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CONTINUOUS CASTING MOLTEN METAL FEED DEVICE

Filed Sept. 1, 1966 3 Sheets-Sheet 1

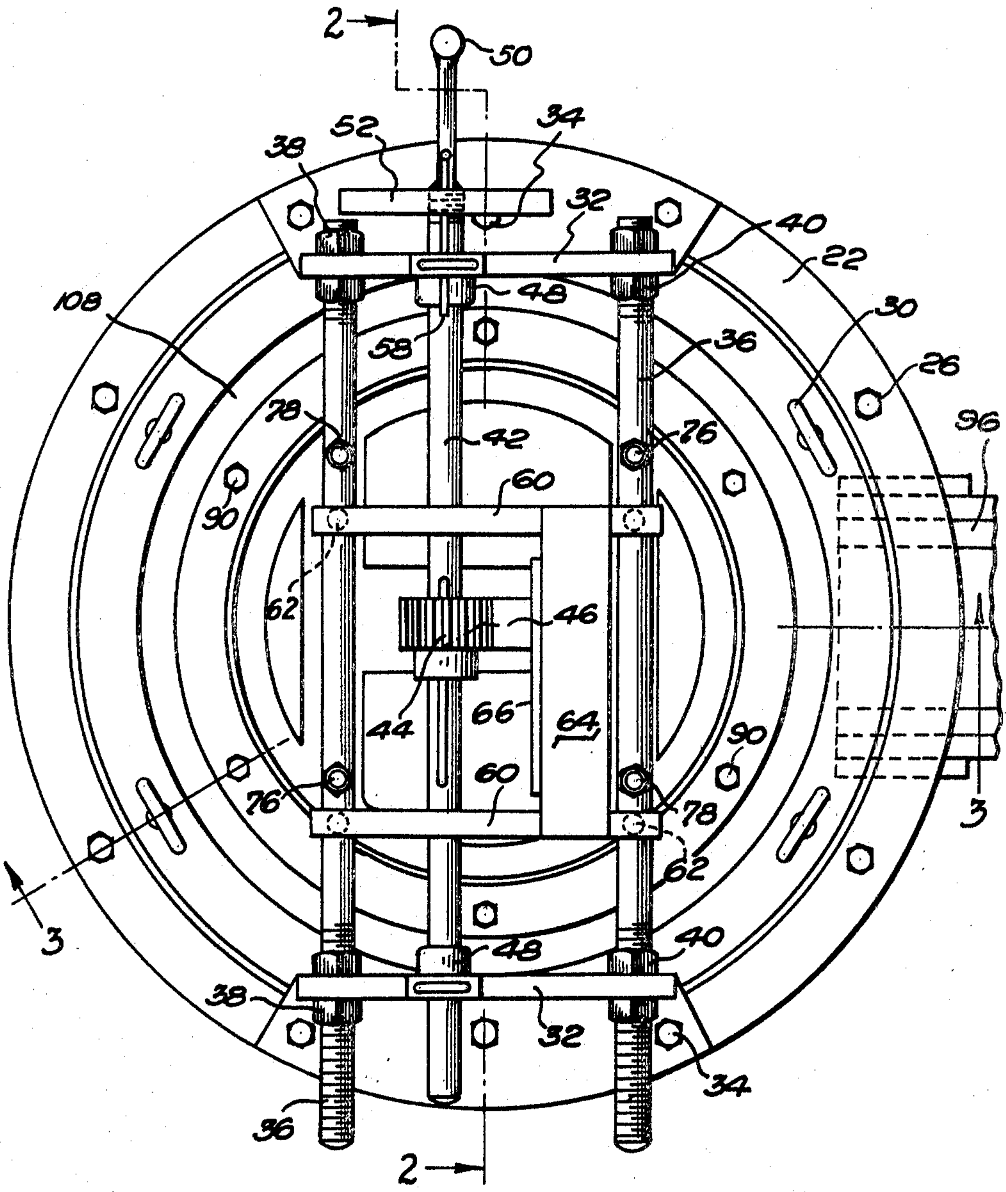

FIG. 1.

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FIG. 2

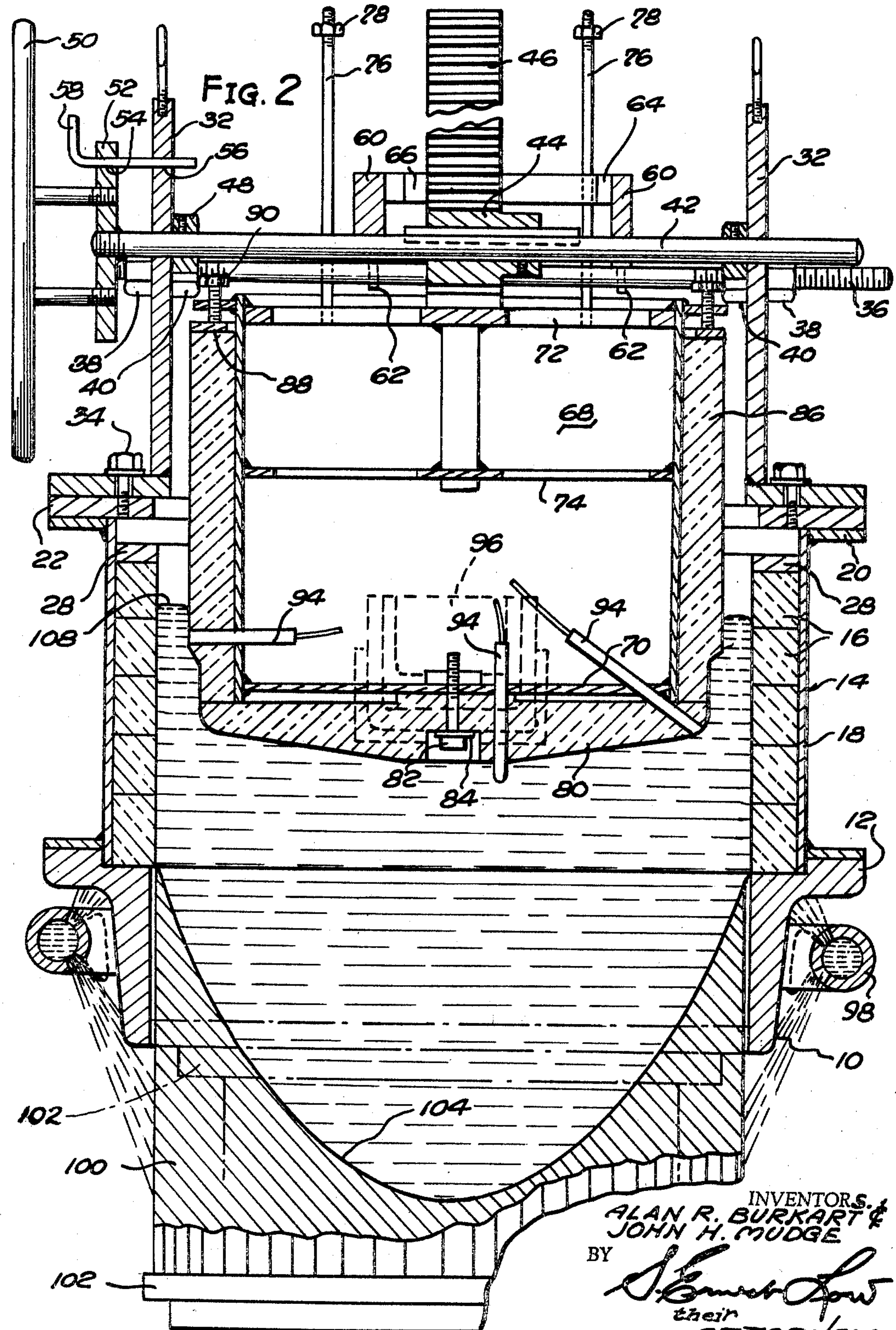

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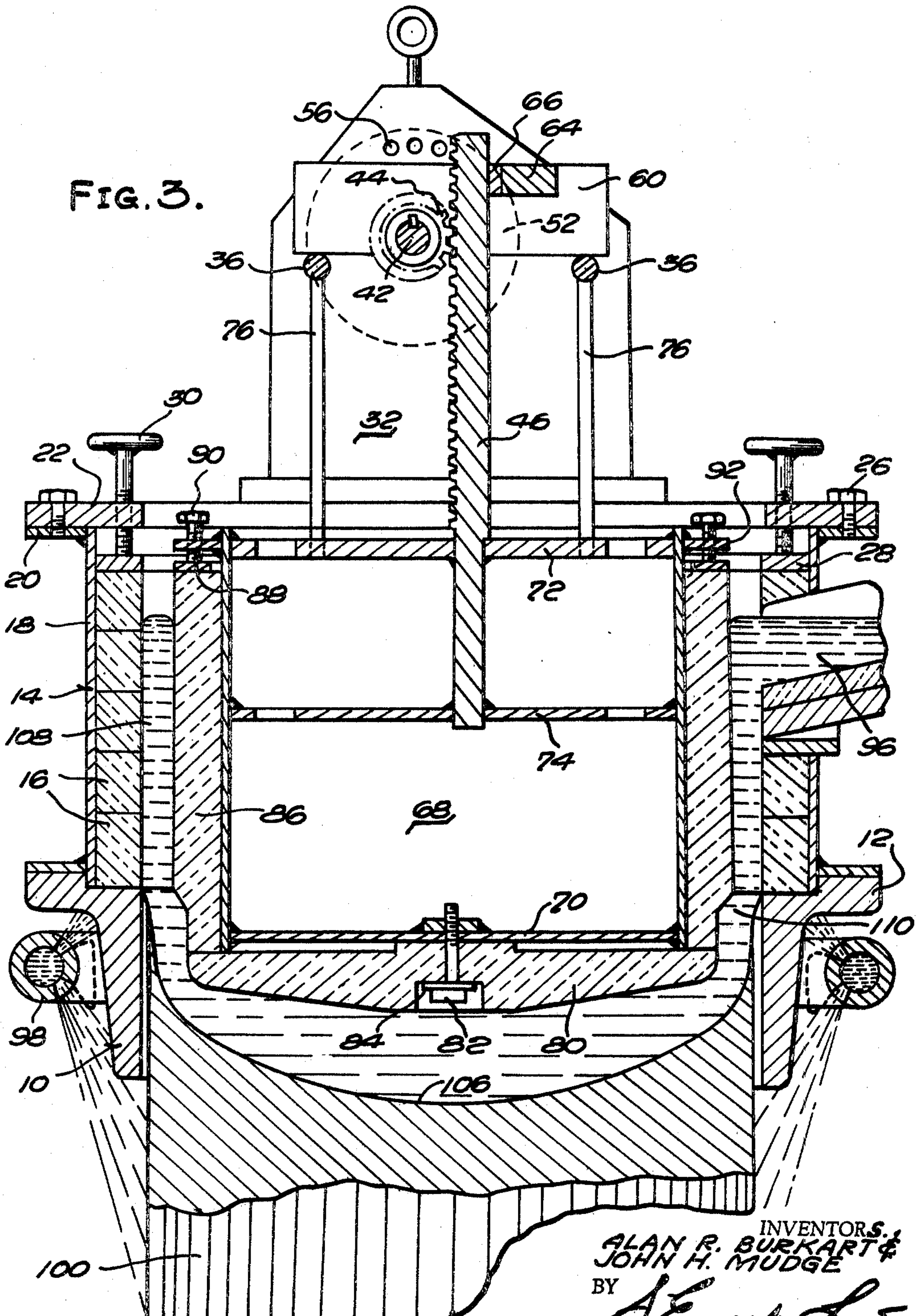
FIG. 3.



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CONTINUOUS CASTING MOLTEN METAL FEED DEVICE

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U.S. Cl. 164—281 2 Claims

ABSTRACT OF THE DISCLOSURE

A continuous casting mechanism comprising a chill mold substantially defining the exterior transverse contiguous surface of a body, such as an ingot or billet, to be continuously cast and extracted therefrom; a heat insulating mold in unitary connection and communication in advance of said chill mold; a core or displacer disposable within and in spaced relationship to interior defining walls of both the chill and heat insulating molds; and the core or displacer contactable by molten metal supplied to the chill mold through the heat insulating mold being of heat insulating material. A method of continuous casting employing the aforesaid mechanism in which the heat insulating core or displacer extends into a molten metal crater defined by solidified exterior walls of a continuously cast ingot or billet.

This invention relates in general to new and improved apparatus and practices for the continuous casting of metals and alloys thereof, and is more particularly addressed to the production by continuous casting of mechanically and metallurgically sound aluminum and aluminum alloy ingots and billets for subsequent working in the production of wrought products therefrom. As herein and hereinafter employed, "aluminum and aluminum alloys" is intended to include aluminum metal and alloys containing at least 65 percent aluminum.

Conventional continuous casting has invariably followed the practice of introducing molten metal into one end of an open-ended relatively axially short chill mold while applying cooling media directly against the exterior of the chill mold in sufficient amount to extract heat from the molten metal adjacent thereto to produce and define surrounding solidified walls and outer surfaces of an embryo ingot or billet of sufficient mechanical strength and thickness to support a molten phase or crater of generally cone or V-shape within the embryo ingot or billet as the same is continuously withdrawn from the exit or opposite end of the chill mold to that at which the molten metal is being continuously delivered. It has also been conventional practice to supply and apply cooling media directly against the exterior surfaces of emanating embryo ingots or billets discharged from the axially short chill molds employed in continuous casting practices in such quantity or amounts as to completely and substantially transversely solidify the initially interior molten phase of the embryo ingots or billets so cast in a plane some axially removed distance away from the discharge open end of the chill mold.

It has also been proposed in the published art addressed to continuous casting to additionally provide heat extracting means extending axially into the interior of the generally cone-shaped molten phase craters of embryo billets and ingots to promote internal heat extraction and acceleration of the rate of interior solidification of the molten phase within the craters of embryo ingots. Such published proposals have invariably recommended chilled cores or vessels of relatively high heat conductive materials extending into the molten phase craters of the embryo ingots or billets being continuously cast.

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In contradistinction to prior art practices, the present invention is basically predicated upon the provision of heat insulating means, such as a core member, preferably axially displaceable, within the molten metal crater of continuously cast products, as well as mechanism and process steps for the manipulation and support thereof, which reacts to displace the molten metal within the crater and thermally controls the freezing rate thereof. The selection and use of a heat insulating means or core for the heretofore employed heat extracting chill core or vessel of the prior art, in combination with means for actuating the same during initiation and prior to completion of a continuous casting operation, has resulted in producing a substantially completely reversed isothermal freezing pattern within the interior molten metal craters of embryo continuously cast products. Phenomenal results have been observed from the substitution and use of the heat insulating core means of the invention and have been evidenced by an increase in the rate of production of continuously cast billets or ingots exhibiting mechanically and structurally sound fine-grained products.

In addition, continuous casting in accordance with the invention of metallic alloy compositions, and particularly aluminum and similar alloys characterized by a tendency to produce exposed and sub-surface zones of depleted normal constituent or constituents under conventional continuous casting practice, has revealed a substantial decrease in the depth of such liquated zones which is directly reflected in the depth of scalping required to provide acceptable continuously cast extrusion ingot and similar cast stock for subsequent working in the production of acceptable wrought products therefrom.

Mechanism or apparatus, exemplary but in no sense limiting the new and improved continuous casting practice of the invention, is hereinafter described in conjunction with the following illustrations, in which:

FIG. 1 represents the molten metal charging end plan view of a continuous casting mechanism illustrating one form of mechanical structure capable of permitting practice of the invention;

FIG. 2 represents a cross-sectional elevation taken on the plane **2—2** of FIG. 1 at the beginning of a casting operation; and

FIG. 3 represents a cross-sectional elevation taken on the plane **3—3** of FIG. 1 at some subsequent period during the continuous casting operation.

Explanatory of the aforesaid illustrations and following description, it is to be understood that the vertical disposition and generally right cylindrical trace or outline of the casting apparatus and ingot continuously produced thereby are not limiting factors, but are merely representative of mechanism and practice of the invention.

Referring now to the aforesaid generally stated practice and description of the invention, a conventional open-ended axially short chill mold **10**, constructed from a relatively highly efficient heat conducting chill-inducing material, such as graphite or aluminum, is outwardly flanged or otherwise configurated at its entry end at **12** in direct communicating continuation with an open-ended non-chilling high heat resistant and heat insulating laterally enclosing mold section **14**. The commercial material known as Marinite (heat insulating asbestos-silica composition) has been successfully employed for the mold section **14**. Other commercially available non-chilling heat resistant materials however, such as fire brick or the like, commonly employed for lining elevated temperature metallurgical furnaces, may be substituted for the Marinite portion of mold section **14**.

The mold section **14** may be a one-piece structure, but it has been found structurally and economically desirable to construct the same from abutting heat insulating plate members or laminae **16** exteriorly enclosed within a protective steel supporting frame or shell **18** unitarily secured to the entrance end flange **12** of the chill mold **10**. The shell **18** surrounding, confining and supporting the non-chilling heat insulating mold section **14**, is preferably of generally channel shape in longitudinal cross-section and is provided with an outwardly directed terminal entry flange **20** which serves as a support for connection thereto of a steel or other metallic base plate or ring **22** in unitary securement to the flange **20** as by means of a peripheral line of bolts **26** (FIG. 1). A pressure plate or ring **28** is also preferably provided within the entry end to the exterior shell **18** in bearing contact against the heat insulating plate or laminae **16** therewithin adjacent the flange **20**, and manually adjustable pressure screws **30** (FIGS. 1 and 3), threadedly engaged within the stationary base plate or ring **22**, bear and exert pressure at their free ends against the ring **28** and insure unitary compact assembly of the plates or laminae **16** within the shell **18** of the non-chilling heat insulating mold section **14**.

Oppositely disposed steel or similar brackets or standards **32** are secured to the outer exposed face of the base plate or ring **22**, as by bolts **34** (FIG. 1), and parallel spacer rods **36**, preferably at least two, each carrying paired clamping nuts **38** and **40** on the opposite threaded ends thereof, provide a unitary appendage or superstructure incorporating the aforesaid standards **32** in rigid association with the base ring **22**.

A cross shaft **42** is rotatably supported in aligned bearing openings in the brackets or standards **32** and axially centrally supports a pinion **44** splined thereon and secured by a set screw, or the like, to insure meshing engagement with a rack **46** to be later described. Positive and accurate disposition of the cross shaft **42** between the standards **32** is maintained and insured by the set screw-secured collars **48** mounted on the cross shaft **42** in abutting engagement against the inwardly facing surfaces of the standards **32**. A manipulating hand wheel **50** (FIGS. 1 and 2) is secured to an outboard extension of the cross shaft **42** which incorporates a disc **52** having an aperture **54** (FIG. 2) through the thickness thereof in concentrical alignability with anyone of a series of like apertures **56** (FIGS. 2 and 3) extending through the thickness of the standard **32** adjacent but spaced inboard therefrom. Reference to FIG. 2 will reveal that an angular locking pin or key bar **58** is employable in extended disposition through the aperture **54** into any selected aperture **56** to positively lock the hand wheel **50**, cross shaft **42** and pinion **44** against relative movement in respect to the axially aligned mold sections **10** and **14**.

A cradle type housing is supported by the transverse spacer rods **36** and is constructed in the form of spaced side rails or frame members **60** provided with extending locating pins **62** projecting into registering apertures in the rods **36** (FIG. 2). The projecting ends of the pins **62** may be threaded for receiviing nuts (not shown or essential in the vertical arrangement of the casting equipment illustrated in the appended drawings) which would permit rigid unitary assembly of the cradle on the spacer rods **36**. The side members **60** of the cradle type housing are rigidly tied together in the plane of their outermost surfaces remote to their supporting spacer rods **36** by means of a cross bar or plate **64**, which supports or carries a bronze anti-friction edge bearing plate **66** in rubbing contact against a surface of the aforementioned rack **46** opposite or remote to the pinion **44** (FIG. 3). It will be manifest from the mechanism thus far described that rotation of the cross shaft **42**, by manipulating the hand wheel **50**, will impart reciprocal motion or translation of the rack bar **46**.

FIGS. 2 and 3 best illustrate essential structure in regard to the practice and advantages attributable to the present invention. Therein it will be observed that a generally cylindrical or box-shaped vessel, herein called a core member or displacer and identified in its entirety by reference numeral **68**, has been unitarily and rigidly secured to the end of a unitary extension of the rack bar **46** remote to the pinion **44** engaging therewith.

The heat insulating core or displacer **68** is concentrically or centrally disposed in respect to the common longitudinal axis of the chill mold **10** and attached heat insulating mold section **14** by proper adjustment and secured location of the cross shaft **42** and pinion **44** carried thereby in their relation to the plane and axis of rectilinear movement of the rack bar **46** in mesh with the pinion **44**.

In addition, the heat insulating core or displacer preferably and generally comprises a hollow steel or other structural metal member provided with opposite end and intermediate transverse plate or reinforcing baffle members **70**, **72** and **74**, respectively, secured as by welding, or the like, to interior surface areas forming an uninterrupted side wall, or side walls, of the drum or box-shaped shell of the displacer **68**. The rack bar **46** is rigidly secured to the displacer **68** and is preferably cross-sectionally reduced in its unitary extension beyond the rack teeth thereof, extended through registering complementary apertures in one opposte end and intermediate plate members **72** and **74** (FIGS. 2 and 3), where welded or other mechanical attachment is made therewith. Also, guide and snubbing rods **76**, secured to the end plate member **72** and projecting outwardly therefrom, are provided for guiding extension through aligned apertures in the spacer rods or bars **36** and carry adjustable nuts **78** (FIG. 2) at their outer threaded end extremities to limit the extent of axial translation of the displacer **68** within the integrated mold sections **10** and **14**.

The cardinal structural feature and touchstone of success of the invention turns on the provision of a non-chilling heat resistant and substantially high heat insulating exposed surface liner or exterior wall for the core member or displacer **68**. This requirement has been satisfactorily met by providing an end plate or disc **80** of Marinite, or similar non-chilling heat insulating material, secured to the adjacent end plate **70** of the displacer **68** in any suitable manner, such as by the central exteriorly manipulated tap bolt **82**. A washer **84** is recommended under the head of the tap bolt **82** to distribute the clamping pressure exerted thereby between the central raised bearing or stepped area of the plate **80** and outwardly directed surface of end plate **70** of the interior shell of the displacer **68** in abutting contact therewith.

The end plate **80** is preferably selected to project laterally or overhang beyond the interior uninterrupted side wall or walls of the core member or displacer **68** to provide abutting contact against an exposed or outer non-chilling heat insulating side wall **86** surrounding the interior wall or walls thereof which supports a pressure-applying and assembly ring or plate **88** of steel, or the like, remote to the end plate **80**. The plate **88** is preferably engaged by the free ends of bolts **90** in adjustable pressure-exerting threaded engagement in an outwardly extending flange **92** in unitary attachment to the side wall of the displacer shell **68** to thus provide unitary assembly of the heat insulative exterior side and end surfaces of the centrally disposed displacer **68** of the invention. Thermocouples **94** (FIG. 2), or similar temperature sensing and/or measuring devices, have been provided in at least three axially separated planes parallel to the transverse plane of the end plate **80** of the displacer **68**, whereby thermal conditions within the mold have been determined.

In the preferred practice and operation of the continuous casting mechanism of the invention thus far described, a conventional translatory end closing chill block or plate **102** is disposed within the otherwise open discharge end of the chill mold **10** in sealing relationship thereto, as indicated in broken line construction in FIG. 2, and with the displacer **68** either completely oppositely axially withdrawn from the insulated mold section **14**, or in conservation of space is disposed axially intermediate the length of the same, as indicated in FIG. 2 and herein termed the preferred starting position or location thereof, molten metal to be cast is delivered through the open end of mold section **14** remote to the chill mold **10** from a suitable source of reservoir, as by means of one or more delivery troughs **96**, to fill the chill mold **10** above the broken line position of the end closing palte **102** (FIG. 2) to a level within the insulated mold section **14** controlled by the delivery trough or troughs **96**.

Coolant, such as water or the like, is supplied against the exterior of the chill mold **10** from a perforated manifold **98** in amount sufficient to extract heat from the molten metal so charged within the mold sections **10** and **14** to freeze an embryo ingot **100** defined by a laterally enclosing and supporting shell within the axial length of the chill mold **10** and an enclosing end wall contiguous therewith in contact with the end plate **102**, and characterized by having a substantially central liquid crater phase of non-solidified metal extending axially into the mold section **14**, where the metal charge remains liquid.

Translation of the end plate **102** out of sealing relationship within the chill mold **10** to some axially removed position thereof disclosed in full line construction in FIG. 2, under uninterrupted regulated delivery of molten metal to the insulated mold section **14** and controlled coolant supplied agains the chill mold **10** and now exposed frozen shell of the embryo ingot **100**, is representative of conventional continuous casting practice.

Preferred practice of the instant invention is initiated in the otherwise conventional continuous casting practice above described by translating the displacer **68** axially through the molten phase creater of the embryo ingot **100** to a position illustrated in FIG. 3, which is representative of its location during continuous casting in accordance with the preferred practice of the invention. It will be understood and observed in this respect, and particularly on comparison of the curvilinear solidus contour lines **104** and **106** of FIGS. 2 and 3, respectively, that the molten metal craters and solidus contour lines defining the same are radically changed in response to translatory movement of the displacer **68** to the position occupied thereby in FIG. 3, wherein it now extends axially through the insulated mold section **14** into the chill mold **10** a distance substantially equal to half the axial length of the chill mold **10**.

Presence and use of the core member or displacer **68**, as hereinabove described, has provided a substantially reduced or narrow feed channel **108** defined in transverse cross-sectional area between the interior wall of heat insulating mold **14** and outwardly directed heat insulating wall of the displacer **68** both in advance of and within the chill mold **10** (FIG. 3), as compared to the respective enclosing transverse cross-sectional areas of the mold sections **10** and **14** in the absence of the displacer **68**, and it is this reduced transverse cross-sectional area of feed channel **108**, coupled with the thermally insulated walls of the insulating mold **14** and core member or displacer **68** forming the feed channel, that has resulted in the increase in casting rate heretofore referred to.

Testing of a mechanism as hereinabove described, the appended illustrations of which are scaled down representations of an apparatus employed in the continuous casting of twenty-five inch diameter 2214 aluminum alloy ingots, established a casting rate of double that for the same ingot composition and same mechanism without incorporating the core member or displacer **68**. The nominal composition of 2214 aluminum alloy on a percent by weight basis is 0.8 silicon, 4.4 copper, 0.8 manganese, 0.4 magnesium and the balance aluminum.

It will be observed that the solidus contour line **106** (FIG. 3) substantially approaches or follows the general configuration of the exposed end of the displacer heat insulating immersed end block **80**, as compared to that of the deeper crater defined in FIG. 2 by the solidus contour line **104**. It will also be observed that the feed channel **108** may be slightly enlarged in transverse cross-section as it enters the embryo ingot, at **110** (FIG. 3), in substantially the transverse plane of the contacting interface formed between the chill mold **10** and heat insulating mold **14**. It is the expressed belief herein that the initially delivered elevated temperature molten metal charge within the feed channel **108** is subjected to maximum drastic chilling and heat extraction in substantial coincidence with the enlarged cross-sectional feed area **110** and that the so chilled molten metal contactingly follows the contour of the heat insulating displacer block **80** to provide a uniformly falling temperature gradient from the center to the outer surfaces of the ingot being cast.

A twenty-five inch diameter 2214 aluminum alloy ingot so continuously cast was found to be mechanically and structurally sound; exhibited a fine grain structure and a decreased depth of surface and sub-surface liquated zones; and was substantially free from cold shuts, all of which characteristics can be attributed to a more uniform and directional heat extraction transversely across the width, or normal to the common longitudinal axis of the molds **10** and **14**, of the continuously cast products, produced in accordance with the invention, substantially within the axial length of the chill mold **10** thereof. The foreshortened axial length of the molten metal phase within the crater of FIG. 3 also points to the fact that the temperature of the molten metal in a transverse plane across the crater is more uniform and that solidification takes place appreciably more uniformly inwardly towards the center of the so-cast products than has been the case in the longer cone-shaped craters heretofore experienced in conventional continuous casting processes illustrated, at least in degree, in FIG. 2.

Operation of the continuous casting method and mechanism hereinabove described can be terminated by interrupting molten metal delivery to the insulating mold section **14**, withdrawing the displacer **68** out of physical contact with remaining molten metal in the crater of the product being cast, and continuing axial extraction of the cast product **100**, while preferably maintaining continuous coolant flow against the chill mold **10** and product **100** until the molten metal crater is completely solidified, at which time the coolant flow can be interrupted and the product **100** removed from the casting apparatus of the invention.

Having thus described and explained one embodiment of apparatus and method of continuous casting employing the same, it will be understood by those skilled in the art to which the invention is addressed, that other embodiments of the invention may be practiced, as hereinafter defined in the appended claims.

What is claimed is:

1. A continuous casting mechanism having an open-ended chill mold, a heat insulating mold adjacent the entrance of the chill mold and having an opening having a transverse cross section of similar size and shape therewith, a core member having heat insulating molten metal contacting surfaces extending within said heat insulating mold and said chill mold for maintaining a body of molten metal within said chill mold, and means for positioning the said core member to provide a space between said core and said heat insulating and chill molds, the space extending around substantially the entire inside periphery of said heat insulating and chill molds.

2. A continuous casting mechanism having an open-ended chill mold, a heat insulating mold adjacent the entrance of the chill mold and having an opening having a transverse cross-section of similar size and shape therewith, a displacer member extendable into said heat insulating mold and said chill mold for maintaining a body of molten metal within said chill mold, said displacer having heat insulating molten metal contacting surfaces, means for positioning said displacer to provide a space between said displacer and said heat insulating and chill molds, the space extending around substantially the entire inside periphery of said heat insulating and chill molds, and means for relatively axially reciprocating said displacer in respect to said heat insulating and chill molds to provide extension of said displacer axially into the chill mold.

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