures, due to the fact that a portion of the molten metal will immediately flow by gravity out of the mold inlet or inlets as soon as the mold is raised from the molten mass, and that the continued maintenance of the vacuum within the mold cavity will not prevent the escape, which results in the production of worthless or defective castings. This escape of molten metal from the molds is increased when the molds are used at a temperature sufficiently high to prevent the too sudden setting of the metal within the molds.

If an ordinary bottle filled with liquid is inverted, air bubbles rise through the neck and the liquid runs out. If the neck of the bottle is narrowed, a point is reached where the surface tension of the liquid across the neck prevents the entrance of air bubbles and the escape of the liquid.

In the same way, molten metal may be sustained in a mold if the entrance of air into the top of the mold is prevented and any opening in the bottom of the mold is of such size that surface tension of the metal across the opening prevents the entrance of air bubbles. With the opening still further reduced in cross section, surface tension is sufficient to sustain the metal in the mold, even though air be admitted to the upper surface of the metal.

The mold is customarily considerably cooler than the metal being molded. As a result, a layer of metal is immediately solidified against the interior of the mold, including the inlet opening. If the size of the inlet opening is sufficiently reduced, or the mold walls surrounding the inlet or sprue are sufficiently cool, the metal solidified against the walls of the inlet opening may entirely fill the opening and form a plug; or the solidified metal may partly close the opening, so that the portion of the metal in the inlet opening which remains molten is so narrow that its surface tension prevents the entrance of air, or sustains the metal in the mold.

My invention takes advantage of the surface tension of the molten metal across a small sprue opening, or the solidified metal in such an opening, or preferably a combination of the two, to enable the prompt removal from a source of molten metal of a filled mold having a sprue in its bottom, without having the still molten metal in the interior of the mold run out through the sprue opening.

It will be understood that surface tension of molten metal always tends to resist its passage through a narrow opening, and that the resistance increases as the opening becomes narrower. How wide an opening may be and still prevent the passage of molten metal depends upon the kind of metal, its temperature, and the pressure tending to force the metal through the opening.

In order for the surface tension alone to sustain molten metal in a mold, the opening must be made narrow enough for the sur-

face tension of the metal across the opening to overcome the pressure of the metal in the mold above the opening, which depends upon the kind of metal and its depth. A wider opening can be used in practice, both because it is narrowed almost instantly by the film of metal solidified against the interior of the mold, including the opening, and because this solidified film completely surrounds the molten metal in the mold and acts like the walls of an inverted bottle to prevent the entrance of air to the molten portion of the metal.

My invention in its preferred form consists primarily in the provision of a filling inlet or inlets in the form of an opening or a series of openings so narrow in one dimension that the metal to be molded will not flow readily therethrough by gravity, especially when the temperature of the metal is lowered slightly below that at which it is maintained in the pot or tank. These filling openings are preferably made in the form of one or more narrow slots, but they may be in other shapes so long as one dimension thereof is narrow enough to prevent the free flow of the metal therethrough by gravity unaided by other pressure. The pressure tending to force the metal into the mold is easily made greater than that exerted by the head of molten metal above the opening in the filled mold, so that metal may be forced in through an opening narrow enough to prevent the escape of metal due to gravity, or the head of molten metal above the opening, and the width of the slot may be considerably increased, and the entrance of the metal made easier, because of the action of the chilled film, as described above. The size of the openings in their smallest dimension depends somewhat upon the character of the metal being molded and the size and shape of the articles being formed. I have found that in molding articles of lead, openings approximately 1/16th of an inch in width in their narrowest dimension are suitable for thin or hollow articles, the walls of which do not exceed approximately 1/4th of an inch in thickness, but that in molding solid articles of substantial size slightly narrower openings or some additional means for cooling the metal within the openings may be required, depending on the volume of the molten metal in the mold and its tendency to maintain the temperature of the metal in the openings as well as to press downwardly through gravity on the metal in the openings.

My invention further contemplates the use of artificial means for cooling the mold near the edges of the inlet openings, consisting of the circulation of a cooling medium therethrough, such as air, water or other suitable fluid.

The invention is fully described in the following specification, and while, in its broader aspect, it is capable of embodiment in numerous forms, a preferred embodiment thereof is illustrated in the accompanying drawings, in which:

Figure 1 is a central vertical section of a mold embodying the invention with a molded article therein and with parts in full. Fig. 2 is a cross-section thereof on the line 2—2 in Fig. 1, with the molded article removed. Fig. 3 is a section on the line 3—3 in Fig. 2, with the core removed. Fig. 4 is a view of the mold bottom with the parts in assembled position. Fig. 4^a is a section on the line 4^a—4^a of Fig. 4. Fig. 5 is a view of a mold bottom having a plurality of small suction openings in lieu of a slot. Fig. 6 is a side elevation of the core member of the mold with a part broken away. Fig. 7 is a bottom view of the core member. Figs. 8 and 9 are inner side views of the different hinged members or halves of the mold with the mold bottom removed. Fig. 10 is a top view of one of the mold members with a part broken away. Fig. 11 is a central vertical section of a different form of mold embodying the invention. Fig. 12 is a cross section on the lines 12—12 in Fig. 11. Fig. 13 is an upper end view of the mold removed from the suction head. Fig. 14 is a bottom view of the mold. Fig. 15 is a central vertical section of a different form of mold embodying the invention, and Fig. 16 is a bottom view thereof with parts broken away.

Referring to the drawings, 1, 1 designate the two sections or halves of a mold of the suction type, which sections are hinged together for relative opening and closing pivotal movements, the pivot pin 2, in the present instance, being carried by a bracket arm 3 in the customary or any suitable manner. Each mold section 1 is provided with a bottom plate 4, which cooperates with the bottom plate of the other mold section to close the bottom of the mold, except for the provision of one or more suction slots or openings therein through which molten metal may be drawn into the mold by suction. Each mold section 1 has its walls provided with a space 5 adapted to have communication with a source of vacuum and having communication with the cavity or interior of the mold preferably through a plurality of fine or narrow slots or openings 6 in the inner wall of the mold. The space 5 of each mold section also has communication with the mold cavity through a plurality of perforations 7 leading from the space 5 to the inner edges of the respective mold sections where they communicate with a narrow elongated slot or passage 8 opening into the cavity and formed in part by each mold section by recessing the edge thereof, as indicated at 9, Figs. 1, 8 and 10.

The core member 10 of the mold is adapted to fit down into the cavity formed by the mold sections 1, 1, and to cooperate therewith to form an article of predetermined shape from molten metal drawn into the cavity around the core, as well understood in the art. The core 10 is hollow and has the upper end of its cavity 11 extending upward through a stem 12 and communicating through a tube or other passage-forming means 13 with a source of vacuum. The core is provided with a flange 14 adapted to overlap and form a close joint with the upper ends of the mold sections when in closed position and having passages 15 for opening communication between the interior suction space of the core and the suction space 5 of the mold sections through the upper open ends of the spaces 5, which open ends are shown in Fig. 10. The suction cavity 11 of the core has communication with the article-molding space between the mold sections 1 and core through restricted openings or narrow slits 16 in the core wall. The core is carried by a bracket arm 17, which has an opening therethrough for receiving the core stem 12.

The feature of the mold embodying my invention resides particularly in the provision of an inlet opening or openings of such shape and size as to enable metals having low viscosity at molding temperatures, such for instance as iron, lead, copper, aluminum or the like, or their alloys, to be drawn therethrough into the article-forming cavity of the mold and then retained therein or prevented from running back out of the mold when raised from the molten bath or source of supply. This is accomplished by making the suction opening in the mold bottom in the form of a narrow slot 18, or plurality of such slots, or in the form of a plurality of small perforations or openings 19 (Figs. 4 and 5), which openings are so small in at least one dimension that the temperature of the metal within the openings will be quickly lowered through contact with the walls of the openings to an extent sufficient to prevent escape of the metal under the influence of gravity. The slots or holes are preferably provided between the meeting edges of the bottom plates 4 of the mold sections. The number, shape and location of these filling slots or openings may be varied to suit the article to be formed or metal acted on.

The mold may be filled through one slot 18 or row of holes 19 formed between the meeting faces of sections of the mold bottom; or there may be additional inlets, as indicated at 18^a in Figs. 3 and 4. When the mold sections are moved relatively to each other, the narrow fins in slots 18^a are easily sheared off. The shrinkage of the metal in the openings is sufficient to loosen it, so that the sheared-off fins may be easily removed from the openings, preparatory to casting another article.

In the form of the mold shown in Figs. 11 to 14, 20 designates the mold body or cup which is connected to and suspended from a suction head 21 by a union nut 22. A hollow core member 23 is detachably suspended from the suction head and is adapted to project down into the mold member 20 to cooperate therewith to form a mold cavity of desired shape. The suction passage 24 of the head has a plurality of passages 25 leading therefrom to an annular passage 26 in the head, which latter passage is in communication with the upper end of the mold cavity through a plurality of small passages 27. The interior of the core 23 is also in communication with the mold cavity through a plurality of thin slits or openings 28. The bottom of the mold is provided with a removable part 29 in which the desired number of suction slots or openings 30 are provided to suit the molding requirements in accordance with my invention. 31 designates passages through the mold bottom adjacent to the inlet openings 30 to permit a cooling fluid to be directed therethrough from any suitable source if it is desired to artificially chill the mold adjacent to the openings to effect a more rapid setting of the metal within the openings.

The mold shown in Figs. 15 and 16 is substantially the same as that shown in Fig. 11 except that the mold cavity is of a shape to form an article which is open at both ends, the core for such purpose fitting down closely against the bottom of the body member of the mold. In this case the bottom of the mold is provided with a plurality of slots or openings 32 conforming to the invention and arranged in communication with the lower end of the mold cavity, as illustrated.

I have found from experiments that in molding large articles from lead, such for instance as lead battery jars, the best results are obtained by the use of suction slots or holes of approximately 1/16 of an inch in width or diameter, such size being reduced down to 5/1000 of an inch for smaller articles. It is also found that, for ordinary purposes and for rapid molding, the slots or openings should not be greater than 3/32 of an inch in width or diameter, although it will be understood that extreme conditions may make possible the use of slots narrower than 5/1000 of an inch or wider than 3/32 of an inch. In the use of my mold, when used in connection with the molding, for instance, of lead, which melts at approximately a temperature of 600° F., good results are obtained with the mold at approximately 200° F. This may be varied, however, without departing from the spirit of

the invention, but the mold should be kept hot enough to prevent chilling of the metal before the mold cavity has been fully filled and it is preferable not to allow it to become so hot as to destroy the chilling effect of the mold on the thin film of molten metal remaining within the filling openings upon removal of the mold from the molten metal supply.

While the inlet may be chilled so that the metal is solidified entirely across the inlet opening, or the inlet end of the mold where it is most subject to the heat of the molten metal may become so hot that films of solidified metal do not form on the sides of the opening, it is preferable to have the condition of the metal at the time the mold is removed from the bath substantially as shown in Fig. 4ª.

In this figure it will be noted that the molten metal has been chilled to form a thin film 40 of solidified metal against the walls of the mold and that the opening 18 is of such a width that the solidified metal 40 on the two sides of the opening leave a narrow slot 41 between them where the metal is sustained by air pressure, it being understood that film or shell 40 completely encloses the molten metal except at point 41. This remaining exposed portion 41 of the molten metal is so narrow that the pressure of air from beneath does not break the surface tension and cause bubbles to arise through the metal.

In the form of slot shown, particularly in Figs. 3, 4 and 4ª, the slot is narrower where it contacts the metal bath than it is at the upper point 42 where it reaches the casting. There is an advantage in shaping the slot in this manner because it somewhat reduces the speed of the metal entering the mold and so reduces the danger of forming hollows in the casting due to the spurting of the metal through the slot into the mold. However, I make no claim to this feature of the mold in this application as that is claimed in my co-pending application Serial No. 94,716 filed of even date herewith.

While I have referred to "metal" in the above description, and, for convenience, refer to "metal" in many of the appended claims, it will be readily understood that substances not usually considered metals may be treated in accordance with my invention where such substances have the necessary characteristics, such as low viscosity when in condition for casting. Therefore, the term "metal," as used in the specification and claims, is intended to cover all materials having the characteristics of metals for purposes of casting.

I claim—

1. A mold for liquid molten metals, the mold having an inlet opening for the metal, which opening in one dimension is of a size to prevent the metal flowing by gravity therethrough when the mold is disconnected from the source of supply of metal immediately after filling is completed, and while the main body of the metal in the mold is still liquid.

2. A suction mold for liquid molten metals, the mold having a plurality of inlet openings for the metal, which openings are of such size and shape as to prevent the metal flowing by gravity therethrough when the mold is disconnected from the source of supply of metal immediately after filling is completed, and while the main body of the metal in the mold is still liquid.

3. A mold for liquid molten metals, the mold having an inlet slot for the metal which slot is so narrow as to prevent the metal flowing by gravity therethrough when the mold is disconnected from the source of supply of metal immediately after filling is completed and while the main body of the metal in the mold is still liquid.

4. A suction mold for liquid molten metals, the mold having an inlet opening for the metal, which opening in one dimension is of a size to prevent the metal flowing by gravity therethrough when its temperature is lowered slightly below its molten working state.

5. A suction mold for liquid molten metals, the mold having a plurality of inlet openings for the metal which openings are of such size and shape as to prevent the metal flowing by gravity therethrough when its temperature is lowered slightly below its molten working state.

6. A suction mold for liquid molten metals, the mold having an inlet slot for the metal which slot is so narrow as to prevent the metal flowing by gravity therethrough when its temperature is lowered slightly below its molten working state.

7. A suction mold for liquid molten metals, the mold having an inlet opening for the metal in a wall thereof, which opening in one dimension is of a size to prevent the metal flowing by gravity therethrough when its temperature is lowered slightly below the molten working state, the mold wall having provision for cooling the same adjacent to the opening.

8. A suction mold for liquid molten metals, the mold having a suction opening therein not to exceed three thirty-seconds of an inch in one dimension.

9. A suction mold for liquid molten metals, the mold having an inlet opening for the metal not to exceed three thirty-seconds of an inch in one dimension and being not less than approximately five-thousands of an inch in such dimension.

10. A suction mold for liquid molten metals, the mold having an inlet slot of not

more than three thirty-seconds of an inch and not less than five-thousands of an inch in width.

11. A suction mold for liquid molten metals, the mold having an inlet slot for the metal which is approximately one-sixteenth of an inch in width.

12. The method of molding liquid molten metal, which consists in filling the mold cavity with liquid molten metal introduced through an opening below the upper part of the cavity in said mold, and disconnecting the mold from the source of supply of metal immediately after filling is completed and while the main body of the metal in the mold is still liquid.

13. The method of molding liquid molten metal, which consists in filling the mold cavity with liquid molten metal introduced through an opening below the upper part of the cavity in said mold, disconnecting the mold from the source of supply of metal immediately after filling is completed and while the main body of the metal in the mold is still liquid, and utilizing surface tension to prevent escape of the molten metal through said opening.

14. The method of molding liquid molten metals, which consists in filling the metal into a mold through an opening below the upper part of the mold cavity, the opening being of short cross-section in one direction, disconnecting the mold from the source of supply of metal immediately after filling is completed and while the main body of the metal in the mold is still liquid, and preventing the escape of molten metal through said opening by means of surface tension of the metal and chilled films of metal on the sides of the opening.

15. The method of molding liquid molten metals, which consists in sucking the metal through one or more openings into a mold having a lower temperature than the molten metal, the openings being so narrow in one dimension that the temperature of the metal will be sufficiently lowered by contact with the mold as not to flow from the openings by gravity.

16. The method of molding liquid molten metals, which consists in sucking the metal into a mold through an opening in a wall thereof, the opening being so narrow in one dimension and the temperature of the wall surrounding the opening being sufficiently lower than that of the molten metal in its working state that the metal will be quickly lowered in temperature to such extent as to prevent it from flowing by gravity through the opening.

17. The method of molding liquid molten metals, which consists in sucking the metal into the mold through an opening in a wall thereof, the temperature of the wall in surrounding relation to the opening being artificially lowered to such a degree and the size and shape of the opening being such that the metal will be quickly lowered in temperature to such extent as to prevent it from flowing by gravity through the opening.

18. The method of molding liquid molten metals, which consists in sucking the metal into a mold through a plurality of openings therein, the temperature of the mold wall surrounding the openings being such and the openings being so narrow in one dimension that the metal passing therethrough will be quickly lowered in temperature to such extent as to prevent it from flowing by gravity through the opening.

19. The method of molding liquid molten metals, which consists in forcing metal into a mold through a narrow slot while maintaining a difference between the pressure on the metal supply and the pressure within the mold greater than the pressure which will be exerted by the weight of molten metal above the opening in the filled mold, and separating the mold from the source of supply of molten metal immediately after filling is completed, the opening being of great enough dimension in one direction that surface tension across the opening will be overcome by the said differential pressure and narrow enough in the same dimension that molten metal will not flow out of it when the filled mold is removed from the source of supply of molten metal.

In testimony whereof I have hereunto signed my name to this specification.

AUGUST KADOW.