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CONTINUOUS CASTING MOLD VENTING APPARATUS

Filed Oct. 22, 1963

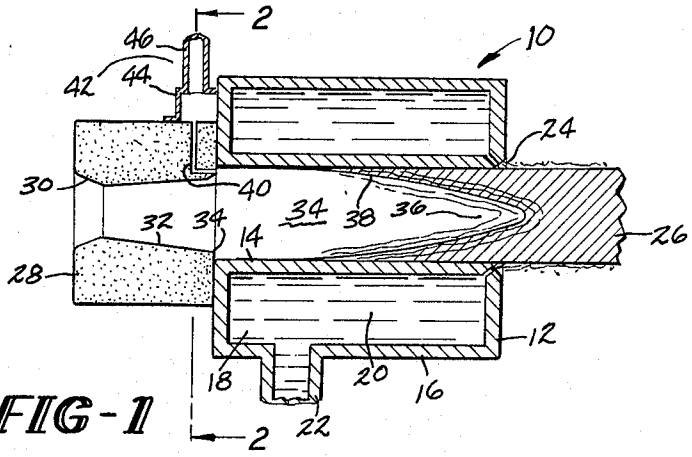


FIG-1

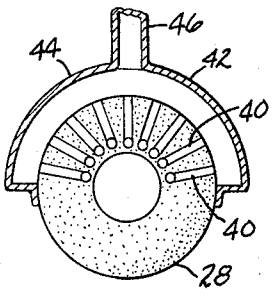


FIG-2

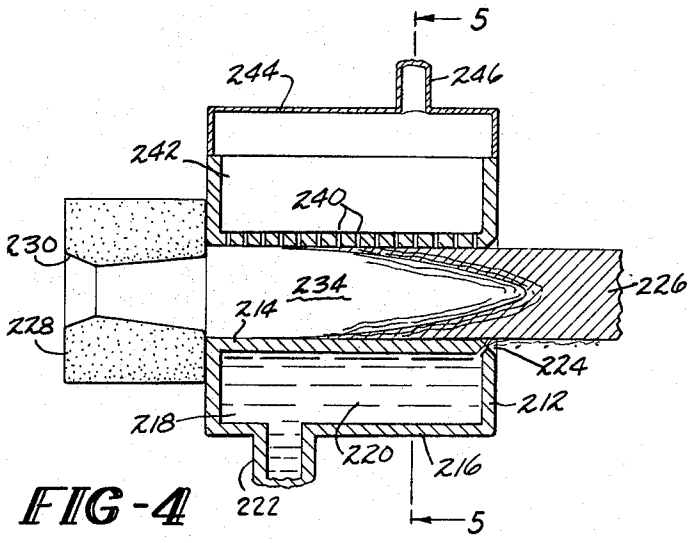


FIG-4

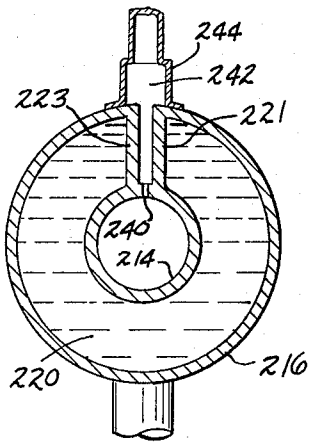


FIG-5

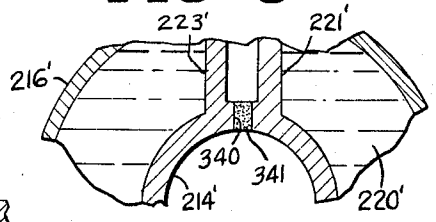


FIG-6

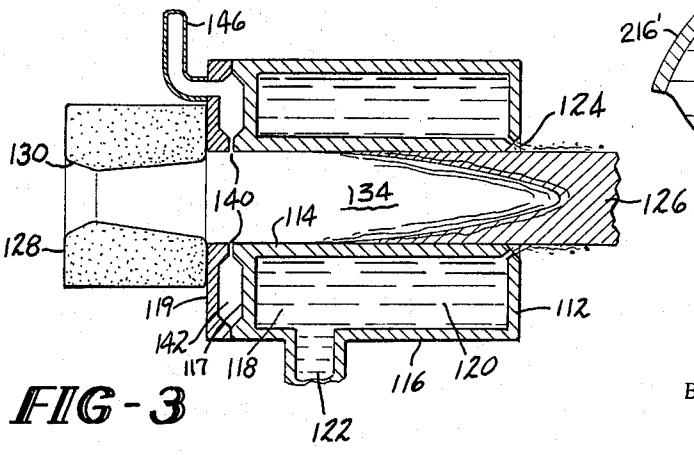


FIG-3

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CONTINUOUS CASTING MOLD VENTING APPARATUS

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This invention relates to improvements in apparatus and method of continuous casting of metals and more particularly to an improved continuous casting mold which provides for the escape of gases or vapors created during the casting process, and to the method of vapor removal.

In the art of continuous casting, many advantages have been derived by disposing the longitudinal axis of the mold in a horizontal orientation so that the casting of the ingot takes place in a horizontal direction from the inlet end of the mold to the outlet end thereof. One of these is that in casting continuously, ingots of great length can be formed without the need for deep pits or other facilities which would be required to receive or handle vertically oriented lengths of ingot. Also, horizontal casting facilities higher production speed as a result of the elimination of casting interruptions inherent in vertical casting techniques due to the finite lengths of ingot which can be formed without removal of these lengths from the casting apparatus.

Production speed, with acceptable quality being understood, is the most important test of a casting process in industrial application. Efforts to increase the output from a casting machine and/or to reduce the manpower needed to make a given quantity of cast metal are important for the economic feasibility of a particular casting machine or process.

One of the primary factors preventing attainment of higher casting speeds in the horizontal continuous casting of aluminum alloys and other non-ferrous metals is non-uniform heat removal in the mold. This problem has been traced to a vapor barrier or bubble in the top of the mold cavity which is formed by the vaporization of mold lubricant and/or entrapment of air at the start of the cast. The vapor barrier greatly reduces heat transfer from the molten metal to the mold wall and produces a nonsymmetrical solidification front and a weak zone in the top of the forming embryo ingot shell. Casting speed, of course, is limited by the ability of this shell to contain the still liquid metal at the center of the casting as the ingot emerges from the mold.

It is well known in the casting art that one of the principal causes of failure in the continuous direct chill casting of metal is the friction between the work and the casting die, and/or wetting of the casting die by the molten metal which produces welding of the ingot shell to the mold and gauling. It is accordingly a conventional practice to apply a lubricating medium, generally oil, to the interface between the ingot shell and mold during the solidification stage of the casting process. A great variety of processes and apparatuses are present in the casting art for applying the lubricant to the ingot-mold interface at some point within or adjacent to the casting mold. The amount of lubricant used and the point of introduction are both critical factors in conventional processing, and little or no casting difficulty is encountered if these factors are very closely controlled. However, such close control is difficult to maintain and frequently cannot be achieved due to the many variable circumstances which enter into casting practice. The difficulty, of which it is the basic object of this invention to overcome, is the creation of the aforementioned vapor barrier or bubble formed by the almost instantaneous vaporization of an excess of lubricant when it contacts the extremely hot surface of the forming ingot, or when lubricant is not introduced at the correct point. The removal of the top gaseous layers in the mold resulting from this lubricant vaporization, or from air entrapment in the mold by the molten metal at the start of casting, broadens the range of operating parameters and makes lubrication less critical, and is essential for uniformity of heat removal in the horizontal casting process. It has been found that a thin gas layer, even on the order of a thousandth of an inch in thickness, can be a controlling resistance to heat conduction and extraction.

This invention provides improved mold constructions which allow the horizontal continuous casting of aluminum alloys and other non-ferrous alloys at speeds substantially higher than those presently possible. These constructions provide for escape of vapor gases trapped in the mold cavity to insure uniform heat removal from the molten metal to the mold wall thereby resulting in a more symmetrical solidification of the forming embryo ingot shell.

The mold designs of this invention comprise generally an elongate mold of varying cross section having a mold cavity an inlet for molten metal at one end and an outlet for the solidified ingot at the other. The mold cavity is surrounded by a chamber or area for the association therewith of a cooling means, which may take the form of spray quenching apparatus or a simple cooling medium circulation means, either of which facilitates a high rate of heat removal from the mold wall which in turn induces rapid solidification of the molten metal within the mold cavity. Means are provided to control the rate of flow of molten metal into the mold, and means are also provided for withdrawing the solidfied ingot from the discharge end of the mold.

The improvement of this invention consists generally of providing an escape route for the gases or vapors that accumulate in the mold cavity. This escape route is preferably located around or adjacent the upper portion of the mold, and at least at the inlet end thereof, and comprises generally a ported distribution nozzle or ported mold wall, either of which communicates with a vapor collection plenum which in turn connects with a vacuum system to assist in the removal of vapors collected in the plenum.

Having thus described the invention in a general manner, it is a primary object thereof to provide a mold design for continuous casting apparatus which eliminates the aforementioned vapor barrier problem and thus allows substantially higher casting speeds.

It is another object of this invention to provide a horizontal continuous casting mold which will eliminate even an extremely thin gas film surrounding the solidifying ingot so as to improve ingot to mold heat transfer and consequently increase casting speeds.

It is yet another object of this invention to provide a horizontal continuous casting apparatus which provides a vapor escape route for vapors or bubbles created in the mold by vaporization of mold lubricant and/or entrapment of air.

It is still another object of the present invention to provide a horizontal continuous casting apparatus having vapor escape means communicating directly with the ingot-mold interface at the location of highest vapor or air concentration.

It is still another object of the present invention to provide a horizontal continuous casting apparatus in which a vacuum system is in communication with the areas of highest vapor concentration within the mold to facilitate the vapor removal.

It is still another object of the present invention to provide horizontal continuous casting apparatus which is

simple in construction, efficient in operation and economical to manufacture and maintain.

It is still another object of the present invention to provide a method of continuous casting which achieves removal of vapor or gases created in the casting process.

These and other objects and advantages of the invention will be more readily apparent from a consideration of the following detailed description when read in conjunction with the accompanying drawings, in which:

FIGURE 1 is a vertical sectional view of one embodiment of the invention illustrating the mold and vapor release means during the solidification stage of the casting process;

FIGURE 2 is a vertical sectional view taken on line 2—2 of FIGURE 1;

FIGURE 3 is a view similar to FIGURE 1 illustrating another embodiment of the invention;

FIGURE 4 is a view similar to FIGURES 1 and 3 illustrating still another embodiment of the invention;

FIGURE 5 is a vertical sectional view on the line 5—5 of FIGURE 4; and

FIGURE 6 is a partial sectional view similar to FIGURE 5, illustrating a further embodiment thereof.

Referring now to FIGURES 1 and 2, wherein one embodiment of the invention is illustrated, the reference numeral **10** indicates generally a horizontal casting apparatus comprising a substantially cylindrical hollow casting mold **12** having inner and outer walls **14** and **16**, respectively, which define a chamber **18** for the circulation therein of a cooling medium **20**. Generally, the cooling medium is water, either at room temperature or at some elevated temperature depending upon various characteristics of the casting process, although other cooling media may be used. The cooling medium **20** enters through an inlet port **22**, circulates within the chamber **18** and all or a portion of it is withdrawn through an exit port (not shown).

The discharge end of the casting mold **12** is provided with a plurality of apertures **24** through which a portion of the cooling medium passes and comes into direct contact with the outer surface of the newly solidified ingot **26**, thereby providing a direct cooling effect on this portion of the still hot ingot. If desirable additional cooling or quenching apparatus, such as spray nozzles, may be distributed around this portion of the ingot to provide more or less cooling effect thereon in accordance with the requirements of the particular quenching process being utilized.

The mold **12** is further provided with a ported distribution nozzle **28** having a molten metal inlet end **30** for the introduction of the molten metal into the casting mold. The distribution nozzle **28** has an outwardly tapered surface **32** which terminates at **34** adjacent the inlet end of the casting mold **12**. It will be observed from FIGURE 1 that the terminal portion **34** has an outward flare or taper which is much steeper in degree than the tapered surface **32** which extends over a major portion of the length of the distribution nozzle **28**. It is to be understood that this nozzle configuration is merely illustrative of a variety of nozzle designs which may be utilized with the present invention.

Molten metal is fed into the distribution nozzle through any suitable flow control means, and passes from the distribution nozzle into the mold chamber **34** defined by the interior surface of the inner mold wall **14**. As the molten metal passes through this chamber, solidification thereof commences adjacent the inner surface of the mold wall **14** and continues through the mass of molten metal toward the center thereof, thereby forming the crater **36** of molten metal surrounded by an annular shell **38** of solidified metal.

In order to provide an escape route for the gases or vapors that accumulate in the mold chamber or cavity, nozzle **28** is provided with a plurality of radially extending vapor escape ports **40** which connect interiorly in the

flared portion **34** of the distribution nozzle located immediately adjacent the inlet end of the casting mold **12**, and which extend rearwardly therefrom for a short distance and then outwardly to the outer surface **42** of the distribution nozzle. As will be seen from FIGURE 2, the ports **40** are distributed radially around approximately the upper half of the distribution nozzle, although more or less of the circumferential extent of the distribution nozzle may be provided with vapor escape ports depending upon the amount of lubricant used, the point or method of introduction, and extent of vaporization of mold lubricant or gas or air entrapment encountered in the particular casting apparatus to which the invention is applied.

While the escape ports **40** may in some instances be sufficient of themselves to provide adequate vapor removal, it is desirable to assure removal of as much as possible of the vapor or gases in order to reduce to a minimum, if not eliminate, the heat transfer barrier which the vapor or gases create. To facilitate vapor removal, the escape ports **40** communicate with a collection plenum **42** which illustratively comprises a semicylindrical hood **44** having outlet means **46** adapted to be connected to a vacuum system providing a reduced pressure within the collection plenum of approximately 5 to 125 millimeters of mercury below atmospheric pressure. The molten metal static head, the amount and type of lubricant used, and the point of lubricant introduction into the mold are among the factors which determine the extent of vacuum maintained in the plenum.

It should be noted that the ports **40** must be of such a size that the surface tension of the molten metal will be sufficient to prevent the metal from entering the ports and either solidifying therein, thereby blocking the passage of vapors to the collection plenum **42**, or being drawn by the reduced pressure into the collection plenum **42** and solidifying therein. At the same time, the ports **40** must not be of such small size as to prevent free passage of the vapors from the mold cavity to the collection plenum **42**.

The extent of sircumferential coverage of the ports **40**, the number provided, and the diameter of the ports are all variables which are determined by the vapor circulation or gas or air entrapment characteristics of the particular casting apparatus being utilized. Accordingly, these features of the vapor escape means will vary from one installation to another.

A second embodiment of the invention is illustrated in FIGURE 3 in which the mold is constructed to have the vapor escape means as an integral part of the mold. More specifically, the mold **112** is again divided with interior and exterior concentric walls **114** and **116**, respectively, to provide a circulation chamber **118** for the cooling medium **120** which enters through the port **122** and circulates within chamber **118** and exits, at least in part, through ports **124** to provide direct cooling effect upon the solidifying portion of the ingot **126**. Molten metal is introduced into the mold through distribution nozzle **128**, the inlet end of which **130** is associated with appropriate flow control means.

In this embodiment of the invention the inner wall **114** is provided with a continuous slot or annulus **140**, or, if desirable, an annular series of closely spaced radially extending apertures, which communicates between the mold cavity **134** defined by the inner surface of wall **114** and a collection plenum **142** defined by extensions of inner and outer mold walls **114** and **116**, an annular partition wall **117** and the end wall **119** of the mold **112**. The collection plenum **142** is connected by means of outlet **146** to a suitable vacuum system as described above in connection with FIGURES 1 and 2. The annulus or slot **140** may be continuous around the mold wall **114**, or it may be confined to as little as the top 60° of the mold, again depending upon the same factors mentioned above regarding the circumferential extent of ports **40** in distribution nozzle **28**. It should also be noted that the an-

nulus or slot **140**, or the apertures as the case may be, must be of such a size that surface tension of the molten metal will prevent entry thereof into the slot or passage therethrough into the collection plenum in order to prevent the deleterious effects which this would have upon the vapor escape means and upon the casting itself.

Still another embodiment of the invention is illustrated in FIGURES 4 and 5 which includes casting mold **212** having inner and outer concentric walls **214** and **216**, respectively, defining the circulating chamber **218** for a cooling medium **220** which enters through entrance port **222** and exits through the apertures **224** for direct cooling of the solidifying portion of ingot **226**. Distribution nozzle **228** receives molten metal at its inlet end **230** from a flow control means and discharges the molten metal into the inlet end of mold **212**.

The vapor escape means of this embodiment comprises a series of closely spaced ports or holes **240** which are disposed in a single row located in the uppermost part of the mold and extending substantially from one end of the casting mold to the other. This vapor escape route may also, if desirable, take the form of a continuous slot rather than the series of holes illustrated in FIGURE 4. The holes or slot communicate between the interior of the mold cavity and a collection plenum **242** which is defined in part by a hood **244** mounted on the upper portion of exterior mold wall **216**, and in part by a pair of upstanding longitudinally extending walls **221** and **223** respectively which interrupt the continuity of the circulation chamber **218** along the upper portion of the mold **212**. The collection plenum **242** is provided with an outlet port **246** which is suitably connected to a vacuum system in order to maintain a reduced pressure in the collection plenum to assist in the removal of vapors and gases.

It is to be noted that this embodiment of the invention offers an advantage over those previously described in that it allows vapor to be collected along the entire length of the mold. Thus, no isolated bubbles or vapor pockets can be formed and exist some distance from the inlet end of the mold and not be accessible to the vapor escape ports located at the inlet end of the mold. Also, in the case of the slot, problems associated with the entry and freezing of metal in the vapor escape ports is minimized. Since the slot is parallel to the direction of casting, any metal that flashes into the slot will be withdrawn with the ingot thus making the slot self cleaning.

It should again be remembered that the holes **240**, or in the alternative the continuous slot, must be small enough to prevent the entry of molten metal therein.

Further modifications which are deemed to be within the scope of the invention are suggested by reference to the accompanying drawings. For example, referring to FIGURE 1 in place of the ported distribution nozzle shown therein, a non-ported nozzle may be substituted which is fabricated from a porous material, the material being of such porosity that the accumulated vapors or gases will pass therethrough but molten metal will not. Additionally, a porous metal ring or insert may be placed within the upper portion of the nozzle **28** of FIGURE 1 in place of the apertures **40** in order to provide a vapor escape route, in which case the nozzle **28** would be fabricated of non-porous material.

In either of these embodiments, a collection plenum is utilized to facilitate removal of the vapors, the plenum, in the case of the porous nozzle, covering substantially the entire nozzle.

Among the materials suitable, either for the porous nozzle or for the porous insert or ring for use with a non-porous nozzle are the following: porous carbon, cellular silicon carbide, other cellular or porous ceramic and refractory materials resistant to melting and attack by molten metals.

Referring to FIGURES 3 and 4 it is also contemplated that a porous metal insert be substituted for the continuous annulus **140** of FIGURE 3 or the row of holes **240** of FIGURE 4. The latter expedient is illustrated in the enlarged partial sectional view of FIGURE 6, analogous to FIGURE 5 with analogous structure **214, 216, 220, 221,** and **223** indicated by the same reference characters primed. Instead of employing holes **240**, there is provided a continuous slot **340**, in which may be situated a suitably shaped porous metal insert **341**.

It will be apparent from the foregoing description and accompanying drawings that there has been provided an improved mold for high speed horizontal continuous casting which is believed to provide a solution to the foregoing problems and achieve the aforementioned objects. It is to be understood that the invention is not limited to the illustrations described and shown herein which are deemed to be merely illustrative of the best modes of carrying out the invention, and which are susceptible of modification of form, size, arrangement of parts and detail of operation, but rather is intended to encompass all such modifications as are within the spirit and scope of the invention as set forth in the appended claims.

What we claim and desire to secure by Letters Patent is:

1. Casting apparatus comprising:

(A) an elongate mold having a wall defining a molten metal solidification cavity therewithin, said mold having

(1) an inlet and an outlet end and

(2) cooling means disposed in heat transfer relationship with said cavity for rapidly inducing solidification of molten metal within said cavity,

(B) a distribution nozzle associated with said inlet end of said mold,

(C) vapor escape means disposed in said mold and communicating between said mold cavity and ambient atmosphere for removing vapor or gases from said solidification cavity formed during solidification of molten metal therewithin whereby said cooling means is in more effective heat transfer relationship with said solidifying metal, and

(D) a collection plenum communicating with said vapor escape means and maintained at a subatmospheric pressure, said collection plenum comprising an elongate chamber overlying said vapor escape means and traversing the longitudinal extent of said mold cavity, said chamber being defined by integral radial extensions of said mold wall.

2. Casting apparatus as set forth in claim **1** wherein said vapor escape means comprises a passageway extending through said mold wall and communicating with at least said inlet end of said mold cavity.

3. Casting apparatus as set forth in claim **2** wherein said passageway comprises a plurality of longitudinally aligned holes formed in an upper portion of said mold wall.

4. Casting apparatus as set forth in claim **2** wherein said passageway comprises a longitudinally extending slot disposed in the uppermost portion of said mold wall.

5. Casting apparatus as set forth in claim **2** wherein said passageway comprises a longitudinally extending porous metal insert disposed in the uppermost portion of said mold wall.

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