March 23, 1954 O. M. GARDNER ET AL 2,672,665

CASTING METAL

Filed March 13, 1950

FIG. 1.

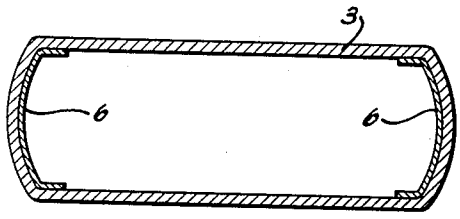


FIG. 2.

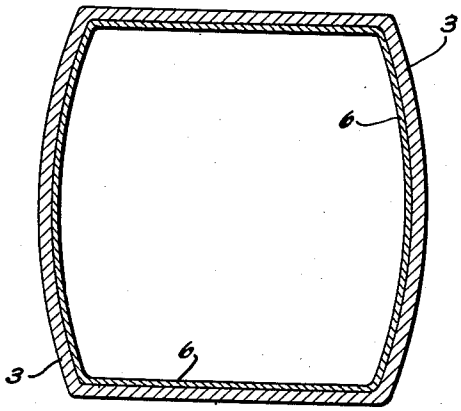


FIG. 3.
(PRIOR ART)

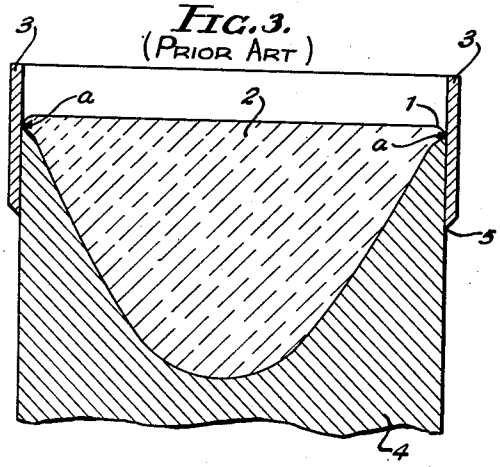


FIG. 5.

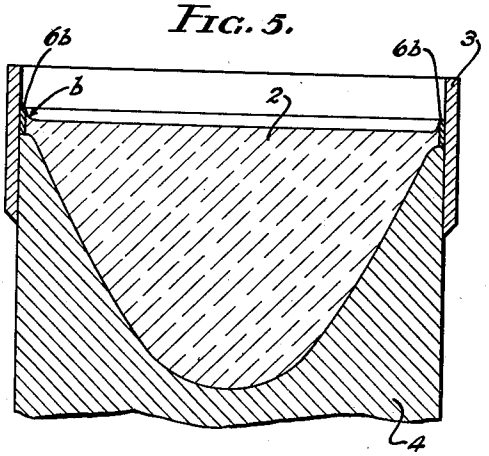
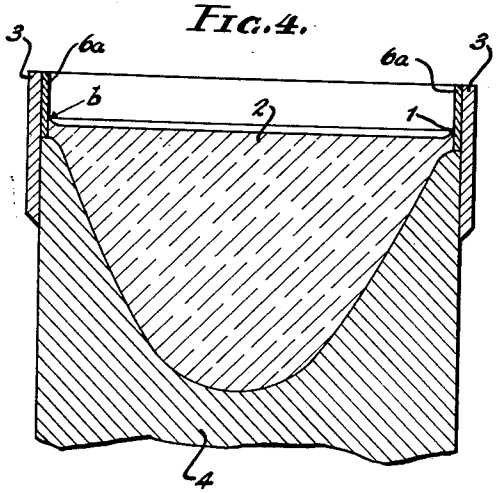


FIG. 4.



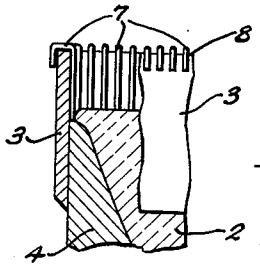


FIG. 6.

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CASTING METAL

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3 Claims. (Cl. 22—200.1)

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This invention relates generally to the casting of light metals and alloys thereof. More particularly, the invention relates to an improved method and apparatus for the continuous casting of ingots, billets and the like of light metals and alloys thereof.

In the continuous casting of metals, an open-ended mold, usually shallow and cast in light alloy, is provided and molten metal is continuously fed or poured into one end thereof (the top end in the case of a vertical mold), a supply of cooling fluid, usually water, is applied in a continuous manner to the outside surface of the mold to withdraw at least a part of the heat from the metal, and/or to the surfaces of the at least externally solidified casting as it emerges from the opposite end of the mold (the bottom in the case of a vertical mold). The mold may be either horizontal or vertical but in the case of large castings, such as rolling ingots and extrusion billets, it is preferably vertical. The withdrawal of the casting is regulated at a desired rate, usually by means of a movable bottom for the mold, for example, a platen of a hydraulic plunger which is lowered into a casting pit. The pouring rate for the molten metal and the rate of withdrawal of the solidified casting are correlated to maintain a substantially uniform or constant head level of metal within the mold. The term "head" indicates the depth of the metal in the mold, that is, the distance from the plane of the lower periphery of the mold to the surface of the molten metal in the mold.

The cross-sectional shape of the mold, and consequently the ingot or billet may be practically any desired configuration, although usually it is square, rectangular, circular or elliptical; and in some cases, annular or hollow where a mold core is employed. In the casting of large ingots or billets, the mold cross-section is in most cases angular and often elongated in one direction, that is, of a shape having major and minor axes, for example, substantially rectangular.

The method and apparatus for directly chilled (DC) continuous casting which are widely used in the casting of ingots and billets of light metal and light metal alloys, such as aluminum and its alloys, and to which this invention is particularly applicable are fully shown and described in U. S. Patent No. 2,301,027, dated November 3, 1942, issued in the name of William T. Ennor.

A difficulty that has been frequently encountered in the continuous casting of aluminum and

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aluminum alloy ingots, particularly those which contain edges or corners, for example, those which are substantially square or rectangular in cross-section, is the impairment of the ingot edges or end surfaces (in the case of elongated angular shapes) by so-called cold shuts. This occurrence of cold shuts is a phenomenon primarily restricted to the very narrow vertical area or line of contact between the molten metal and the inside periphery of the mold at the top of the molten surface, that is, at the edge of the normal head level of the metal in the mold or the edge of the meniscus of the molten metal.

It has been determined that cold shuts occur when a non-uniform or excessive amount of heat is transferred from the molten metal or a portion of the molten metal through the mold in this critical area or plane, particularly at the edges or corners of the mold, for example, the end sections of the mold in the case of a mold of substantially rectangular cross-section. Such an excessive or non-uniform withdrawal of heat increases the surface tension and meniscus effect, which, in turn allows intermittent wetting of the mold surface by the molten metal with the result that freezing or solidification takes place at points removed from the mold surface. Cold shuts are thus formed by this "prefreezing" of a portion of the metal.

Cold shuts may be induced by improper transfer of molten metal into the mold, such as permitting turbulence during pouring of the metal, or by excessively slow transfer or pouring. Also, cold shuts are occasioned by utilizing a pouring temperature which is too low. In addition, as indicated above, cooling the molten metal too rapidly and/or non-uniformly at or near the edge of the molten metal meniscus may result in cold shuts.

The first two above-named conditions favoring formation of cold shuts may be obviated by proper pouring technique and temperatures. It is with the last-named condition and the solution of the problem presented thereby that the present invention is primarily concerned.

Accordingly, it is a primary object and purpose of the invention to improve the surface qualities of continuously cast light metals and alloys thereof by eliminating the formation of cold shuts.

Another object is to provide an improved method and apparatus for the continuous casting of ingots, billets and the like of light metals and light metal alloys. A further object is to provide an improved method and apparatus for

the directly chilled (DC) continuous casting of aluminum and aluminum alloys susceptible to the formation of cold shuts to eliminate the same.

A more specific object is to provide an improved method of regulating heat transfer and an improved mold construction therefor in the directly chilled (DC) continuous casting ingots and billets of aluminum and aluminum alloys to eliminate formation of cold shuts in the metal during casting. These and other objects and advantages of this invention will be apparent from the following detailed description thereof.

It has been discovered that formation of cold shuts during continuous casting of light metals and alloys thereof is substantially completely eliminated by regulating the withdrawal or transfer of heat from the metal through or to the mold in a manner such that cooling of the molten metal is substantially retarded and solidification is prevented at the edge of the meniscus thereof or around the periphery of the normal head level of the metal. It has further been found that the objects of the invention and the process thereof may be suitably accomplished and performed by the provision of a casting mold having a thermally insulating material disposed in close contact with or adherent to the inside surface of the mold extending longitudinally throughout the area of the mold surface which contacts the edge of the metal meniscus or the periphery of the molten metal at normal head level.

The insulating material placed either around the entire periphery of the mold surface at the indicated area or only on the surfaces of the end sections of the mold prevents contact of the molten metal and the mold surface and thus retards the transfer or withdrawal of heat from the metal. Solidification cannot take place in this area since the metal remains above the melting point, or highest eutectic point. Initial solidification thus is forced to occur below the edge of the metal meniscus, that is, below the metal level in the mold where heat is rapidly extracted, and therefore, the freezing is not influenced by surface tension and meniscus effect as in the case where molten metal-mold contact occurs at the metal level or top surface which frequently results in formation of cold shuts. The insulator retains sufficient heat in the molten metal to preclude any "prefreezing" thereby eliminating formation of deep cold shuts.

In its foregoing generic aspect, the invention is applicable to continuous casting of ingots of a variety of shapes, but particularly to ingots having somewhat angular configurations, that is, including edges or corners, since the cold shut problem appears to be particularly manifest in the edge qualities of such ingots. The thermally insulating material in such case may be disposed or applied around the entire inside periphery of the mold within the above-defined critical longitudinal area.

In a particular application or embodiment of the invention wherein the mold and solid ingot is of an elongated angular cross-section, for example, substantially rectangular, with or without curved ends, it is preferred to locate the insulating material only on the end sections of the mold, since cold shuts are not as pronounced on the surfaces of the relatively long intermediate section of the ingot. However, if desired, even in this case, the high temperature insulator may be disposed on the whole inside periphery of the mold within the appropriate longitudinal area with eminently satisfactory results.

The invention contemplates the use of a wide variety of high temperature insulating materials, which in some instances may be directly applied to the inside surface of the mold and adherent thereto, while in other cases the material may be merely held in close contact with the mold surface by suspension from the top of the mold or in some other suitable manner.

Among the various materials particularly suitable as high temperature insulators may be mentioned a fibrous material, such as asbestos, felted or in the form of paper, and secured to the mold wall by a suitable adhesive, such as a cement or mold grease suitably resistant to high temperatures. Because of the excellent results, economy of use and ease of application, the foregoing insulator is preferred.

Also, a high temperature cement may be applied to the critical area of the mold wall to effectively retard withdrawal of heat through the mold shell. A particularly suitable cement is one having a refractory base or filler of glass fibers, a binder of an appropriate synthetic rubber, such as Buna-S, or Buna-N, and an evaporative solvent, such as methyl ethyl ketone.

In the above specific examples of high temperature insulating materials, they constitute upon application a relatively thin or thick lining or coating for the mold area affected.

A further suitable high temperature insulator was found to be a refractory coated metal, such as, lime-coated steel wires suspended from the top of the mold shell and held in close contact with the mold surface.

Optimum results are obtained by disposing the insulating material on the mold surface to extend from any transverse plane above the narrow area or plane of the molten metal meniscus or normal head level of the metal in the mold to a transverse plane about one-half inch below the narrow area or plane of the meniscus. Alternatively stated, the lower edge of the insulator preferably should be not substantially less than one-half inch or substantially more than five-eighths of an inch below the area of the edge of the metal meniscus. However, these limits need not be strictly maintained, since the insulator may extend farther below the metal meniscus with good results, it being necessary only to avoid an undue retardation in solidification, which, if excessive, would affect the quality of the casting.

The invention is more fully defined and illustrated by reference to the accompanying drawings, which are not to be construed as a limitation thereof, in which:

Figure 1 is a transverse sectional view of a mold showing an insulating lining disposed in the end sections thereof;

Figure 2 is a transverse sectional view of a mold showing an insulating material disposed around the entire periphery of the mold;

Figure 3 is a vertical section of a mold and metal ingot forming therein with no thermal insulator;

Figure 4 is a vertical section of a mold and ingot forming therein showing an asbestos lining disposed according to the invention;

Figure 5 is a vertical section of a mold and ingot forming therein showing a coating of high temperature cement at the critical area on the mold; and

Figure 6 is a fragmentary vertical section, partly in side elevation, of a mold showing refractory coated wires as the thermal insulator.

Referring now to Figure 3, it may be seen that

the meniscus 1 of the molten metal 2 is of the convex type, indicating that the molten metal does not wet the mold 3, which, in this case, is constructed of aluminum alloy. Rapid cooling occurs during the casting operation and the initial solidification of the metal occurs at or near the line of contact of the periphery of the molten metal meniscus and the mold wall. The casting 4 consisting of a skin of solid metal of a certain thickness depending on cooling and lowering rates emerges from the bottom of the mold 5 with a crater of molten metal 2 in the interior extending vertically from the normal head level of the metal to the point at which the temperature of the ingot is below the lowest melting eutectic of the alloy.

Although this method of rapidly extracting heat from the metal is necessary to produce sound castings, the rapid cooling at the metal level or meniscus was found to result in cold shuts, particularly on the curved end surfaces of the ingots, and particularly in the casting of the softer more ductile aluminum alloys or commercially pure aluminum, having little or no positively added alloying constituents, for example, aluminum alloys designated as 2S, commercially pure aluminum, and 3S aluminum containing manganese on the order of 1%. The formation of these discontinuities, as set forth above, was induced by excessive heat extraction from the region near the edge of meniscus, indicated at *a* in the drawing.

Referring to Figure 1, the preferred embodiment of the invention is shown wherein the insulating material 6 is disposed only on the curved end sections, including the edges or corners. It was observed that with molds of substantially elongated angular cross section, for example, substantially rectangular, as shown in Figure 1, the occurrence of cold shuts on the ingot predominated at the end sections or edges, as opposed to the straight sided intermediate section. Thus, formation of cold shuts was substantially eliminated by employing the embodiment of Figure 1.

In Figure 2, a substantially square mold 3 is shown, and, in this case, the insulating material 6 is placed around the entire inside periphery of the mold to eliminate cold shuts.

Figures 4 and 5 illustrate the use of two different insulating materials, namely, an asbestos paper lining 6*a* adhesively secured to the mold surface, and a high temperature resistant cement 6*b*, respectively. It may be seen that as the molten metal 2 contacts the asbestos 6*a* or the cement 6*b*, the insulating material is wetted by the metal and a concave meniscus 1 results. Heat extraction from the metal through the mold is substantially retarded including the narrow region marked *b* and solidification is prevented from occurring in this meniscus region. Solidification can only initially occur below the lower edge of the insulator which is located, as shown in the drawings, about one-half to about five-eighths of an inch below the meniscus edge or head level of the metal.

Figure 6 shows in fragmentary vertical section partly in side elevation, that embodiment wherein lime-coated steel wires 7 suspended at 8 from the top of the mold 3 act as the insulator. In this case, also the lower ends of the wires are disposed about one-half to five-eighths of an inch below the meniscus edge. The wires are spaced one from the other, illustrating that the insulating surface may be discontinuous as well as continuous to accomplish the desired result. The spacing of the wires may be varied, the drawing being intended to show about 10 wires to the inch. It is to be noted, however, that the invention also contemplates a continuous sheet of refractory coated metal as the insulator.

The elimination of cold shuts may be satisfactorily attained by the use of any high temperature insulating material resistant to temperatures of the order of 1200° F. or such temperature as must be employed with the particular metal being cast, and which material is not adversely affected by contact with the molten metal and which will not adversely affect the metal. Accordingly, it is to be understood that the invention is not limited to the preferred embodiments of materials illustrated in the drawings.

Although the invention is generally applicable to light metals and alloys thereof and in particular to aluminum and aluminum alloys, the character of the metal being cast also has an influence on the tendency toward formation of cold shuts. A eutectic alloy and an alloy which contains an intermetallic phase has less tendency to form cold shuts than the unalloyed metal or intermediate alloys of either the homogeneous or heterogeneous types. In the case of aluminum and aluminum alloys, the strong heat-treatable types have less tendency to form cold shuts than do the common (non heat-treatable) alloys under similar casting conditions. Accordingly, the invention finds particular application in the casting of the softer, more ductile aluminum alloys, such as 2S and 3S, referred to above.

A specific illustration of the application of the invention follows. In producing hot rolling ingots, smooth ingot edges are essential to minimize side trim on the rolled sheet. In attempting to produce satisfactory edges on 3S ingots, a high temperature pouring practice was adapted which produced 3S ingots having edges satisfactory in minimizing edge cracks encountered on hot rolling. However, this practice increased susceptibility of 3S ingot to cracking during casting. Excessive cracking led to adoption of lower pouring temperatures, and this deviation was immediately reflected in poorer edge quality of the 3S ingots due to cold shuts, which, in turn necessitated excessive side trimming of the hot rolled sheet.

To eliminate formation of cold shuts and thereby improve ingot edge quality, an asbestos paper insulating liner was adhesively secured to the inside surface of the mold with mold grease at the end sections thereof and extending longitudinally from above the normal head level to about one-half to five-eighths inch below normal head level.

The 3S ingot produced with the insulator at the mold edges using lower pouring temperatures (hot holding temperature of 1350°–1380° F.) had smooth glassy edges which resulted in a minimum side trim of hot rolled sheet. A saving of one to one and one-half inches side trim was accomplished thus increasing hot line metal recovery by at least 3 percent.

Although the invention is described with particular reference to continuous casting of aluminum and aluminum alloys, it is not intended to limit the same to this particular metal or type of casting, as the invention is applicable to other metals and other types of casting where similar problems are encountered.

What is claimed is:

1. In the continuous casting of ingots of light metals and alloys thereof in open-ended molds

wherein the ingot cross-section is of substantially angular configuration including corners or end surfaces, molten metal is continuously fed into the mold to maintain a molten metal level therein, a portion of the heat is withdrawn to initially solidify the peripheral portions of the metal in contact with the mold shell, and the partially solidified casting is continuously withdrawn from the mold, the improvement of eliminating cold shuts at the corners or end surfaces of the ingot, which comprises, retarding the extraction of heat from the molten metal at the corners or end surfaces by thermally insulating such portions of the metal from contact with the mold at the molten metal level to prevent initial solidification of the metal where the molten metal miniscus exists, and thereafter rapidly extracting heat from the molten metal to cause initial solidification of the peripheral portions of the metal by direct contact of the molten metal with the mold not substantially less than about ½ inch nor substantially more than ⅝ inch below the molten metal level.

2. In the continuous casting of aluminum and aluminum alloys in open-ended molds wherein the ingot is of elongated cross-section including corners and end surfaces, molten metal is continuously fed into the mold to maintain a molten metal level therein, a portion of the heat is withdrawn to initially solidify the peripheral portions of the metal in contact with the mold shell, and the partially solidified casting is continuously withdrawn from the mold, the improvement of eliminating cold shuts at the corners or

end surfaces of the ingot, which comprises, retarding the extraction of heat from the molten metal only at the corners and end surfaces of the mold by thermally insulating only the corresponding portions of the metal from contact with the mold at the molten metal level to prevent initial solidification of the metal where the molten metal meniscus exists, and thereafter rapidly extracting heat from the molten metal to cause initial solidification of the peripheral portions of the metal by direct contact of the molten metal with the mold not substantially less than about ½ inch below the molten metal level.

3. A process according to claim 2 in which the molten metal is thermally insulated at the corners or end surfaces with an asbestos material.

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