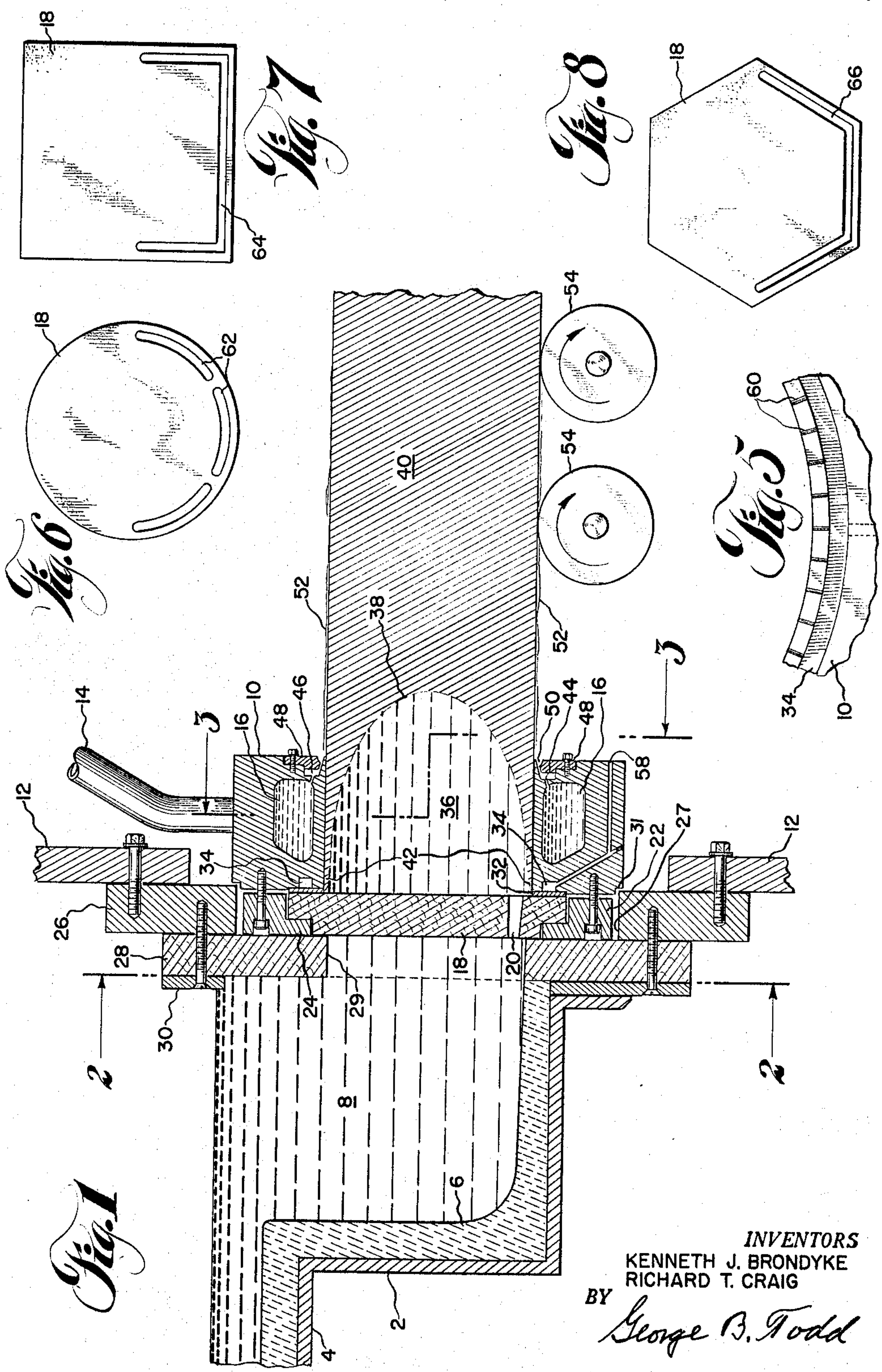
Nov. 22, 1966 K. J. BRONDYKE ETAL 3,286,309

METHOD AND APPARATUS FOR HORIZONTAL CASTING OF INGOTS

Filed June 6, 1963

2 Sheets-Sheet 1



INVENTORS
KENNETH J. BRONDYKE
RICHARD T. CRAIG

BY *George B. Todd*

ATTORNEY

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2 Sheets-Sheet 2

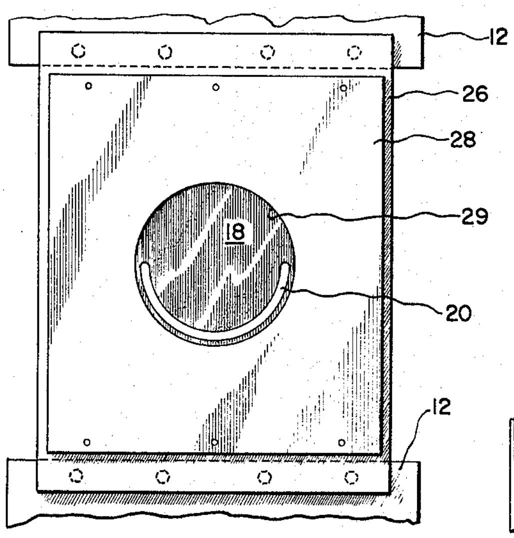

Fig. 2

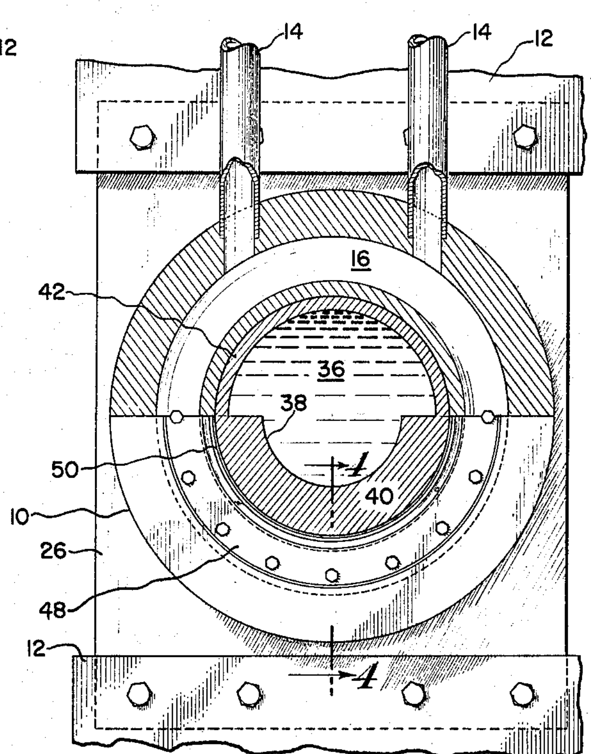

Fig. 3

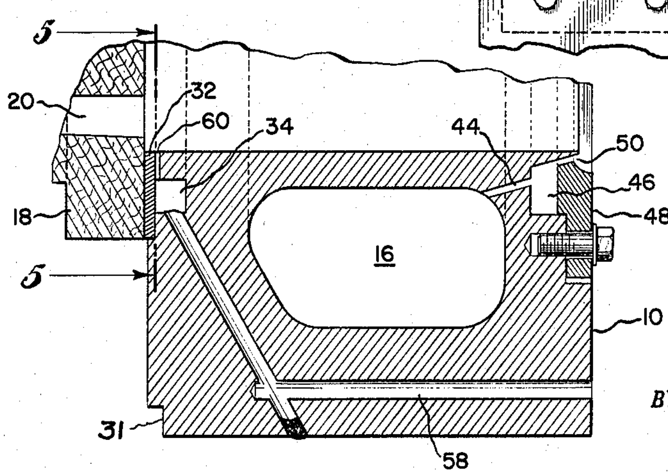

Fig. 4

INVENTORS
KENNETH J. BRONDYKE
RICHARD T. CRAIG
BY George B. Todd
ATTORNEY

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METHOD AND APPARATUS FOR HORIZONTAL CASTING OF INGOTS

Kenneth J. Brondyke, Oakmont, and Richard T. Craig, New Kensington, Pa., assignors to Aluminum Company of America, Pittsburgh, Pa., a corporation of Pennsylvania

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This invention relates to the continuous casting of ingots in horizontally disposed molds, especially ingots of light metals. In referring to light metals it is to be understood that this includes aluminum and the alloys in which that metal predominates as well as magnesium and those alloys wherein that metal is the major component.

The continuous casting of ingots for commercial production purposes has generally been carried out in molds arranged in a vertical position, the metal being fed to the upper end of the mold and the ingot withdrawn from the lower end, the mold, of course, being severely chilled to effect extraction of heat. Provision must be made below the mold for cutting the ingot into suitable lengths or the ingot casting operation is halted when a predetermined length has been attained, the ingot removed, and casting of the next ingot started. These arrangements usually involve elevating the mold at some distance above floor level or providing a pit from which the ingots are hoisted. In both cases the installations are relatively expensive and where the casting operation is interrupted, there is a loss in productive time.

To overcome at least some of the vertical casting problems it has been proposed that ingots be continuously cast in horizontally positioned molds and either cut to desired length or passed directly to a rolling mill. In some of the proposed forms of apparatus the molten metal supply is at some distance from the mold and the metal travels to the mold through a conduit. In that case there is a problem of maintaining a proper metal temperature during transfer. In addition, the art has shown horizontal molds having either no constriction of metal flow at the head end, or a constriction in the form of a plate having a central opening therein. Under such conditions the ingots do not have a uniform grain structure or a satisfactory surface.

We have devised a method and apparatus for continuous casting ingots in a horizontal position of high quality and which involves modest installation expense. The term "ingot" as used herein refers to a cast rod or bar as well as cast bodies of much greater cross sectional dimensions adapted to the production of large wrought articles. The term is also used herein in a broad sense to embrace both the partially formed ingot and the completely solidified product. The ingots may have different cross sectional shapes, for example, circular, rectangular, polygonal or oval. These elongated cast products are generally subjected to one or more working and shaping operations wherein the internal cast structure is largely converted into a wrought structure in the course of making finished or semi-finished wrought products.

It is an object of our invention to provide a method of supplying molten metal to a horizontally disposed mold which controls the distribution of the liquid metal to obtain improved extraction of heat without adverse effect upon the surface quality.

Another object is to provide a method of feeding molten metal to a horizontally disposed mold wherein the metal is introduced to the mold under a relatively low pressure and over the lower portion of the inner mold wall surface.

A further object is to provide a method of supplying molten metal to a horizontally disposed mold wherein the distribution of metal within the mold is so controlled that substantially uniform freezing conditions exist around the mold wall where freezing starts.

Another object is to provide a method of supplying molten metal to a chilled horizontally positioned mold which permits initiating freezing at the head of the mold and thus utilize effectively the entire chilled mold surface to promote formation of an ingot.

Still another object is to provide a method that is especially adapted to the continuous casting of light metal ingots in a horizontal position that yields a product having a uniform grain size across the ingot cross section.

A further object is to provide apparatus for the continuous casting of an ingot in a horizontally disposed chilled mold closed at its head end with a heat insulating material except for a relatively narrow gate opening whereby the metal freezing rate is substantially the same at the top and bottom of the mold.

Another object is to provide continuous horizontal casting mold apparatus having a relatively narrow elongated gate in a heat insulative mold head plate which will deliver metal to the lower mold section in close proximity to the inner wall of the mold.

Another object is to provide continuous horizontal casting mold apparatus wherein the metal supply receptacle adjoins a mold having internally chilled walls and coolant is discharged upon the emerging ingot whereby the molten metal is rapidly frozen and a high quality ingot is produced.

A further object is to provide continuous horizontal casting mold apparatus wherein the seal between the mold and head plate is combined with the lubricant distribution system.

For an understanding of the apparatus, in a preferred form, that can be used to achieve the foregoing objects, reference is made to the following drawings wherein

FIG. 1 is a side elevation, partially in section, of apparatus adapted to cast cylindrically shaped ingots;

FIG. 2 is an end elevation taken on line 2—2 of FIG. 1;

FIG. 3 is a stepped section partially in section of the mold and forming ingot taken on line 3—3 of FIG. 1;

FIG. 4 is an enlarged sectional view of the mold showing the lubrication and coolant discharge systems taken on line 4—4 of FIG. 3;

FIG. 5 is an enlarged fragmentary view of the machined end of the mold showing the lubrication distribution channels taken on line 5—5 of FIG. 4;

FIG. 6, an end view, represents a modification of the gate opening in the mold head plate seen in FIG. 2;

FIG. 7, also an end view, represents the arrangement of the gate opening in the head plate for casting a rectangular shaped ingot; and

FIG. 8, another end view, represents a modification of the gate opening in the head plate adapted to casting a polygonally shaped ingot.

Our method of casting is predicated upon the discovery that high quality ingots can be produced in a horizontally disposed chilled mold by introducing substantially all the molten metal in the lower half section of the mold and in a relatively thin stream generally conforming to the shape of the mold and close to the inner mold wall thereof. The metal is introduced under a relatively low pressure and hence the stream extends but a relatively short distance into the mold. The metal freezing conditions which characterize the central feeding of a horizontal mold in the prior art are substantially eliminated by our method of combining contoured feeding with a controlled chilling of the metal. The contoured feeding appears to establish thermal conditions within the molten metal at the head of the ingot which aid in the rapid extraction of heat with resultant improvement in uniformity of internal structure and surface quality. To introduce fresh molten metal close to the mold wall and still obtain a freezing of the metal on the wall indicates a rapid heat transfer and yet we obtain ingots without cracks or other defects which often occur where there is an abrupt change from liquid to a solid state. Further evidence of the effectiveness of our method is to be seen in the fact that it can be carried out in a relatively short distance which makes it possible to employ a short mold. Moreover, the molten metal is supplied at customary pouring temperatures thus avoiding premature freezing or other difficulties that are often associated with maintaining metal in a liquid condition close to its melting point.

It will be appreciated that when continuously casting an ingot in a horizontally positioned mold, the head end must be closed except for the gate which admits metal to the mold and the exit or discharge end is filled with the freezing ingot. For the purpose of convenience the head closure member is referred to herein as a head or header plate. The plate, of course, must be made of a refractory heat insulative material to withstand heat and any chemical action of the molten metal.

The molten metal for filling the mold and producing the ingot is supplied from a suitable reservoir adjacent the mold so that the distance the metal travels from the reservoir to the mold is short and there is substantially no drop in temperature during transfer. We therefore consider that the molten metal entering the mold has substantially the temperature of that in the reservoir.

The mold, as stated above and described in greater detail below, is chilled by a liquid coolant so that there is a high rate of heat transfer from metal to mold. Furthermore, in our preferred practice additional heat is removed from the ingot emerging from the mold through direct application of coolant to the ingot surface. We have found it to be advantageous to use the coolant that has circulated in the chamber around the mold and project it upon the moving ingot at a low angle.

In the continuous casting of ingots in a horizontal position there is a tendency for the ingot to come into closer contact with the bottom section of the mold than the top by reason of the weight of the ingot. By the same token, there is a slight increase in the space between the ingot and upper mold section with the result that heat transfer is impeded. Our method is designed to overcome that condition with respect to heat transfer. This, we believe, is accomplished by extracting some of the heat from the incoming metal such that the portion which fills the upper section of the mold contains less heat and is therefore more easily converted from the liquid to the solid state than would occur if the metal were introduced through a central or near-central opening in the head plate. Our belief is supported in part by temperature measurements made in the mold wall of a short water-cooled circular mold at locations along the mid-point line of the top and bottom sections that showed a temperature differential of about 40 to 100° F. where an aluminum base alloy ingot was being cast. Such measurements are illustrative of a small but significant temperature differential and are not to be regarded as establishing limits. Although such a difference in temperature might be thought to adversely affect the grain structure of the ingot we have not found this to be true, for, as mentioned above, the grain structure of the cross sections of ingots has been found to be uniform. Moreover, from these tests and others there is evidence that the metal can freeze over the entire length of the mold and thereby utilize the heat extractive ability of the mold to an exceptionally high degree.

To accomplish the desired extraction of heat from the metal entering the mold and obtain the freezing of metal upon the entire inner mold surface, we have found that the molten metal should be introduced over an extended peripheral portion of the lower mold section and close to the head end wall of the mold. The molten metal may be introduced over substantially all of the lower half section or only a portion thereof depending on the size of the ingot. Also the metal may enter the mold as a continuous stream between the lateral ends thereof or as a plurality of streams from closely spaced orifices or segments of the gate opening. In the latter case the streams merge and act as a continuous stream and hence for purposes of our invention the incoming metal is considered to be in stream-like form. In addition, the incoming stream of metal should be relatively thin as it enters the mold, and preferably in a diverging form, and continue for but a short distance in the direction of ingot movement. In referring to a relatively thin stream of metal it is to be understood that the lateral length of the stream is many times its width, for example, in the ratio of 15 to 125 to 1 depending on the size of the ingot. The path of the incoming metal conforms generally to the shape of the mold wall inasmuch as the metal is introduced in close proximity to the inner wall of the mold. The proximity of the incoming metal to the chilled mold wall is important in order to obtain the desired extraction of heat from the metal. By close proximity we mean that the incoming metal is so close to the mold wall that some heat is immediately extracted therefrom through the mold wall as compared to the gradual loss of heat that occurs when the metal enters the central portion of the mold cavity. Moreover, the velocity of the metal stream is so small that there is no evidence of scouring of the mold surface or erosion of the surface of the freezing metal.

The molten metal enters the mold under a relatively low pressure such as provided by hydrostatic pressure, that is the difference in metal level between that in the metal reservoir and the top of the ingot mold where the entire system is operating under normal atmospheric pressure. We have found that higher pressures are not required to gain the desired results.

The rate of withdrawal of the ingot of course depends upon the rate of heat extraction which in turn is determined by the mass of metal being cooled and frozen. In the case of casting circular aluminum base alloys ingots having a cross sectional area of about 28 square inches, a withdrawal rate of 6 inches per minute has been employed with highly satisfactory results. On the other hand, the rate is reduced as the cross sectional area is increased, a rectangularly shaped ingot having a cross sectional area of 576 square inches, for example, is withdrawn at a rate of 2 to 3 inches per minute. In referring to the withdrawal of an ingot from the mold it is to be understood that this does not imply that the metal has completely solidified as it passes the vertical plane of the discharge end of the mold. It is important, however, that solidification shall have progressed far enough to prevent any rupture or melting through of the walls of the forming ingot. Where a short mold is employed, ordinarily the central portion of the ingot will still be molten as the end of the mold is passed. Although the term "ingot" has been used to refer to both the partially formed and completely formed ingot body the expression "embryo" or "partial" can be employed to define the stage of formation which precedes complete solidification. As applied to the withdrawal of an ingot from a short mold it can be said that it is the embryo ingot which generally emerges from the mold.

Withdrawal of the ingot from the mold can be effected by any convenient means, such as described below, care being taken to maintain alignment with mold.

To prevent adhesion of the metal to the mold as the ingot is being formed and withdrawn from the mold a lubricant is supplied at the head end of the mold and around the entire inner wall surface. The lubricant appears to spread over mold surface and thus prevent metal-to-metal contact. Inasmuch as the casting operation is continuous, the lubricant is continuously supplied at a rate that provides enough lubricant while avoiding width of the slot **50** is conveniently established by choice of the external dimensions of the control ring **48**. The walls of slot **50** are at a small angle, between 5 and 10°, to the inner surface of the mold. By this arrangement no seepage of water occurs in the space between the ingot and mold wall. The control ring **48**, which is detachably mounted on the end face of the mold, can be replaced by another ring having different external dimensions which will widen or narrow the opening **50** and thus increase or diminish the flow of water onto the ingot surface. The opposite side of slot **50** is defined by a tapered mold wall, the angularity of which corresponds to that of the opposing surface on the control ring **48**. The tapered tip at the exit end of the mold not only aids in directing the water upon the ingot surface but it provides a useful degree of flexibility for movement of the ingot in an otherwise rigid mold.

Lubrication of the ingot and mold wall is necessary for the continuous casting operation of the invention. Various systems can be used for supplying lubricant but we have found that a low pressure system is adequate which delivers the lubricant at the head end of the mold. This can be achieved by providing drilled passageways **58** connected to a source of supply, and feeding the lubricant to an annular channel **34** as seen in FIG. 4. The lubricant from the channel traverses the remaining distance to the mold surface through very small radial grooves **60** distributed around the entire periphery of the mold head as seen in the enlarged fragmentary view of FIG. 5 and thereby obtain a uniform distribution of the lubricant. The grooves are small enough that molten metal does not penetrate them and preferably they are normal to the surface of the inner mold wall. The lubricant, in the form of grease or oil is applied by known means to prevent adhesion of the ingot to the mold wall. Although the machined end face of the mold with lubricant grooves therein can abut the refractory head plate **18**, better results are obtained if the grooves are covered with a plate-like ring member **32**, as shown in FIG. 4, which also serves to control extraction of heat from the freezing metal as more fully described and claimed in co-pending application Serial No. 286,349, filed June 7, 1963, now abandoned, and to its continuation application, Serial No. 542,424, filed April 13, 1966.

The slot gate in the header plate, as indicated hereinabove, generally conforms to the shape of the mold but does not extend into the upper half of the mold section. However, under some conditions it may be advisable to extend the slot a short distance into the upper half section but substantially all of the molten metal is still delivered to the lower half section of the mold. On the other hand, the slot need not extend over the full lower half section but can be of lesser length where the ingot is large. Also, instead of a continuous aperture, the gate may be divided into segments **62** as illustrated in FIG. 6 but still subject to the same limitations as the continuous slot. It is to be understood that the individual segments may be short and may even be in the form of holes arranged in a series which in effect deliver a thin stream of metal to the mold cavity. In casting a square ingot the gate **64** may assume a rectangular shape as seen in FIG. 7, while a polygonally-shaped gate **66** should be employed in casting a polygonally-shaped ingot as seen in FIG. 8.

To produce an ingot in the manner and with the apparatus of the kind described above, a starting block is positioned in the exit end of the mold **10** and molten metal introduced to the reservoir **2** which should be preheated to prevent freezing of metal therein. The liquid metal **8** immediately passes through the gate **20** into the mold cavity thereby filling the cavity defined by the mold, the starting block and the head plate **18**. The metal starts to freeze on the mold walls and starting block and when this has progressed to the point that the layer of metal frozen on the starting block is thick enough to be self supporting, the block and attached ingot are gradually withdrawn from the mold and the rate of withdrawal increased until

a predetermined rate is attained. At some distance beyond the mold and after the ingot has reached the power driven rollers **54** or their equivalent, the starting block is detached from the ingot. The ingot is generally cut into convenient lengths by a saw or other means as it moves away from the mold. It will be appreciated that adjustments are usually necessary in casting different metals and even alloys of the same base metal. Also, suitable mold materials should be employed with respect to the metal being cast. In the case of casting aluminum and aluminum base alloys, molds can be used which are aluminum alloys since the chilling is sufficiently drastic as to prevent any melting of the mold.

The invention is illustrated in the following examples.

Example 1

An aluminum base alloy having a nominal composition of 0.7% magnesium, 0.4% silicon, balance aluminum, was melted and fed to the reservoir adjacent the mold, the metal in the reservoir having a temperature of 1260 to 1280° F. The mold of cast aluminum alloy had a length of 3 inches and an internal diameter of 6 inches. Water was supplied to the cooling chamber in the mold wall and projected therefrom upon the emerging ingot at the rate of 40 gallons per minute. The slot gate, extending over an arc of 180°, had an exit width of ⅜ inch and the lower edge was spaced from the inner mold wall by ¼ inch. The body of molten metal in the reservoir was maintained at a height of about 3 inches above the top of the forming ingot thus providing a small hydrostatic pressure on the metal fed to the mold. After the mold with starting block in place had been filled and withdrawal of the ingot begun, the rate of withdrawal was maintained at 5 inches per minute. An oil base lubricant was supplied at the head end of the mold to prevent adhesion of the metal to the mold. The ingot produced in this manner had a uniform fine equi-axed grain structure across the entire cross section and the surface of the ingot showed only slight ripples apparently the result of incipient exudation of alloy constituents as contrasted to the rough surface produced on ingots of the same alloy cast in conventional vertical water cooled mold of the type illustrated in U.S. Patent 2,301,027. The roughened surface in the latter case consists of narrow bands of exuded alloy constituent which is commonly referred to as "liquation." Where the surface of the ingot is to be worked it is usually necessary to remove the rough surface layer by machining, this operation being usually designated as scalping. The cut made by scalping normally extends to a depth of ¼ inch or more. Ingots cast in the horizontal mold described above exhibited only slight evidence of liquation and hence would require but a light cut if one were necessary with obvious economic advantage to the producer.

Example 2

Another aluminum base having a nominal composition of 5.5% copper, 0.5% lead, 0.5% bismuth, balance aluminum was melted and cast in the same mold as in Example 1. The metal was supplied to the mold at a temperature of 1250 to 1260° F. The other casting conditions were the same as in the preceding example. The resulting ingot also had a uniform fine equi-axed grain structure and the surface of the ingot showed only slight evidence of liquation.

Example 3

The same alloy was used as in Example 1 but the mold had an internal diameter of 9 inches and was 4 inches in length.

The slot gate, which extended over an arc of 80°, had the same exit width and spacing from the inner mold wall as the gate described in Example 1. Water was supplied at a rate of 60 gallons per minute and the rate of ingot withdrawal was 4 inches per minute, thus reflecting the lower rate needed when the mass of metal to be chilled is increased. The resulting ingot had the same quality an excess. An excessive amount not only yields vapors that may become entrapped in the metal but may leave a carbonaceous film on the ingot surface.

The essential features of the apparatus according to our invention comprise a molten metal reservoir, a chilled horizontally positioned mold open at the discharge or exit end and closed in the opposite end with a high heat insulating member except for the slot shaped gate for delivering molten metal in close proximity to the mold wall over substantially the lower half section of the mold. Molten metal is supplied from the reservoir to the gate under a relatively low pressure. In a preferred form of apparatus a metal supply reservoir is provided immediately adjacent to the gate opening in the heat insulating member, for example, by using the heat insulating member as a common wall between the reservoir and the mold. In this arrangement the reservoir is of such a depth that the top surface of the body of molten metal held therein can be maintained above the uppermost portion of the mold. The mold is provided with a jacket or chamber within the mold wall for circulating a liquid coolant and chilling the mold. A preferred arrangement involves discharging coolant from that chamber upon the emerging ingot through passageways which project a sheath of coolant upon the moving ingot. The chilling of the molten metal and emerging ingot in this mold arrangement is very rapid yet both the internal structure of the ingot and its surface are free from major defects. Conventional power driven means are used to move the ingot from the mold.

Referring now to the drawings, the general arrangement of the apparatus is seen in FIG. 1 where an open top molten metal reservoir **2** and associated supply trough **4** are covered with a suitable refractory **6**, the reservoir having the general transverse shape of a U and of sufficient width to embrace all of gate **20** in the wall member **18**. The back wall of the reservoir consists of a vertical plate-like refractory heat insulative member **18** having an elongated aperture or slot **20** which conforms generally to the shape of the mold on the opposite side of the wall member. The choice of refractory will be determined by the nature of the metal being cast, in the case of casting aluminum and aluminum base alloys the commercial asbestos-silica product sold under the trade name "Marinite" is satisfactory. On the opposite side of wall member **18** and compressed against it in sealing disposition is the chilled mold **10** which can be composed of aluminum or copper where light metals are being cast. Although the mold can be made as an assembly, a more convenient arrangement is to make the mold as an integral casting and machine the surface where required as well as any passageways. The mold **10** is cooled by circulation of water or other coolant supplied through pipe **14** to annular chamber **16** in the mold wall. The coolant is discharged from the chamber **16** through drilled passageways **44** to a second or mixing chamber **46** and from thence it is projected as a sheath **52** onto the emerging ingot through channel **50**. Also seen in FIG. 1 is passageway **58** for continuously supplying lubricant to channel **34** from where it is fed to the head of the mold at the inner wall surface through suitable small openings.

The aforesaid mold **10** is supported on a framework **12** through intermediate members consisting of a heavy metal plate **26** having an opening **27** therein of slightly smaller dimensions than the outside dimension of mold **10**. The plate **26** is bolted to lugs on the mold, not shown, to hold the mold in place. The mold is aligned and centered with the reservoir and plate **26** by means of the rabbet groove **31** in the completed assembly. The refractory plate member **18**, positioned within the opening **27** of metal plate **26**, is clamped against a portion of the end face of mold **10** by a stepped ring member **22** having a flange **24**, said ring being secured to the mold by bolts situated in suitable counter bores. To protect the ring **22** and metal plate **26** against contact with the molten metal in the reservoir a plate-shaped refractory insulating member **28** is placed over the ring **22**, the circular opening **29** being small enough to permit the plate **26** to establish contact with refractory head plate **18** and prevent seepage of molten metal to the stepped ring **22**. The protecting plate **28** is secured in position through a thin metal clamping plate **30** by suitable fastener means which extend into metal plate **26**. The underside of reservoir **2** is joined to plate **30** by any conventional means, such as welding, through the angle projection which is a part of the steel shell. If a portion of plate **30** is to be in contact with the molten metal, as shown in FIG. 1, it should have a suitable protective coating, coatings of this nature being well known in the art. In this arrangement the portion of the surface of the head assembly exposed to molten metal, with the exception of a portion of plate **30**, consists of a non-metallic refractory heat-resistant material. A suitable material for this purpose, as indicated above, is one composed of asbestos, silica and a binder where aluminum and aluminum base alloys are being cast.

The molten metal supply in relation to the solidified ingot is also evident in FIG. 1 where molten metal **8** in the reservoir passes through the gate **20** in the head plate **18** and establishes a molten head of metal **36** within the mold **10**. The metal coming in contact with the mold surface freezes immediately to form the walls of the embryo ingot, the freezing starting at **42** next to the refractory head plate **18**. The head of molten metal generally extends beyond the exit end of the mold, the boundary between liquid and solid metal being generally illustrated by line **38**. The solid ingot **40** is moved away from the mold by means of power actuated rollers **54**, or the like.

The shape of the slot gate **20** in header plate **18** is to be seen in the end view appearing in FIG. 2. The semi-circular slot extending over the lower half of the mold is relatively narrow and long, for example, the ratio of the total length to the width, whether the slot is continuous or segmented, is between 15 and 125 to 1. The lower edge of slot **20** is close to the inner surface of the mold wall in order to secure the necessary cooling of the incoming metal. The entire slot should be within one fourth of the distance from the inner mold surface to the center or axis of the mold as measured in a direction normal to the surface and at the midpoint of the lower half section. The rectangular external shape of the refractory protective plate **28** and the underlying metal plate **26** are also seen in FIG. 2 and as well as a portion of the supporting frame **12**.

Viewed from the mold side of the header plate **18** FIG. 3 illustrates in the lower half portion thereof the arrangement of the mold with respect to the freezing ingot while the upper portion, in section, indicates the locations of coolant supply pipes **14** with respect to the coolant chamber **16**.

FIG. 4 shows in detail the passageways in mold **10** for coolant and lubricant. The coolant chamber **16** is preferably spaced but a short distance from the inner mold wall in order to obtain a high rate of heat extraction from the liquid and solid metal. Although it is not essential that the coolant passing through the chamber be discharged upon the emerging ingot, it being possible to use separate cooling systems, it has been found to be convenient and highly effective to project the water from the chamber upon the ingot in a controlled manner.

A very effective means of accomplishing this is to discharge water from cooling chamber **16** into another and smaller continuous chamber **46** extending around the entire mold near the exit end thereof. Small drilled passageways **44** are satisfactory for this purpose but openings or passageways of different shape and size can, of course, be used. The water is delivered to the ingot surface from the chamber **46** through a slot or continuous opening **50**. In a preferred form of our invention the of grain structure and surface as the one described in Example 1.

Having thus described our invention and certain embodiments thereof, we claim:

1. The method of continuously casting ingots in a horizontally disposed chilled mold open at one end and closed at the opposite end with a heat insulating member except for an opening therein for passage therethrough of molten metal, said method comprising maintaining a body of molten metal adjacent said chilled mold, feeding to the lower half section of said mold substantially all of the metal entering the mold, said feeding being in the form of a stream which is inwardly of and in close proximity to the mold wall in said lower half section, said stream being relatively short in the direction of metal feed and in general conformity with, and extending around and upwardly along, the periphery of said lower half section of the mold wall, initiating freezing of the metal at the head of the mold next to the insulating closure member and around the entire periphery of the mold and progressively increasing the thickness of the frozen metal toward the exit end of the mold and withdrawing the ingot from the mold.

2. The method according to claim 1 wherein the metal being cast is a light metal.

3. The method according to claim 1 wherein the molten metal is fed in a laterally continuous stream to substantially all of the lower half section of the mold.

4. The method according to claim 1 wherein the molten metal is fed to the mold in the form of a plurality of streams in the lower half section of the mold.

5. The method according to claim 1 wherein the stream of metal enters the mold in diverging form.

6. The method according to claim 1 wherein the molten metal is chilled and solidification initiated immediately adjacent to the incoming stream of metal.

7. The method according to claim 1 wherein the lateral width of the stream entering the mold is 15 to 125 times its thickness.

8. Apparatus for the continuous casting of an ingot in a horizontally disposed mold having internally chilled walls comprising an open top molten metal reservoir, a common wall of refractory heat insulative material between said reservoir and said mold except for a gate opening for passage of molten metal from said reservoir to said mold, said gate opening being long and narrow and generally conforming to the shape of and confined to substantially the lower half section of the inner mold wall, said gate opening also being spaced inwardly from said wall but in close proximity thereto, means for supplying lubricant to the inner mold wall at the head end of said mold, said mold having a coolant chamber within the walls thereof and a passageway from said chamber to the exit end of the mold terminating outwardly of the inner mold wall surface, said passageway also converging toward the exit end of the mold whereby the coolant is discharged upon the ingot emerging from the mold, and means for withdrawing the ingot from the mold.

9. Apparatus according to claim 8 wherein the gate opening is spaced inwardly from the inner mold wall by a distance not more than one-fourth the distance from the said inner mold wall to the center line of the mold as measured in a direction normal to the surface of said inner wall at the midpoint of the lower half section of the mold.

10. Apparatus according to claim 8 wherein the gate is divided into segments.

11. Apparatus according to claim 8 wherein the gate opening diverges from the intake to the discharge end.

12. In apparatus for the continuous casting of an ingot in a horizontally disposed mold having internally chilled walls, an open top molten metal reservoir, a common wall of refractory heat insulative material between said reservoir and said mold except for a gate opening for passage of molten metal from said reservoir to said mold, said gate opening being long and narrow and generally conforming to the shape of and confined to substantially the lower half section of the inner mold wall, said gate opening also being spaced inwardly from said wall but in close proximity thereto, means for supplying lubricant to the head end of the mold comprising passageways from the external surface of the mold to a channel in the head face of the mold adjacent the inner wall of the mold and extending around the entire mold, grooves in said head face of the mold between said channel and the inner mold wall surface, said head face being in sealing disposition to the said common heat insulative wall whereby the open faces of the channel and grooves are closed, said mold having a coolant chamber within the walls thereof and a passageway therefrom to the exit end of the mold, and means for withdrawing the ingot from the mold.

13. In apparatus according to claim 12 in which the grooves from the lubricant channel to the inner mold wall are normal to the inner mold wall surface.

14. In apparatus according to claim 12 wherein the open faces of the channel and grooves in the head face of the mold are closed by a gasket member between said mold face and the heat insulative common wall.

15. In apparatus for the continuous casting of an ingot in a horizontally disposed mold having internally chilled walls, an open top molten metal reservoir, a common wall of refractory heat insulative material between said reservoir and said mold except for a gate opening for passage of molten metal from said reservoir to said mold, said gate opening being long and narrow and generally conforming to the shape of and confined to substantially the lower half section of the inner mold wall, said gate opening also being spaced inwardly from said wall but in close proximity thereto, means for supplying lubricant to the inner mold wall of the head end of the said mold, said mold including a cooling system comprising a coolant chamber within the mold wall and extending around the entire mold, a second and smaller chamber between said first chamber and the exit end of the mold, also extending around the entire mold, passageways from said first to said second chamber for transfer of coolant, a continuous slot between said second chamber and the discharge end of the mold, said slot converging from the second chamber toward the inner mold wall but terminating in exit end of the mold, and means for withdrawing the ingot from the mold.

16. In apparatus according to claim 15 wherein the continuous slot converges at an angle of between 5 and 10 degrees to the inner mold wall.

17. In apparatus according to claim 15 wherein a detachable ring secured to the exit end of the mold constitutes a portion of the wall of the second chamber and the inner edge of said ring constitutes one wall of the continuous slot passageway between the second chamber and the exit end of the mold.

18. In apparatus according to claim 15 wherein the inner wall of the continuous slot passageway between the second chamber and the exit end of the mold is tapered at an angle of 5 to 10 degrees to the inner mold wall, and the taper terminates at substantially the inner mold wall.

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J. SPENCER OVERHOLSER, *Primary Examiner.*

R. D. BALDWIN, *Assistant Examiner.*