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PROCEDURES AND APPARATUS FOR CONTINUOUS CASTING OF METAL INGOTS

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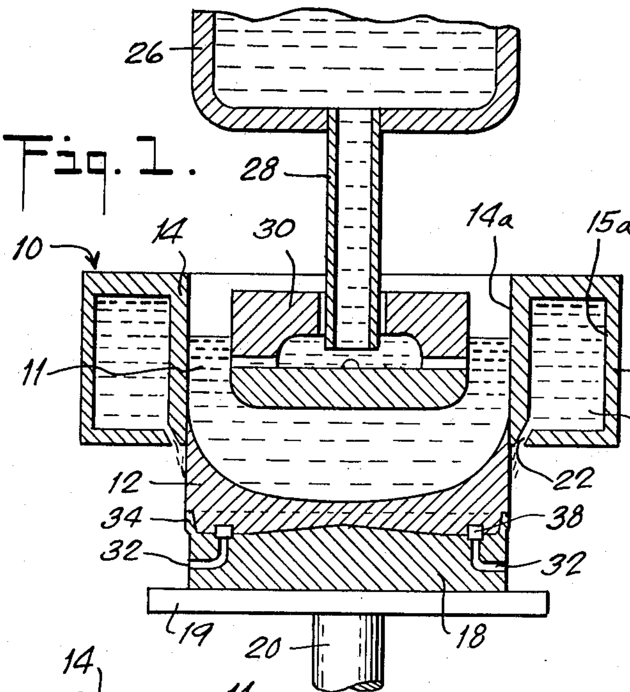

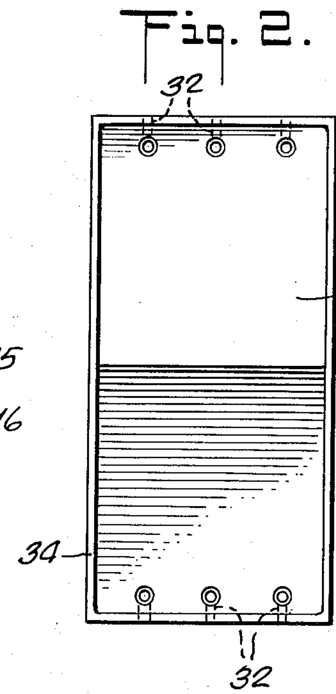

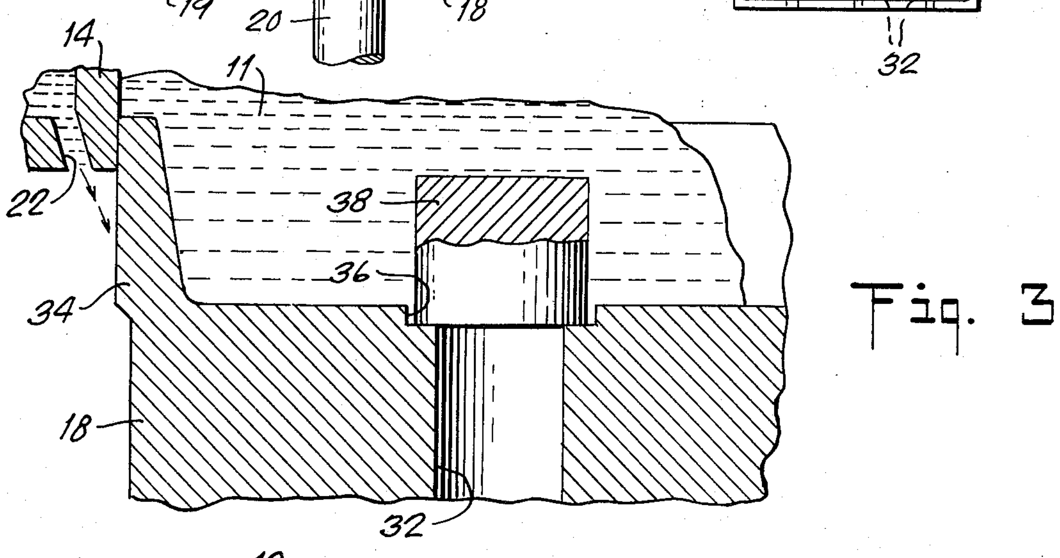

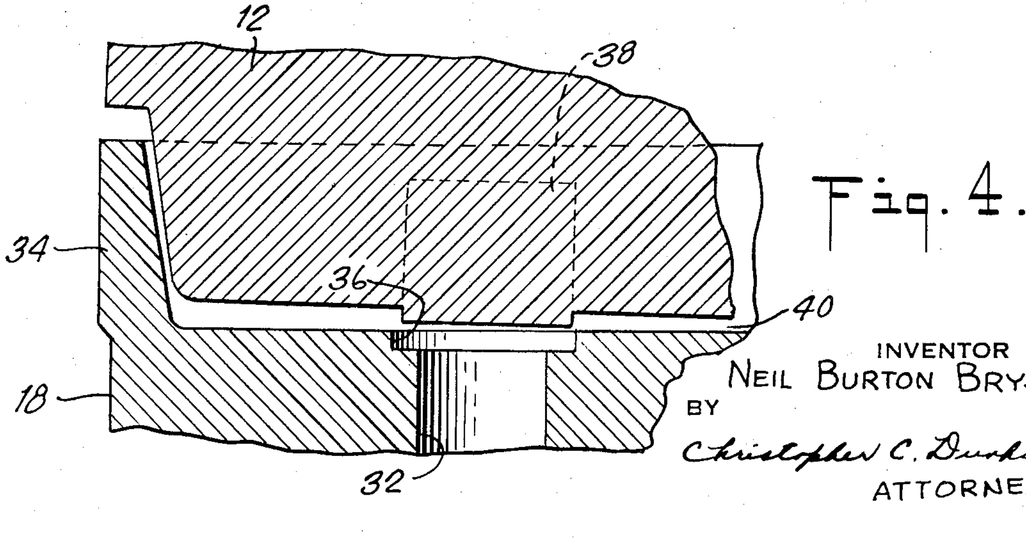

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PROCEDURES AND APPARATUS FOR CONTINUOUS CASTING OF METAL INGOTS

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ABSTRACT OF THE DISCLOSURE

In continuous casting of metal ingots by delivering molten metal to an open-ended mold while withdrawing cast ingot continuously from the open mold end and while directing liquid coolant onto the ingot surface emerging from the mold, the extremity of the ingot is supported by a stool that initially closes the mold open end and moves progressively away from the mold as the ingot is cast. The stool is provided with plural drainage passages loosely closed with plugs positioned to be frozen into the butt of the ingot. Contraction of the solidifying butt pulls the plugs out of the drainage passages sufficiently to permit discharge through the passages of fluid collecting between the ingot butt and the stool.

BACKGROUND OF THE INVENTION

This invention relates to the continuous casting of metal ingots, and in a specific sense is directed to new and improved procedures and apparatus for so-called direct chill casting of ingots. By way of illustration, the invention will be particularly described with reference to the casting of aluminum ingots, it being understood that the term "aluminum" as herein employed embraces pure aluminum metal and alloys thereof.

In a typical example of present-day practice, the continuous direct chill casting of an aluminum ingot is effected in a shallow open-ended axially vertical mold which is initially closed at its lower end by a downwardly movable platform or stool. The ingot is surrounded by a cooling jacket through which a coolant fluid such as water is continuously circulated to provide external chilling of the mold wall. Molten aluminum is introduced to the upper end of the chilled mold, and as this molten metal solidifies in a region adjacent the periphery of the mold, the stool is moved downwardly. With effectively continuous downward movement of the stool and correspondingly continuous supply of molten aluminum to the mold, there is produced an ingot of desired length.

The ingot emerging from the lower end of the mold is externally solid but is still molten in its central portion; in other words, the pool of molten aluminum within the mold extends downwardly into the central portion of the downwardly moving ingot for some distance below the mold as a sump of molten metal having a progressively decreasing cross section as the ingot solidifies inwardly until its core portion becomes completely solid. As an important feature of the direct chill casting process, continuously supplied coolant fluid such as water is brought into direct contact with the outer surface of the advancing ingot below the mold. This direct chilling of the ingot surface serves both to maintain the peripheral portion of the ingot in solid state and to promote internal solidification of the ingot.

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In the initial stages of the casting operation, the butt of the ingot resting against the stool tends to shrink away from the stool (e.g. in its central portion) owing to contraction incident to solidification and cooling. Commonly, the upper face of the stool is dished or concave to aid in retaining the initial portion of the cast ingot during solidification. Thus, very commonly, as the ingot begins its descent from the mold, a gap or space forms, between the ingot and the stool, in which fluid can collect. The liquid coolant (e.g. water), directed against the ingot surface in streams or jets, tends to collect in this space or cavity.

Such accumulation of liquid between the butt of the ingot and the stool especially at the initial stage of casting is highly undesirable. Heat from the solidifying ingot evaporates the trapped water, causing a build-up of steam pressure beneath the ingot, and as this steam from time to time escapes, the ingot is subjected to shocks and vibrations in a vertical direction. Especially within the first few inches of travel of an ingot butt below the mold, the vibrations or bumps imparted to the ingot by entrapped and escaping steam between ingot and stool cause disturbance of the molten metal meniscus in the mold, and produce in the cast ingot structural defects such as surface cracks and so-called cold shuts for as much as 12 inches to 18 inches above the butt. These defects are not readily removable; hence it is often necessary to cut off as scrap an uneconomically long portion of the ingot or (if the ingot is rolled into slab transversely of its long axis) it may be necessary to shear an unusually wide edge portion of the slab to remove slab defects resulting from the aforementioned structural flaws in the ingot butt.

The defects described above are encountered particularly often in the casting of large ingots, e.g. of aluminum-magnesium alloys, having a rectangular cross section (that is, cast in rectangular molds) and adapted for rolling into sheet. However, like problems may be encountered in the casting of other types of ingots as well.

SUMMARY OF THE INVENTION

An object of the present invention is to eliminate or minimize the incidence of vertical vibrations or bumps resulting from entrapment of fluid between ingot butt and stool in the continuous direct chill casting of metal (e.g. aluminum) ingots, and thereby to eliminate or minimize the creation of structural defects in the ingot butt portion by such bumps or vibrations. Another object is to provide procedures and apparatus for preventing accumulation of fluid between an ingot butt and stool, such as might cause the aforementioned bumps and vibrations.

To these and other ends the present invention broadly contemplates improvements in procedures and apparatus for continuously casting a metal ingot in a mold having a wall laterally defining a casting zone with an open outlet end, i.e. in casting operations of the type wherein molten metal is in effect continuously delivered by suitable means into the casting zone of the mold, and wherein a stool, initially closing the outlet end of the mold and supporting the extremity of the ingot being cast, is moved away from the mold outlet end for effecting continuous advance of the ingot from the mold during casting, and wherein coolant liquid is directed by suitable means onto the surface of the ingot emerging from the mold.

The improvement in accordance with the invention broadly comprises the provision of at least one drain passage in the stool for conducting fluid away from a locality defined between the stool and the ingot extremity, and means for closing the drain passage or passages while the stool is in position closing the mold outlet end, such passage-closing means being openable in response to solidification and contraction of the ingot extremity for permitting discharge of fluid through the passage or passages as the ingot extremity hardens and contracts, so that coolant liquid entering the locality between the ingot extremity and the stool is discharged therefrom through the passage or passages. In its procedural embodiments, the invention contemplates the step of opening one or more drainage passages in the stool incident to and in response to the contraction of the ingot butt that occurs as the butt solidifies and cools.

Further in accordance with the invention, the drain passages may be formed in the body of the stool, and may open toward the butt end of the ingot. Plugs e.g. fabricated of metal, are placed in the openings of these passages so as to close the passages, the plugs being positioned to be immersed and ultimately frozen in the molten metal supplied to the mold while the stool is disposed in its mold-closing position. In other words, the plugs that close the drain passages of the stool become frozen in the ingot butt, and as the solidifying butt contracts, the plugs are lifted out of the drain passages by such contraction sufficiently to permit release of fluid from between the ingot butt and the stool. Hence fluid (e.g. coolant water, from the jets or streams that are directed onto the emerging ingot surface) cannot accumulate to develop steam pressure under the ingot butt such as would cause defect-producing bumps or vibrations of the ingot.

Further features and advantages of the invention will be apparent from the detailed description hereinbelow set forth, together with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a simplified sectional elevational view of a continuous casting apparatus embodying the present invention in a particular form;

FIG. 2 is a plan view of the stool of the casting apparatus of FIG. 1;

FIG. 3 is an enlarged fragmentary sectional elevational view showing the disposition of one of the drain-closing plugs of the stool during initial supply of molten metal to the casting mold, in the apparatus of FIG. 1; and

FIG. 4 is a view similar to FIG. 3 showing the change in position of the plug that occurs as the ingot butt solidifies.

DETAILED DESCRIPTION

Referring to the drawing, there is shown in FIG. 1 a form of apparatus for continuously casting aluminum ingots, including an axially vertical mold **10** (open at its lower end) to which molten aluminum metal **11** is supplied for casting an ingot **12**. The mold **10**, fabricated of a metal suitably resistant to deterioration under the conditions for casting aluminum, has a vertical inner wall **14** which defines an axially vertical casting zone **14***a* of desired horizontal cross section (e.g. circular, square or rectangular), it being understood that this mold wall configuration determines the cross-sectional shape of the produced ingot; merely by way of specific illustration, reference will be made herein to a mold which is rectangular, i.e. in cross section, for producing an ingot of corresponding rectangular cross section.

Surrounding the outer surface of the mold wall **14** is a cooling jacket **15** shown for simplicity as formed of further wall portions cooperating with the wall **14** to define and enclose an annular chamber **15***a* completely laterally surrounding the casting zone. This enclosed chamber is supplied by suitable means (not shown) with a cooling fluid such as water for chilling the mold wall

14, and is preferably kept continuously filled with a flowing or circulating body of fluid, designated **16**.

At the start of the casting operation, the lower end of the casting zone **14***a* is closed by a stool **18** which is carried on a platform **19** that is in turn supported on a hydraulic ram **20**. As molten aluminum in the casting zone solidifies around the lower portion of the periphery of that zone, the stool **18** and platform **19** are drawn slowly vertically downward by operation of the hydraulic ram **20**. The solidifying base of the ingot being cast, resting on the stool, then begins to emerge from the lower end of the casting zone.

The mold apparatus is arranged to direct a spray or stream of cooling fluid such as water onto the emerging solidified ingot surface immediately below the casting zone. Thus, as shown, there may be provided a slit **22** in the lower wall of the cooling jacket **15**, extending entirely around the mold periphery, and oriented to direct water from the chamber **15***a* of the cooling jacket onto the surface of the emerging ingot. This spray of water, striking the ingot surface, acts to enhance the cooling and consequent solidification of the ingot as it moves downwardly away from the mold. In this arrangement, water is continuously supplied to the chamber **15***a* and is continuously dischaged through the slit **22** onto the ingot surface so that there is a continuous flow of coolant fluid for removing heat from the solidifying metal.

Molten aluminum is supplied to the mold from a body or source shown as contained in a launder **26** positioned at a level above the mold and communicating therewith through an axially vertical dip tube **28** that extends downwardly from the launder into the casting zone **14***a* in coaxial relation to that zone. The lower end of dip tube **28** opens at a level in the casting zone somewhat beneath the level of the molten aluminum pool therein. A filter, baffle or the like may be positioned at or adjacent the lower end of dip tube **28** within the mold for filtering and/or directing the supply of molten aluminum as the molten metal enters the mold. For example, in FIG. 1 there is shown a float-type baffle **30**, buoyantly supported in the molten aluminum pool **11** in surrounding relation to the outlet end of the dip tube for directing the major flow of metal laterally (toward the side walls of the mold) and for controlling the level of molten metal in the mold by effectively closing off the lower end of the dip tube incident to rise of molten metal above a desired maximum level in the mold.

The foregoing structures are broadly conventional and their operation, for continuously casting an aluminum ingot, will be familiar to those skilled in the art. The present invention, as embodied in the illustrated casting apparatus, is directed to improvements in the structure of the stool **18** for preventing accumulation of fluid between the stool and the butt end of the ingot resting thereon. As embodied in procedures that may be performed with the apparatus of FIG. 1, the invention resides in steps for effecting discharge of fluid that may accumulate between the ingot butt end and the stool, all as now to be described.

In accordance with the invention, a plurality of drain passages **32** are provided in the stool **18** for conducting fluid down and away from the stool upper surface. Each of these passages, in the form shown, is of L-shaped configuration, opening upwardly through the generally horizontal upper surface of the stool **18** and extending downwardly and thence outwardly therefrom, to discharge liquid through an adjacent side of the stool. The rectangular stool illustrated in the figures has three such openings disposed in spaced relation to each other adjacent each end of the stool, and the upper surface of the stool may be pitched toward both ends so as to promote flow of liquid from the stool surface into the openings of the passages **32**. An upwardly projecting rim **34**, formed integrally with the stool, extends around the entire periphery of the stool so as to give the ingot-supporting surface of the stool a dished or concave contour which aids in supporting the solidifying ingot butt at the start of the casting operation; this rim **34** is dimensioned to fit closely within the lower end of the mold when the stool is in its mold-closing position.

Further in accordance with the invention, the upper end of each passage **32** is somewhat enlarged as shown at **36**, i.e. at and adjacent the upper surface of the stool **18**, to provide a seat for a short cylindrical plug **38**. At the start of a casting operation, each of the drain passages **32** is provided with such a plug, which sits more or less loosely in the plug seat **36** but entirely covers the opening of passage **32** so as to prevent flow of molten metal into the drain passages when the initial molten metal is introduced to the mold. The provision of a shallow seat for each plug **38** prevents lateral displacement of the plug away from its passage-closing position when metal is introduced to the mold, yet facilitates subsequent lifting of the plug from the mold as hereinafter described.

In the practice of the method of the invention, with the stool **18** in its initial mold-closing position, molten metal (e.g. aluminum) to be cast is introduced to the casting zone **14*a*** of the mold while coolant fluid (e.g. water) is circulated through the cooling jacket **15** to promote solidification of the peripheral portion of the metal in the mold. At this point in the operation, the plugs **38** are at rest in the seats **36**, covering the passages **32** and preventing flow of molten metal into the passages, as shown in FIG. 3.

As the base or butt of the ingot **12** solidifies, downward movement of the stool **18** is begun by operation of the ram **20**, and as the stool rim **34** clears the lower edge of the mold, the solidified periphery of the ingot **12** is exposed to streams of coolant water directed toward the ingot surface through the slit **22**. The ingot butt contracts as it solidifies, shrinking away from the surface of the stool **18**, e.g. in the central portion thereof, so that a gap or space **40** is defined between the stool and ingot, as shown in FIG. 4. Coolant water from the slit **22**, impinging against the side of the ingot and the stool, may enter and collect in this gap **40**. Unless provision is made to remove such water, the heat from the ingot will evaporate the water and cause a build-up of steam pressure beneath the ingot that may ultimately cause undesired bumps or vibrations of the ingot, leading to structural defects in the butt portion of the ingot.

With the present invention, however, the molten metal forming the ingot flows in surrounding relation to the plugs **38** and as the ingot butt solidifies, the plugs **38** become frozen in the butt. Then, as the ingot butt contracts, shrinking away from the stool surface, the plugs frozen in the ingot butt are by that contraction lifted out of their seats sufficiently to open the drain passages **32** for discharge of any water and/or steam that may enter or collect in the gap **40**, as shown in FIG. 4. This provision of drainage for the space between the ingot and the stool, opening in response to solidification and contraction of the ingot butt (when there is no longer need to keep the passages closed against molten metal, and at the very time when the need arises for drainage of the stool surface), thus effectively prevents build-up of steam pressure beneath the ingot and consequent structural injury to the ingot such as results from vertical bumps or vibrations.

The plugs **38** may be fabricated of the metal being cast, although this is not necessary. They are frozen into the butt of the ingot, and simply removed therewith when the butt is trimmed after casting, as in conventional procedures.

In an illustrative example of a continuous casting stool having a configuration as shown in FIG. 2, with six drain passages **32**, each passage had in its main portion a diameter of ⅞ inch and a plug seat ⅛ inch deep and 1$\frac{5}{16}$ inches in diameter. The plugs used were 1¼ inches in diameter and one inch in axial length. Drains and plugs having the foregoing dimensions functioned effectively to substantially eliminate bumping problems in the casting of large (e.g. 18-inch by 45-inch stool) rectangular ingots of aluminum alloys.

It is to be understood that the invention is not limited to the features and embodiments hereinabove specifically set forth but may be carried out in other ways without departure from its spirit.

I claim:

1. A method of continuously casting a metal ingot including the steps of

(a) delivering molten metal in continuous flow into a casting zone of an open-ended mold wherein said molten metal collects and progressively solidifies to form an ingot, while

(b) initially closing the outlet end of the mold with a movable stool supporting the extremity of the ingot being cast, and

(c) as the periphery of the ingot solidifies in the mold, progressively moving the stool away from the mold outlet end for continuously drawing the ingot out of the casting zone while

(d) directing coolant liquid onto the surface of the ingot emerging from the casting zone for promoting solidification of the ingot;

wherein the improvement comprises

(e) opening at least one drain passage in the stool in response to contraction of the ingot extremity supported thereon for discharging fluid from a locality between said ingot extremity and said stool to prevent build-up of fluid pressure at said locality resulting from entry of coolant liquid into said locality.

2. A method according to claim **1**, wherein said step of opening at least one drain passage in the stool comprises covering an end of said passage with a movable closure element positioned to come into contact with molten metal introduced to the mold, freezing said movable element in the ingot extremity by solidification of the ingot extremity, and displacing said movable element away from said end of said passage, for opening said passage to permit discharge of liquid therethrough from said locality, by contraction of said ingot extremity in which said movable element is frozen.

3. Apparatus for continuously casting a metal ingot including

(a) a mold having a wall laterally defining a casting zone with an open outlet end;

(b) means for delivering molten metal into said casting zone;

(c) means including a stool for closing the outlet end of said mold, said stool being positioned and adapted to support the extremity of an ingot being cast in said zone and being movable away from said mold outlet end for effecting continuous advance of the ingot from the mold during casting; and

(d) means for directing coolant liquid onto the surface of the ingot emerging from the outlet end of said mold;

wherein the improvement comprises

(e) said stool having at least one drain passage for conducting fluid away from a locality defined between said stool and said ingot extremity; and

(f) means for closing said one drain passage while said stool is in position closing said mold outlet end, said passage-closing means being responsive to and openable by contraction of said ingot extremity for permitting discharge of fluid through said one passage so that coolant liquid entering said locality between said ingot extremity and said stool is discharged therefrom through said one passage.

4. Apparatus as defined in claim **3**, wherein said passage-closing means is a movable element positioned to cover an end of said one passage and to be in contact with and frozen in molten metal introduced to said mold and forming said ingot extremity, so that said movable element is displaced from said passage end to open said passage incident to contraction of the ingot extremity.

5. Apparatus as defined in claim **4**, wherein said stool has a substantially horizontal surface on which the ingot extremity rests, wherein said one passage opens through said stool surface, wherein said one passage is enlarged at said surface to form a recessed seat larger in diameter than said passage and wherein said movable element comprises a plug dimensioned to be received loosely within said seat and to cover the entire opening of said passage.

6. Apparatus as defined in claim **5**, wherein said stool has a plurality of said passages disposed in spaced relation to each other along opposite edges of said stool.

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