Sept. 16, 1969 W. M. CHARMAN, JR 3,467,168

CONTINUOUS CASTING APPARATUS AND METHOD INCLUDING MOLD LUBRICATION, HEAT TRANSFER, AND VIBRATION

Filed April 25, 1966 4 Sheets-Sheet 1

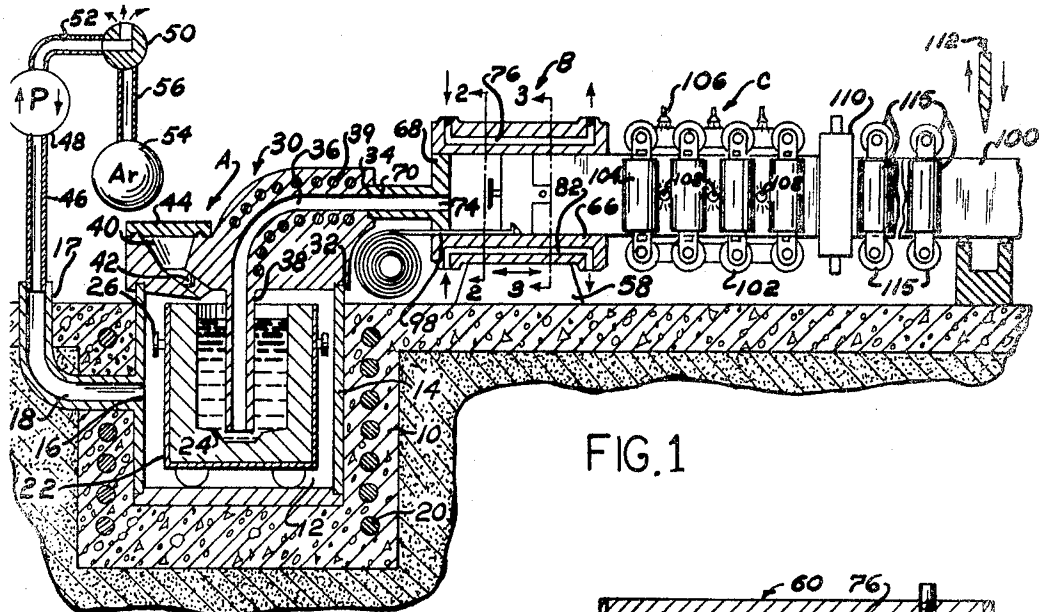

FIG. 1

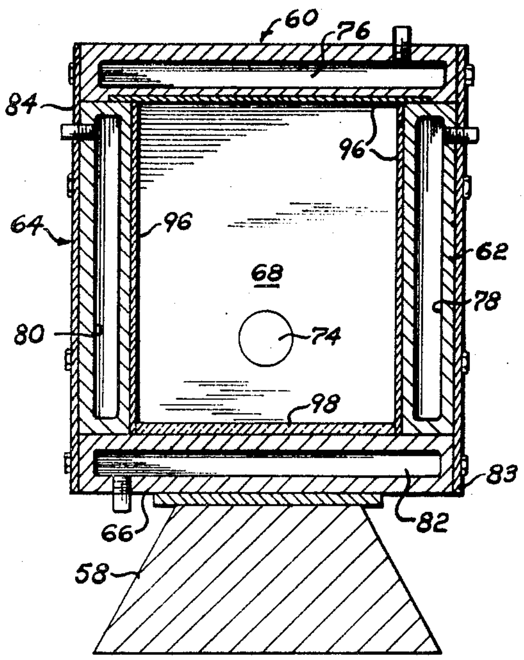

FIG. 2

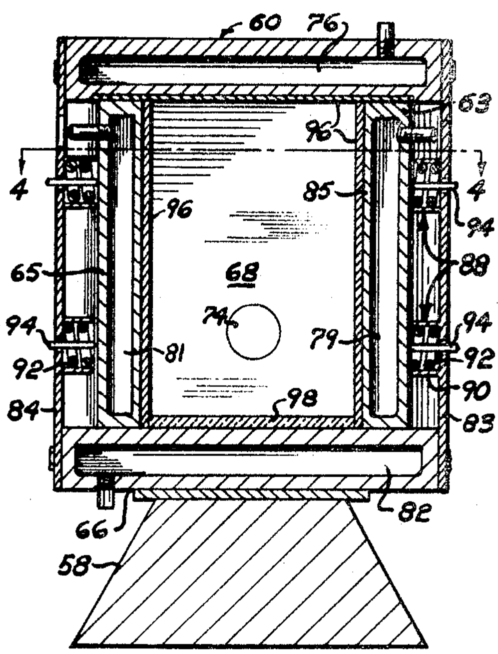

FIG. 3

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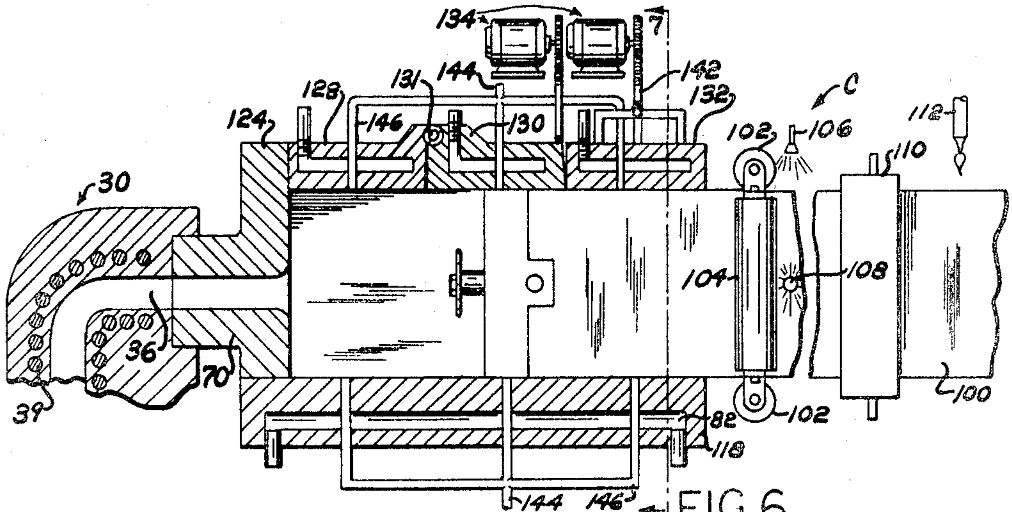

FIG.6

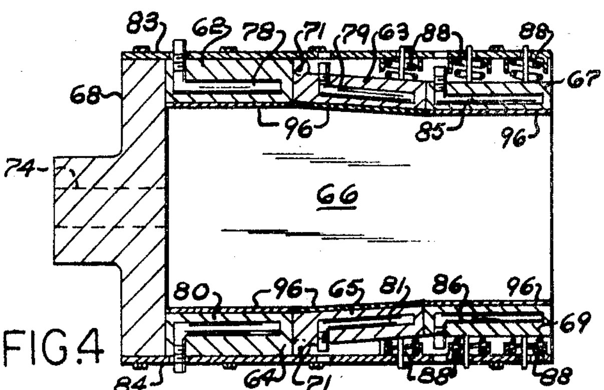

FIG.4

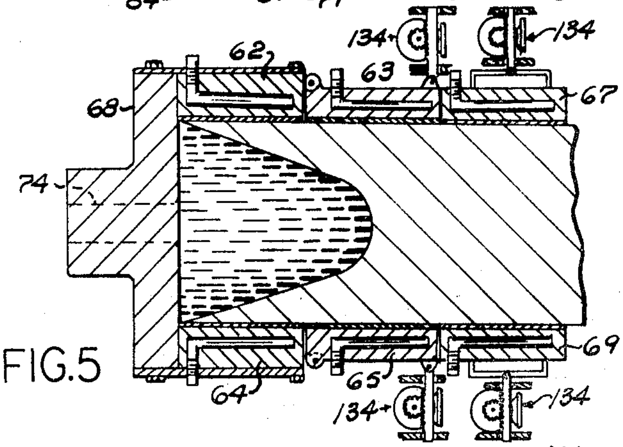

FIG.5

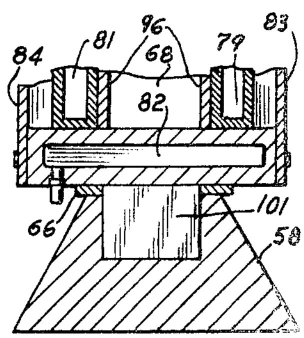

FIG. 3A

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CONTINUOUS CASTING APPARATUS AND METHOD INCLUDING
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Filed April 25, 1966 4 Sheets-Sheet 3

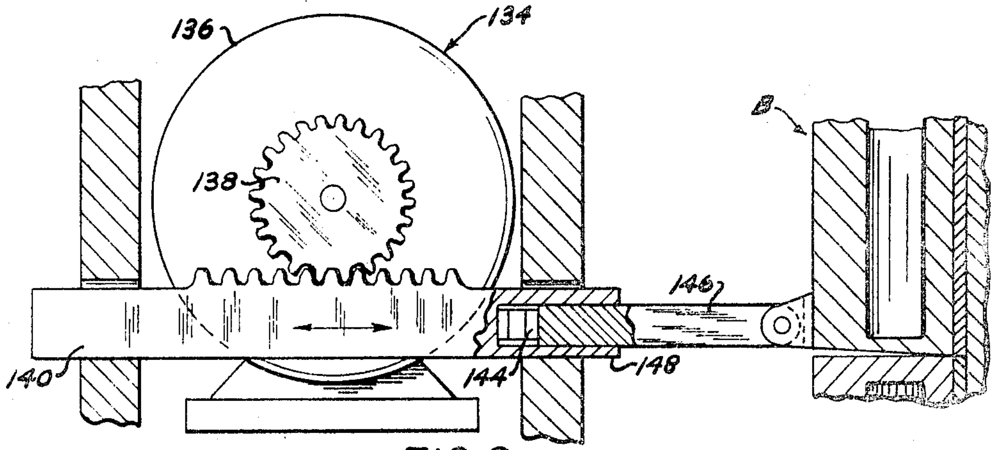

FIG.8

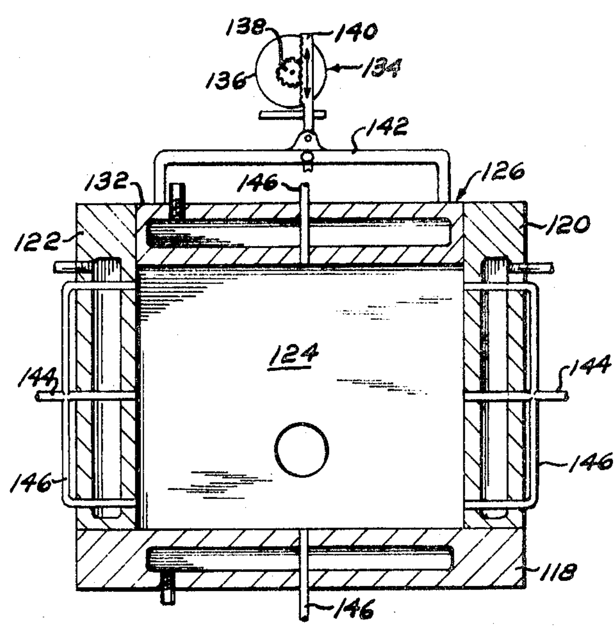

FIG.7

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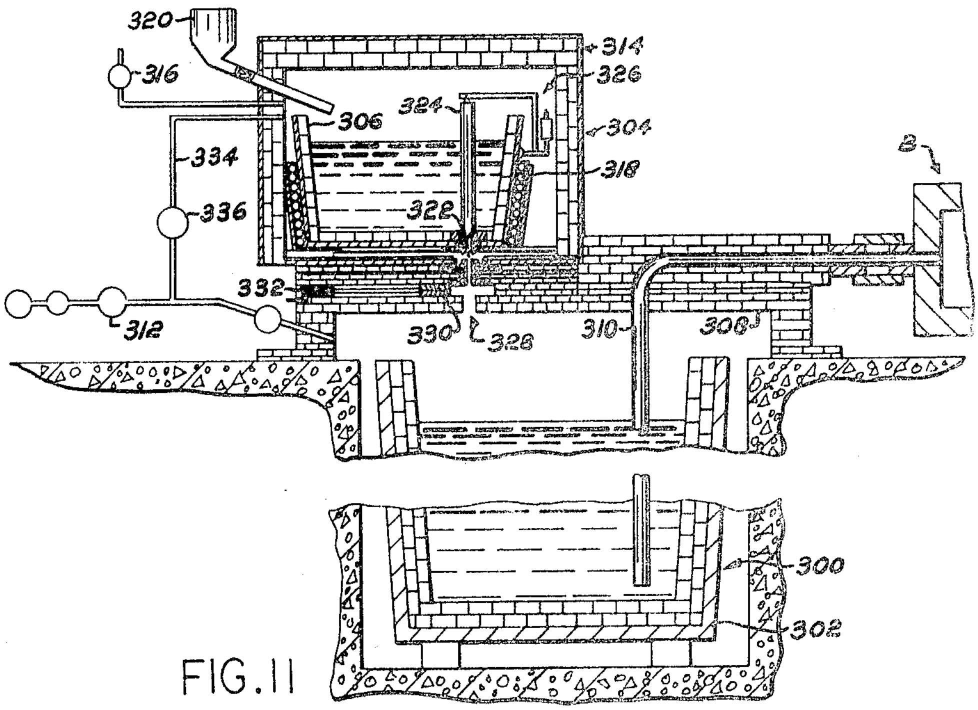

FIG. 11

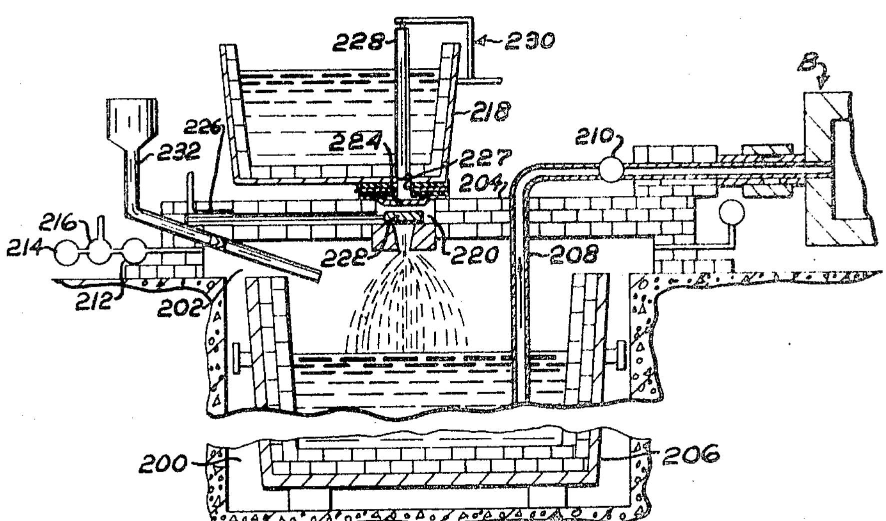

FIG. 10

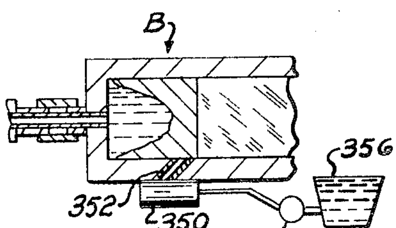

FIG. 9

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CONTINUOUS CASTING APPARATUS AND METHOD INCLUDING MOLD LUBRICATION, HEAT TRANSFER, AND VIBRATION

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Int. Cl. B22d *11/10, 11/06, 11/12*
U.S. Cl. 164—64 34 Claims

ABSTRACT OF THE DISCLOSURE

An improved casting apparatus includes a container from which molten metal is conducted upwardly to a horizontally extending mold. In one embodiment, the mold has a plurality of relatively movable metallic wall sections having graphite inserts for engaging the molten metal to retard adherence of the molten metal to the wall sections. The wall sections are urged inwardly into engagement with the sides of the casting as it cools and shrinks to thereby promote a transfer of heat between the casting and the wall sections. A lubricating tape is moved through the mold between the bottom wall of the mold and the molten metal to retard sticking of the molten metal to the bottom wall. In another embodiment, a vibrating means is provided for vibrating the bottom wall to retard sticking of the molten metal to the bottom wall.

The present invention relates to a method and apparatus for continuously casting metal, particularly steel.

The continuous casting machines which are presently in use are vetrical casting machines. Predominantly, the machines have vertical chill molds which are oscillated vertically and which are lubricated with rapeseed oil or other lubricant to minimize the sticking of the steel being cast to the chill mold. When a mold is reciprocated to minimize sticking of the steel skin to the chill mold, the casting is marked where the reciprocation reverses due to the tearing of the casting skin.

Vertical casting machines which are presently in use also have built-in limitations relating to the section size and steel casting rates. Different grades and section sizes of steel must be cast at different rates to provide good internal soundness and in a vertical casting machine, the height must be great enough to provide sufficient cooling length below the chill mold for the fastest casting rate. The actual vertical height necessary can, in many cases, present major problems.

Not only does the vertical height required for fast casting rates present high construction cost problems, but rapid casting rates in a vertical apparatus involves a ferrostatic head of metal which may cause the newly formed skin of the casting to actually bulge and the casting to bind in the casting mold. The bulging of the casting walls results in mechanical damage and erosion to the mold walls, and this has prevented the commercial use of graphite molds which are highly desirable for superior casting surface.

Pyrolytic graphite has heat transfer characteristics which make it satisfactory for use as the internal walls of a chill mold. When pyrolytic graphite is used as the mold wall, the mold wall is non-sticking and self-lubricating and has heat transfer properties nearly equal in one direction to copper which is predominantly in current use for the mold wall. Graphite has low structural strength and graphite molds have not, therefore, been successfully used on vertical casting machines. The commercial apparatuses use copper chill molds with reciprocation and/or some type of oil lubrication, such as rapeseed oil.

In addition to the foregoing, the present commercial vertical continuous casting machines are generally fed by gravity from a bottom pour primary ladle which discharges from a nozzle controlled by a stopper rod into a tundish, which in turn, has one or more nozzles emptying into one or more vertical casting strands. The use of a tundish to supply the chill mold causes some turbulence in the mold and drives any impurities present in the molten metal down into the casting. Moreover, the open tundish provides for a great source of heat loss and allows oxidation of the metal being poured. Further, control of the pouring can be uncertain since failure of the stopper rod system in the primary ladle can cause loss of pouring control, which is extremely damaging and dangerous with the primary ladle elevated over 100 feet.

While certain of the disadvantages of vertical casting machines have been described, other disadvantages are also present. One such disadvantage is that failure of the bar or slab cut-off means will stop discharge of product from the casting machine, unless the casting machine has provisions for bending the cast product from the vertical to the horizontal position.

In addition to the foregoing, problems have been encountered with known casting apparatuses in that the newly formed steel skin of the casting tends to shrink away from the copper mold creating an insulating air gap which retards heat transfer from the molten case of the casting to the mold wall and lessens the casting rate.

Further, de-gassing the molten steel prior to direct casting is generally done in a separate operation from the direct casting operation requiring additional handling. During the casting operation, gas is often burned around the metal stream from the tundish to the chill mold to minimize oxygen and hydrogen pick-up by the steel, but such pick-up still occurs partially defeating the purpose of de-gassing.

While various types of apparatuses including horizontal casting machines and vertical machines with curved molds to form the steel casting in an arc from the vertical to the horizontal plane have been tried to minimize the heighth and the other problems set forth above, the apparatuses which have been proposed or tried have not provided a continuous casting machine which has met with complete commercial success.

Accordingly, important objects of the present invention are to provide a new and improved casting apparatus which (1) minimizes the vertical space necessary to house the machine, permitting use of existing buildings and cranes; (2) minimizes or eliminates the casting markings due to the mold reciprocation; (3) minimizes the ferrostatic head and turbulence within the chill mold as well as bulging of the casting walls; (4) permits the use of graphite insert chill molds; (5) has a wide range of flexibility with regard to casting rates, section size, and length of casting cut off; (6) eliminates tundish heat losses, metal oxidation, and refractory problems, and provides more positive control of pouring; (7) increases direct casting machine utilization time; and (8) enables the metal temperature in the ladle and along its path to the chill mold to be controlled.

Another object of the present invention is to provide a new and improved apparatus as in the foregoing object in which the metal can be de-gassed in the casting machine and preferably additives introduced into the metal prior to casting and the metal protected by an inert gas in a closed system after de-gassing and during casting.

A further object of the present invention is to provide a new and improved continuous casting apparatus which is commercially acceptable and which embodies graphite mold walls.

A still further object of the present invention is to provide a continuous casting machine in which the casting operation can be stopped immediately.

Another object of the present invention is the provision of a novel continuous casting apparatus wherein molten metal is cooled as it moves through a mold to form a casting by maintaining the mold in contact with at least two sides of the casting as the casting shrinks in response to cooling thereof by the mold walls.

A further object of the present invention is the provision of a novel continuous casting apparatus wherein the molten metal is cooled as it moves through the chill mold and characterized by a mold having sections defining first and second portions of the mold cavity, the second mold cavity portion having a cross-sectional area less than the minimum cross-sectional area of first mold cavity portions whereby the mold can maintain contact with the shrinking casting while in the second portion of the mold cavity.

Another object of the present invention is the provision of a novel continuous casting apparatus having a chill mold which is adapted to receive and cool molten metal for forming a casting and through which the casting is drawn and wherein the mold is lubricated by introducing a lubricant in the form of a strip between the casting and the bottom mold wall as the casting moves through the mold.

Another object of the present invention is the provision of a continuous casting apparatus characterized by a ladle in a closed chamber for maintaining a supply of molten metal which is to be fed into a chill mold and formed continuously into a casting and wherein the metal is fed into the mold at a controlled rate corresponding to the casting rate of the apparatus by regulating the pressure of an inert gas introduced into the closed chamber, and the metal is de-gassed in the chamber by establishing a vacuum therein prior to being fed to the mold by the inert gas under pressure.

A further object of the present invention is the provision of a casting apparatus wherein the metal to be cast is maintained in a ladle in a closed pressure casting chamber which is pressurized to feed the metal to the mold and additional metal to be added is de-gassed as it flows from a supply ladle source into the ladle in the closed chamber by establishing a vacuum environment in the chamber during metal transfer.

A still further object of the present invention is the provision of a casting apparatus wherein a continuous supply of de-gassed, molten metal is maintained under pressure in a primary chamber for feeding to the chill mold and which is periodically replenished from a source of metal in a secondary chamber wherein the metal is de-gassed and transferred to the primary chamber by establishing a pressure in the secondary chamber which is substantially equal to the pressure in the primary chamber so that the transfer is made without interrupting the casting operation.

Another object of this invention is to provide a new and improved continuous casting method including the steps of flowing metal to one end of a horizontal extending mold, vibrating a bottom wall of the mold to retard sticking of the molten metal to the bottom wall as the molten metal cools in the mold, and removing the cooled metal from the other end of the mold.

Another object of this invention is to provide a new and improved method of continuously casting metal which comprises the steps of flowing molten metal to one end of a horizontally extending mold, removing the cooled metal from the other end of the mold, and pulling a lubricating tape through the mold as the metal is removed from the mold with the lubricating tape being located between the molten metal and a bottom wall of the mold to thereby retard sticking of the molten metal to the bottom wall of the mold.

These and other objects will be apparent from the following detailed description of the invention made with reference to the accompanying drawings forming a part of the specification and in which:

FIG. 1 is an elevational view section of a casting apparatus embodying the present invention;

FIG. 2 is a sectional view of the mold taken generally along line 2—2 of FIG. 1;

FIG. 3 is a sectional view taken generally along line 3—3 of FIG. 1;

FIG. 3A is a sectional view of another embodiment of the invention;

FIG. 4 is a sectional plan view taken generally along line 4—4 of FIG. 3;

FIG. 5 is a sectional plan view similar to FIG. 4 showing another means for moving the mold walls;

FIG. 6 is a sectional elevational view of a modified casting apparatus according to the present invention;

FIG. 7 is a sectional view taken generally along line 7—7 of FIG. 6;

FIG. 8 is an enlarged view of the motor means shown in FIG. 5;

FIG. 9 is a fragmentary sectional view of another lubricating arrangement for the mold;

FIG. 10 is a partial sectional view of a modified casting apparatus; and

FIG. 11 is a view similar to FIG. 10 showing still another modified casting apparatus.

Referring to the drawings, the preferred embodiment of the present invention and as disclosed therein the preferred embodiment is a horizontal casting apparatus which is supported on a concrete base **10** having a well at one end for receiving a ladle **22** of molten steel. The well is lined with a steel lining **14** which extends above the top of the side walls of the well in the concrete base to define an open top end which is closed by a cap **30**. The cap **30** and the steel lined well define a closed chamber **12** for receiving the ladle of molten steel. In the preferred and illustrated embodiment, the closed chamber **12** may be evacuated or subjected to a gas under pressure. To this end, the lining **14** has an opening **16** therein which receives a conduit **17** that extends through the wall of the well and provides a passageway **18** for communicating with the chamber **12** to introduce a gas under pressure into the chamber or to evacuate the chamber.

The cap **30** is removable from the top of the lining **14** to allow the ladle **22** to be lifted from or placed in the chamber **12**. Normally the ladle **22** of the molten metal is handled by an overhead crane and trunnions **26** are provided on the ladle to receive the crane bail.

As will be explained in more detail hereafter, the molten metal is forced out of the ladle **22** and through the cap **30** into a mold designated generally by the reference numeral B by pressure in the chamber **12**. The cap **30** has a depending portion **38** which is received in the ladle **22** and terminates closely adjacent to the bottom of the ladle. An internal passageway **36** extends through the cap depending portion **38** in a vertical direction and extends horizontally to communicate with an inlet passageway **74** of the mold B. When the pressure is supplied to the chamber **12**, the molten metal is directed upwardly through the passageway **36** into the chill mold B at a rate corresponding to the pressure exerted on the metal column in ladle **22**. A plurality of heating coils **39** are embedded in the cap **30** and extend about the passageway **36** to control the metal temperature as it moves through passageway **36**. The cap **30** is detachably connected to an axially extending part **70** of the chill mold B which provides the inlet passageway **74**. The cap **30** further includes a chute **40** which has an exit end disposed over the open end of the ladle **22** so that additions of various materials can be added to the steel in the ladle. A one-way valve **42** in the chute prevents communication between the atmosphere and the chamber **12**.

As stated above, the chamber **12** may be pressurized or evacuated. A reversible pump **48** is connected by conduits **46** and **17** to pressurize the chamber **12**. The intake of the pump during casting is selectively connected to the atmosphere or to a source of inert gas, such as argon, stored in a tank **54** by a valve **50**. The pump then directs the selected pressure medium into the chamber **12** to establish a pressure on the head of the molten metal column in ladle **22**.

The chamber **12** is evacuated to de-gas the metal in the ladle **22** before the steel is fed into the chill mold B. The metal is stirred during de-gassing by induction coils **20** embedded in the base **10**. When the steel has been de-gassed, the chamber **12** is pressurized by pumping an inert gas, for example, into the chamber building up pressure on the surface of the metal which increases the pressure on the metal column forcing the molten steel through passageway **36** to the chill mold B.

The metal enters the chill mold B through the inlet passageway **74** which extends through the end wall **68** of the chill mold B. Molten metal in passageway **36** enters the cavity of the chill mold B and is cooled by the walls of the chill mold. The metal in the cavity solidifies as it is cooled and is drawn through the cavity initially by a dummy bar **100** and out the open end of the mold cavity. The mold walls are arranged in two sections: the first wall section defines an entrance portion of the mold cavity which is adapted to receive the molten metal and in which section the embryo skin of the casting is formed; and a second section which defines an exit portion of the mold cavity and in which section the casting is further solidified as it is cooled by the walls of this section. The dummy bar **100** is positionable with its ends disposed in the first mold section and is adapted to initiate movement of the casting through the chill mold cavity as the metal solidifies and freezes onto a forward portion of the dummy bar. As the dummy bar draws the casting through the mold, and in particular through the second section thereof, the skin of the casting shrinks due to the cooling out of contact with the chill mold walls and creates an air gap between the casting skin and the mold walls. This air gap functions as an insulation barrier which impedes the heat transfer between the chill mold walls and the casting thereby reducing the casting rate for the apparatus. The present invention minimizes this insulation barrier by movably mounting the walls of the second section so they maintain contact with the mold wall as the casting shrinks. This arrangement maintains good heat transfer and permits an increase of the casting rate of the metal.

In the illustrated embodiment, the mold walls of the first section comprises top and bottom walls **60** and **66** which, as shown in FIGS. 1 and 2, are continuous walls extending the length of the first section, side walls **62** and **64** which are fixedly mounted as are walls **60** and **66**, and back wall **68** through which the molten metal enters the cavity through inlet **74** below the horizontal centerline of wall **68**.

The walls of the second section are movably mounted to maintain them in continuous contact with the casting as it moves through the mold. As best shown in FIGS. 3 and 4, the walls of the second section include a portion of the top and bottom walls **60**, **66**, and movable side walls **63**, **65**, **67** and **69**. The movable side walls **63**, **65**, **67** and **69** are movable relative to one another and to the fixed side walls **62** and **64**. Walls **63** and **65** engage the casting in the second section and represents the area of the exit portion of the mold cavity where the casting commences to shrink. The degree of movement required to walls **63** and **65** to maintain casting contact is not extensive and hence these walls can be pivoted to side walls **62** and **64** respectively about pivot pins **71**. The abutting surfaces between fixed walls **62** and **64** and movable walls **63** and **65** provide sufficient clearance to permit movement of walls **63** and **65** a sufficient distance to maintain engagement with the casting. Of course, if desired, a hidden-type hinge or piano-type hinge could be employed to hinge the walls at their inner side, i.e., the side adjacent to the mold cavity in the event greater wall movement is desired.

The mold walls **63**, **65** are moved in the preferred embodiment of the invention by a plurality of spring assemblies **88** best illustrated in FIGS. 3 and 4. The spring assemblies comprise a cylindrical sleeve **90** secured to the inner faces of the associated mold jackets **83** and **84**, a helical spring **92** partially disposed within the sleeve and through which a rod **94**, secured to the associated walls **63**, **65**, **67** and **69**, projects. The rod **94**, when the spring is compressed, extends through an aperture in the associated jacket walls **83** and **84**. One end of the spring bears against the inner surface of the jacket and the other end bears against the exterior surface of the wall which it is arranged to move. The spring assemblies **88** exert a force on the one end of the walls **63** and **65** to pivot them about pivot pin **71** toward the mold cavity. The spring assemblies are arranged relative to the walls so that when the springs are expanded the associated wall will define an exit portion of the mold cavity which is smaller than the smallest sized casting which will be drawn therethrough so that contact between these walls and the casting is continuously maintained. The expanded spring condition is illustrated in FIG. 4.

Wall sections **67** and **69**, defining the area of the exit portion of the mold cavity where greatest casting shrinkage occurs, are bodily movable toward each other and relative to walls **63** and **65**. A plurality of the spring assemblies **88** are connected along each of the walls **67** and **69** so that portions of the walls are differentially movable the distance necessary to compensate for shrinkage of the casting. Walls **63**, **65**, **67** and **69** are moved initially against the bias of the spring assemblies **88** by dummy bar **100** as it is moved into the mold cavity to a position adjacent side walls **62** and **64** of the first section. As the metal solidifies on the nose of the dummy and the embryo skin of the casting is sufficiently formed, the dummy bar is withdrawn by pinch rolls **110** and draws the newly formed casting from the first mold section into the second section initially engaging side walls **63** and **65**. The cooling action on the casting continues as the casting moves through the second section so that eventually all of the side walls are in engagement with parts of the casting as it is being formed. It should be appreciated that the movable wall arrangement maintains three sides of the casting in contact with the mold in the second section. The two larger sides of the casting are connected by vertical side mold walls **63**, **65**, **67**, **69** and the bottom side of the casting is held into engagement with bottom wall **66** by gravity.

To facilitate good heat transfer between the casting and mold walls, the mold walls should be constructed from material having good heat transfer properties and sufficient lubrication must be present to prevent the casting from sticking to the mold walls. In the preferred embodiment the side walls **62**, **63**, **64**, **65**, **67** and **69**, and top wall **60** are constructed from copper and are lubricated by means of graphite inserts **96**. The graphite inserts are non-wetting and self-lubricating and provide excellent heat transfer to the copper. While the inserts are structurally weak, the overall arrangement of the apparatus is such that the inserts are not subjected to extreme forces.

The bottom wall **66** of the mold supports the weight of the casting and is constructed preferably from ductile iron faced with carbide or Stellite to resist wear and is lubricated by a strip or tape lubricant **98** which is stored in roll-form on a suitable reel adjacent the entrance portion of the mold cavity. The tape may be stainless steel or include a plurality of strips of stainless steel embedded in glass. In the latter arrangement, heat causes the glass to melt and form a film of lubrication for the metal strip and the casting being formed to prevent the casting from sticking to the bottom mold wall. Prior to feeding the molten metal into the mold cavity, the tape

98 is fed through a suitably sealed opening in the back mold wall 68 and is connected to the dummy bar 100 so that as the dummy bar is withdrawn it feeds the tape 98 from the support reel into the mold cavity between the metal and the bottom wall 66. There is a greater tendency for the casting to stick to the bottom wall than the other walls since the weight of the casting is supported primarily by this wall and the tape protects the embryo skin from damage due to sticking to the wall. As an adjunct to or in lieu of tape 98, the bottom wall 66 can be oscillated with ultrasonic vibrations by any well known mechanism, indicated schematically at 101 in FIG. 3A, to prevent the casting from sticking to the bottom wall 66. To prevent leakage of steel when the tape enters the mold, a liquid lubricant under pressure slightly greater than casting pressure may be forced into the mold at this point. Such lubricant may also be forced in about the joints between mold side wall sections 62, 63, 67, and 64, 65, 69 where leakage of molten metal may occur.

The chill mold walls are cooled by providing passageways 76, 78, 79, 80, 81, 82, 85, and 86 in walls 60, 62, 63, 64, 65, 66, 67, and 69, respectively. Means, not shown, are provided for delivering a liquid coolant, such as water to these various passageways and to circulate the water therethrough to absorb and carry away heat in the respective walls in the course of the circulation.

As the casting is drawn out of the chill mold through the exit portion of the chill mold cavity, it enters a roller apron indicated generally by reference character C and which includes a plurality of horizontally disposed rollers 102 formed into two vertically spaced rows cooperating with two vertically disposed, horizontally spaced rows of rollers 104. The rollers cooperate to form therebetween an opening which closely approximates the cross-section of the casting and supports the casting as it is moved through a water spray. The water is directed onto the casting by a plurality of nozzles 106, 108 arranged between adjacent rollers and adapted to spray water directly onto the casting surface to further cool the casting prior to entering a cutoff mechanism indicated generally by reference numeral 112. The cutoff mechanism can comprise a hot saw, mechanical shears, or an oxy-gas cutoff device all of which are well known mechanisms for cutting the casting into desired lengths. To assist in the cutting operation, a plurality of rollers 115 are arranged to form an opening similar to the opening formed by rollers 102 and 104 to support the casting while it is cut by the cutoff mechanism 112.

The operation of the device just described is as follows: Molten metal to be cast is preferably lowered in ladle 22 into chamber 12, closure cap 30 is secured to the chamber and if the metal is to be de-gassed, valve 50 is positioned as shown in FIG. 1 and pump 48 is actuated to evacuate chamber 12 while the metal is stirred by induction coils 20 which are embedded in the walls of the well for receiving the ladle. Additions, as required, are made to the metal through chute 40. Upon completion of the de-gassing operation, the pump is reversed to pressurize chamber 12 with the gas from the atmosphere, or from the container 54 in the case of metal which is to be protected from oxidation, to force the molten metal from ladle 22 through passageway 36 and inlet 74 into the entrance portion of the mold cavity of the chill mold B. Meanwhile dummy bar 100 has been positioned with its inner end in the entrance portion of the mold cavity and one end of tape 98 is secured to the bar. The metal begins to freeze around the front of the dummy bar 100 and the embryo skin is formed as the walls are cooled by circulating the liquid coolant through the wall chambers. After the molten metal cools sufficiently to partially solidify the casting, the dummy bar is gradually withdrawn by the pinch rolls 110 drawing the casting through the mold cavity into contact with the movable walls 63, 65, 67, 69 of the second mold section. These walls are maintained in continuous contact with the casting by spring assemblies 88 to further cool the casting. As the casting leaves the mold it is passed through the water spray in roller apron C wherein solidification of the casting is completed before reaching the cutoff mechanism 112. This operation is continued until the metal in ladle 22 has been cast whereupon the closure 30 is removed from the chamber 12 and a filled ladle substituted for the empty ladle or, alternatively, additional molten metal is poured into the ladle in chamber 12.

It will be noted that during the casting operation, the pressure head on the casting is controllable by controlling the pressure produced by the pump or compressor in chamber 12 and the pressure on the feed metal is controlled so that the side walls and top of mold are not subjected to outward pressures from the casting walls beyond the structural strength of the graphite inserts. Moreover, different casting rates can be provided by controlling the pressure in the chamber 12 in coordination with pinch roll speed. To maintain a selected casting rate the pressure controls increase the pressure in chamber 12 as the molten metal column in ladle 22 decreases. The pressure control can be provided by any suitable pressure regulator operated in response to, for example, decrease in the metal column height or speed of the pinch rolls. The casting operation can be immediately stopped by releasing the pressure in the chamber 12.

In the preferred embodiment of the invention which has just been described, the metal is cast with its largest cross-sectional dimension vertical, as shown in FIGS. 2 and 3, so that by moving the side walls of the second section wall contact is maintained with the three sides of the casting which represent the majority of the casting surface. However, if it is desired to cast metal with the greater cross-sectional dimension of the casting disposed horizontally, the second mold section would be arranged in the manner disclosed in FIGS. 6 and 7. In this casting arrangement the greatest surface of the casting would be the surface in contact with the bottom and top walls of the mold and since gravity will maintain the mold in contact with the bottom wall, only the top wall is mounted for movement to maintain wall contact with the two larger sides of the casting as it is drawn through the mold. In this embodiment the mold comprises a bottom wall 118, side walls 120, 122, back wall 124 and a top wall assembly indicated generally by reference numeral 126. Walls 118, 120, 122 are shown as continuous walls extending the length of the mold similar to walls 60, 66 of the preferred embodiment and are fixedly mounted relative to one another and to the back wall 124. The top wall assembly 126 is similar to the side wall assembly comprising walls 62, 63 and 67 of the preferred embodiment and comprises a wall 128 which is fixedly secured to back wall 124 and defines with back wall 124 and side walls 120 and 122 and bottom wall 118 the entrance portion of the mold cavity. Wall 130 is secured to an end of wall 128 by pivot means 131 supporting the wall for pivoting movement relative to wall 128. Disposed adjacent wall 130 is a wall 132 mounted for movement relative thereto and defines in conjunction with wall 130 and portions of side walls 120 and 122 and bottom wall 118, the exit portion of the mold cavity. It should be appreciated that the top wall assembly 126 is similar in construction and operation to the side walls 62, 63, 64, 65, 67, 69 of the preferred embodiment. Although the casting apparatus as shown in FIGS. 6 and 7 produces one size of casting, the apparatus is adaptable to produce different size casting by increasing the height of side walls 120, 122 and mounting the top wall assembly 126 to slide vertically relative thereto. The top wall assembly is secured in a selected position to provide the desired casting size. When adjusted, the apparatus functions the same as the apparatus shown in FIGS. 6 and 7.

As a further modification, the top wall assembly 126 is moved relative to the other walls by a motor means indicated generally by reference numeral 134. The motor means comprises a motor 136 which drives pinion 138 which is maintained in engagement with a movable rack **140** suitably connected to a bracket means **142** connected to the associated walls **130** and **132** as shown in FIGS. 6 and 7. The motor means **134** function like spring assemblies **88** and move the movable walls **130** and **132** relative to wall **128** to maintain contact with the casting as it is drawn through the mold.

A control mechanism is provided to control the operation of motor means **134** in response to casting shrinkage. The preferred control means, disclosed in FIG. 8, comprises a pressure sensing cell **144** disposed between abutting ends of mating levers **146**, **148** which form rack **140**. The pressure represented by good heat transfer contact between the casting and the mold walls is determined and cell **144**, when sensing this pressure, maintains motor **136** inoperative. As the casting shrinks away from the wall, a decrease in pressure results. When this decrease is sensed by cell **144**, motor **136** is activated to move rack **140** and the connected wall until the desired pressure relationship is re-established and stops the motor. Although the motor means **134** has been described as moving walls **130**, **132** of the top wall assembly, the motor means is equally suitable to move the walls **63**, **65**, **67** and **69** of the preferred embodiment. Such an arrangement is disclosed in FIG. 5. Likewise, the spring assemblies disclosed in the preferred embodiment for moving walls **63**, **65**, **67** and **69** could be substituted for the motor means **134** to move walls **130**, **132** of the mold shown in FIGS. 6 and 7.

The mold shown in FIGS. 6 and 7 includes a modified means for lubricating the mold walls comprising means for presenting a liquid lubricant to the interior faces of the wall. This means comprises main lubrication lines **144** through which liquid lubricant is delivered to a plurality of branch lines **146** extending through the respective walls to present the lubricant to the interior wall faces. This type of lubrication system could be employed in lieu of the graphite inserts and steel and/or glass tape illustrated in connection with the preferred embodiment of the invention.

The present invention provides a further means disclosed in FIG. 9 for injecting a liquid lubricant through the bottom mold wall to form a lubrication film between the casting and mold. This lubricating system comprises a container **350** for a liquid lubricant such as rapeseed oil which is connected to the bottom wall of the mold B adjacent the inlet end of the mold. The rapeseed oil flows from the container through a passageway **352** into the interior surface of the bottom mold wall under pressure provided by a pump **354**. As the casting forms and moves along the mold, the rapeseed oil is distributed between the bottom surface of the formed casting and the interior surface of the bottom mold wall and prevents the casting from sticking. The pump **354** directs the lubricant from a reservoir **356** to the container **350** and maintains the lubricant under a predetermined pressure to insure proper distribution of lubricant in the mold and for preventing molten metal from entering passageway **352**.

The invention further provides a modified means for storing and de-gassing the metal. This modification is disclosed in FIG. 10 and includes a primary chamber **200** for maintaining a source of de-gassed metal for pressure feeding to the mold B. The primary chamber includes a chamber **202** which is enclosed by a cover **204** and in which a pressure and a vacuum environment can be maintained. A primary ladle **206** in the well stores the metal which is fed to the mold through a conduit **208**. One end of the conduit **208** extends into the ladle and the other end communicates with the inlet end of the mold B. The metal flows from the primary ladle **206** through the conduit **208** into the inlet end of the mold by establishing a pressure in chamber **200** acting on the surface of the metal column in ladle **206** as particularly described in connection with the feed arrangement disclosed in FIG. 1. A valve **210** in the conduit **208** operates to seal off the conduit during replenishing of the molten metal in the primary ladle. Otherwise, the valve **210** is positioned to permit flow through conduit **208**.

The chamber **202** is pressurized by a compressor **212** which has its air outlet in communication with the chamber and the air intake end is selectively connected to the atmosphere or to a source of inert gas **214**, such as argon, by a valve **216**. Appropriate setting of the valve directs either air or argon to the compressor which compresses same and directs the compressed medium into the chamber. After sufficient pressure builds up in the chamber and in particular on the surface of the molten metal, the molten metal in the primary ladle is forced through the conduit **208** into the entrance or inlet end of the mold B. Suitable controls not shown, are provided to control the pressure in the chamber to provide for different casting rates of the metal and to change the pressure during a selected casting rate to maintain a substantially constant rate of flow of the metal as the metal column in the ladle decreases.

When the metal in the ladle is expended, additional metal is delivered to the primary ladle from a secondary ladle **218** positioned above the chamber. The second storage ladle **218** temporarily stores a heat of molten metal and is arranged relative to the primary ladle to permit gravity feed of metal to the primary ladle **206** through a fluid passageway **220** in the cover **204** of the primary ladle. The passageway **220** has associated therewith a gate valve **222** disposed in an intermediate portion of the pasageway and a fusible diaphragm **224** capping the exterior end of the passageway. The valve and diaphragm effectively seal the passageway **220** so that the chamber **202** can be maintained under pressure and vacuum. The gate valve **222** is operated by a suitable actuator mechanism **226** in the cover **204** and which is effective to move the valve from the passageway blocking position shown in FIG. 10 to the left to its unblocking position wherein the passageway is sealed only by the fusible diaphragm **224**.

The secondary ladle has a pouring nozzle opening **227** in the bottom thereof which is disposed immediately above and sealed by O-ring to the diaphragm **224**. The opening **227** is controlled by a pouring control mechanism including a stopper rod and head **228** which is moved by linkage **230** to seat and unseat in the pouring nozzle opening. When the stopper head is unseated from the pouring nozzle opening, the metal in the secondary ladle flows by gravity therefrom.

When metal is to be transferred from the secondary ladle **218** to the primary ladle **206** the casting operation is interrupted. Valve **210** in conduit **208** is closed and compressor **212** reversed to establish a negative pressure or vacuum in the primary chamber. The gate valve **222** is moved to the left as viewed in the drawings to its unblocking position and stopper rod and head **228** is then unseated from the pouring nozzle opening **227** in the secondary ladle permitting the molten metal in ladle **218** to flow therethrough into contact with the fusible diaphragm **224**. The diaphragm **224** which may be made of aluminum is melted by the molten metal and opens the passageway **220**. When the diaphragm melts, the molten metal is exposed to the vacuum environment in the primary chamber causing the metal to separate and be stream de-gassed as illustrated in FIG. 10 as it flows from the outlet end of the passageway **220** into the chamber **202**. An additions chute **232** is provided for adding alloys to the metal while the metal flows from the secondary ladle to the primary ladle. From the foregoing, it should be apparent that the apparatus of FIG. 10 provides for stream de-gassing of the metal in the course of flowing from the secondary ladle into the primary ladle.

The present invention further provides another storage system for the molten metal which permits the casting operation to be continuous in that it does not have to be periodically interrupted while another heat of metal is made available. The continuous metal supply system is disclosed in FIG. 11 and includes a primary chamber **300** having a primary ladle **302** from which the metal is pressure fed to the mold and is similar in construction to primary chamber **202** and ladle **206** of the apparatus disclosed in FIG. 10. A secondary chamber **304** is disposed above primary chamber **300** and houses a secondary ladle **306** which initially receives the heats of metal, de-gasses the metal and from which the de-gassed metal is periodically fed into the primary ladle **302**. The primary chamber has a top cover **308**, a conduit **310** for directing the metal from the primary ladle **302** to the inlet end of the mold **B**. A compressor **312** operates to selectively provide air or inert gas under pressure for the primary chamber **300** for pressure feeding of the molten metal in ladle **302** to the mold.

The secondary chamber **304** is a pressure chamber and comprises a removable top cover **314** which is removed to add additional heats of metal to the secondary ladle. A suitable seal is provided for the top cover so that when the cover is in place, the secondary chamber can be pressurized during metal transfer and placed under a vacuum condition during the metal de-gassing operation.

The metal is de-gassed in the secondary chamber prior to transfer to the primary ladle and is accomplished by establishing a vacuum environment in the secondary chamber and stirring the metal in the secondary ladle. The secondary chamber is vacuumized by a vacuum pump **316**. A series of coils **318** surround the secondary ladle and provide for induction stirring of the metal during de-gassing. During the de-gassing operation, alloy additions may be added through an alloy addition chute **320** similar to the alloy addition chute **232** shown in FIG. 10.

The secondary ladle **306** has a bottom pouring nozzle **322** which is closed by a stopper rod and head **324** controlled by a suitable remotely operated auto pour mechanism **326** for moving the stopper head to open or close position with the nozzle opening. The stopper normally closes the hole **322** and during metal transfer the stopper is moved out of the nozzle and metal flows through a passageway **328** provided in the cover **308**. The passageway **328** is normally closed by a gate valve **330** which is similar in construction to the gate valve **222** shown in FIG. 10. During metal transfer, a valve actuator mechanism **332** moves the valve to open passageway **328** to connect the primary and secondary chambers.

The de-gassed metal is transferred into the primary ladle without interrupting the casting operation. The transfer is accomplished by establishing a pressure in the secondary chamber which is substantially equal to the pressure in the primary chamber. The secondary ladle is pressurized by the primary chamber compressor **312** through line **334** connected to the inlet line for the primary chamber. A valve **336** in line **334** is operable to connect the secondary chamber with the compressor **312**. When the pressure in the secondary chamber is substantially equal to the pressure in the primary chamber, the gate valve **330** is moved to the left and the stopper rod **324** is moved to open nozzle **322** and the metal is thus free to flow from the secondary ladle into the primary ladle through the passageway **328**. During the transfer, the metal in the primary ladle continues to feed to the casting mold. Upon completion of the transfer of metal, the gate valve **330** and stopper rod **324** are moved into their positions illustrated in FIG. 11 and the valve **336** moved to block connection between the secondary chamber and compressor **312**. The pressure is relieved in the secondary chamber and the cover **314** is removable to permit another ladle of molten metal to be placed in the secondary chamber for de-gassing and transfer to the primary ladle. From the foregoing, it should be apparent that the metal storage system provides a continuous supply of metal for the mold permitting continuous casting of metal without interruption for making available additional molten metal.

While several embodiments of the present invention have been described in considerable detail, it is hereby my intention to cover further constructions, modifications and arrangements which fall within the ability of those skilled in the art and within the scope and spirit of the present invention.

Having described my invention, what I claim is:

1. A continuous casting apparatus for forming a casting from molten metal by introducing the molten metal into one end of a mold cavity and withdrawing the cooled metal from the other end of the mold cavity in the form of a casting, said apparatus comprising a mold having a plurality of walls defining the mold cavity, one of said walls includes a plurality of relatively movable sections formed of metal with conduits for conducting a coolant to thereby promote the cooling of the motlen metal introduced into said mold and a plurality of inserts of a structurally weak lubricating material, each of said inserts being supported by an associated one of said sections to facilitate movement of the casting relative to said one wall, and means operatively connected to said sections for independently urging each of said sections and the associated insert of lubricating material inwardly to maintain said inserts of lubricating material in contact with the casting as it shrinks on cooling.

2. The casting apparatus as defined in claim **1** wherein said last named means includes spring means operably connected to bias each of said realtively movable sections of said one wall into contact with the casting.

3. The casting apparatus as defined in claim **1** wherein said last named means comprises motor means operatively connected to independently move each of said sections of said one wall to maintain said inserts of lubricating material in contact with the casting.

4. A continuous casting apparatus for forming a casting from molten metal by introducing the molten metal into one end of an open ended mold cavity and withdrawing the cooled metal from the other end of the mold cavity in the form of a casting comprising a mold having a plurality of walls arranged in sections defining a mold cavity, means mounting the walls of one of said sections to define an entrance portion of said mold cavity having a minimum cross-sectional area, means movably mounting certain walls of another of said sections and supporting the latter for movement to positions defining an exit portion of said mold cavity having a cross-sectional area less than said minimum cross-sectional area of said entrance portion of said mold cavity to enable the walls to maintain contact with the casting as it shrinks and means operatively connected to the walls of said another section to maintain same in contact with the casting as it shrinks on cooling, said last named means including motor means operatively connected to move said movable wall of said another section to maintain contact with the casting and control means for sensing the shrinkage of the casting and effective to actuate said motor means to move said movable wall to maintain contact with the casting.

5. The casting apparatus as defined in claim **1** wherein another of said walls includes a plurality of relatively movable sections formed of metal with conduits for conducting coolant to thereby further promote the cooling of the motlen metal introduced into said mold and a plurality of inserts of a structurally weak lubricating material, each of said inserts being supported by an associated one of said sections of said other wall to facilitate movement of said casting relative to said other wall, and means operatively connected to said sections of said other wall for independently urging each of said sections of said other wall and the associated insert of lubricating material toward said one wall and into engagement with a side of said casting opposite from the side of said casting engaged by said one wall.

6. The casting appartus as defined in claim **1** including means for introducing molten metal into said cavity comprising a closed chamber, supply means disposed in said chamber adapted to store the molten metal, means for evacuating said chamber, a conduit means for directing the flow of metal from said supply means to said mold cavity, and means for pressurizing said chamber to force the metal from said supply means through the conduit means to said mold cavity.

7. The casting apparatus as defined in claim 6 wherein said chamber includes an additions chute arranged adjacent said supply means and through which material can be fed into said supply means and said means for pressurizing said chamber comprises a pump means, an inert gas storage means and conduit means providing communication between said inert gas storage means, pump means and compartment.

8. A casting apparatus as defined in claim 1 including a lubricating tape disposed adjacent said mold and adapted to be fed into said mold between the casting and another of said mold walls to prevent the casting from adhering to said other mold wall.

9. A casting apparatus as defined in claim 8 wherein said lubricating tape comprises a plurality of elongated steel members embedded in a glass base.

10. The casting apparatus as defined in claim 8 wherein said lubricating tape is formed of stainless steel.

11. A continuous casting apparatus for forming a casting from molten metal by introducing the molten metal into one end of an open ended mold cavity and withdrawing the cooled metal from the other end of the mold cavity in the form of a casting comprising a mold having a plurality of walls arranged in sections defining a mold cavity, means mounting the walls of one of said sections to define an entrance portion of said mold cavity having a minimum cross-sectional area, means movably mounting certain walls of another of said sections and supporting the latter for movement to positions defining an exit portion of said mold cavity having a cross-sectional area less than said minimum cross-sectional area of said entrance portion of said mold cavity to enable the walls to maintain contact with the casting as it shrinks, means operatively connected to the walls of said another section to maintain same in contact with the casting as it shrinks on cooling, and power means operatively connected to a bottom wall of said mold for imparting reciprocating motion to said bottom wall to prevent the casting from sticking thereto.

12. A casting apparatus as defined in claim 1 further including means operatively connected to at least one of said walls of said mold for imparting a vibrating movement to said one wall to retard sticking of the casting to said one wall.

13. A continuous casting apparatus for forming a casting from molten metal by introducing the molten metal into one end of an open ended mold cavity and withdrawing the cooled metal from the other end of the mold cavity in the form of a casting comprising a mold having a plurality of generally horizontally extending walls arranged in sections defining a generally horizontally extending mold cavity, means mounting the walls of one of said sections to define an entrance portion of said mold cavity, means movably mounting certain walls of another of said sections and supporting the latter for movement to positions defining an exit portion of said mold cavity having a cross-sectional area less than the cross-sectional area of said entrance portion of said mold cavity to enable the walls to maintain contact with the casting as it shrinks, means operatively connected to the walls of said other section to maintain same in contact with the casting as it shrinks on cooling, and means for introducing molten metal into the mold cavity comprising a primary chamber at a lower level than said mold and adapted to store molten metal, means providing fluid communication between said primary chamber and said entrance portion of said mold cavity, a secondary chamber at a higher level than said primary chamber and adapted to store molten metal, means for establishing pressure in said primary chamber to direct molten metal to said mold, means for establishing a vacuum in said secondary chamber for de-gassing the metal therein, means for establishing a pressure in said secondary chamber substantially equal to the pressure in said primary chamber and selectively operable means for communicating said chambers to effect transfer of metal from said secondary chamber to said primary chamber when the pressures in said chambers are substantially equal.

14. A continuous casting apparatus for forming a casting from molten metal by introducing the molten metal into one end of an open ended mold cavity and withdrawing the cooled metal from the other end of the mold cavity in the form of a casting comprising a mold having a plurality of generally horizontally extending walls arranged in sections defining a generally horizontally extending mold cavity, means mounting the walls of one of said sections to define an entrance portion of said mold cavity, means movably mounting certain walls of another of said sections and supporting the latter for movement to positions defining an exit portion of said mold cavity having a cross-sectional area less than the cross-sectional area of said entrance portion of said mold cavity to enable the walls to maintain contact with the casting as it shrinks, means operatively connected to the walls of said another section to maintain same in contact with the casting as it shrinks on cooling, and means for introducing molten metal into said mold cavity comprising a primary chamber at a lower level than said mold and adapted to store molten metal, means providing fluid communication between the primary chamber and said entrance end of said mold cavity, a secondary chamber at a higher level than said primary chamber and adapted to store molten metal, means including valve means for selectively communicating said chambers, means for establishing a pressure in said primary chamber to feed molten metal to said mold, and means for de-gassing the metal as it flows from said secondary chamber to said primary chamber including means for establishing a vacuum in said primary chamber.

15. A continuous casting apparatus for forming a casting from molten metal by introducing molten metal into one end of an open ended mold cavity of a chill mold and withdrawing the cooled metal from the other end of the mold cavity in the form of a casting comprising a mold having a plurality of generally horizontally extending walls arranged to define a generally horizontally extending mold cavity, and lubricating tape means supported adjacent said mold and adapted to be fed into said mold between the molten metal and a bottom wall of said mold which supports the molten metal to prevent the casting from adhering to said bottom wall.

16. A continuous casting apparatus for forming a casting from molten metal by introducing molten metal into one end of an open ended mold cavity of a chill mold and withdrawing the cooled metal from the other end of the mold cavity in the form of a casting comprising a mold having a plurality of walls arranged to define a mold cavity, and lubricating tape means formed of elongated strips of steel embedded in a base of glass and supported adjacent said mold, said tape means being adapted to be fed into said mold between the metal and one of said mold walls to prevent the casting from adhering to said one mold wall.

17. A continuous casting apparatus comprising a horizontally extending mold having an inlet end for receiving molten metal and a delivery end from which a casting is drawn in a continuous manner, means for supplying metal to said mold comprising a closed chamber disposed below the level of said mold and a container for molten metal in said chamber, closed conduit means connecting said container and said inlet end, means for selectively evacuating and supplying gas under pressure to said chamber to force the metal through said conduit means and into said mold, said mold having a bottom wall and a plurality of other walls defining the sides and top of said

mold, said other walls including a plurality of graphite inserts which engage the casting, and means operatively connected to said bottom wall of said mold for reciprocating said bottom wall relative to the other walls of said mold.

18. A continuous casting apparatus comprising a horizontally extending mold having an inlet end for receiving molten metal and a delivery end from which a casting is drawn in a continuous manner, means for supplying metal to said mold comprising a closed chamber disposed below the level of said mold and a container for molten metal in said chamber, closed conduit means connecting said container and said inlet end, and means for selectively supplying gas under pressure to said chamber to force the metal upwardly from said container, through said conduit means and into said mold, said mold having entrance and discharge sections, a bottom wall and a plurality of other walls defining the sides and top of said mold, and means mounting a plurality of said other walls of said mold discharge section for movement to a position wherein the cross-sectional area of said discharge section is less than the cross-sectional area of said entrance section of the mold to maintain wall contact with the casting as it shrinks due to cooling.

19. A continuous casting apparatus as defined in claim 18 including spring means operatively connected to said plurality of said other walls of said discharge section of said mold for biasing said walls inwardly toward said position.

20. The continuous casting apparatus as defined in claim 18 further including motor means operatively connected to move said plurality of said other wall of said discharge mold section and control means for sensing the shrinkage of the casting in said discharge section and operable to control said motor means to maintain said plurality of other walls in contact with the shrinking casting.

21. An apparatus for continuously casting metal comprising a generally horzontally extending mold having an inlet and into which molten metal is adapted to be delivered and a discharge end through which the cast metal is adapted to be discharged, a primary chamber located at a level below the level of said mold for storing molten metal, conduit means providing fluid communication between said primary chamber and said inlet end of said mold, a secondary chamber adapted to store molten metal, passageway means for connecting said secondary chamber in fluid communication with said primary chamber, means for establishing pressure in said primary chamber to force molten metal upwardly from said container through said conduit means to said mold, means for establishing a vacuum in said secondary chamber for de-gassing the metal therein and selectively operable means for effecting transfer of metal from said secondary chamber to said primary chamber through said passageway means.

22. The apparatus for continuously casting metal as defined in claim 21 further including means for establishing a pressure in said secondary chamber which is substantially equal to the pressure in said primary chamber whereby said chambers can be communicated for transfer of metal therebetween without interrupting feeding of metal to said mold.

23. The apparatus for continuously casting metal as defined in claim 21 wherein said selectively operable means includes valve means operatively associated with said conduit means and operable to open said passageway mean permitting flow of metal therethrough.

24. The apparatus for continuously casting metal as defined in claim 21 wherein said mold comprises a plurality of walls defining a mold cavity oriented generally horizontal, means mounting certain of said walls for movement and movable to reduce the cross-sectional area of said mold cavity, and means operatively connected to move said movable walls to maintain contact with the casting therein.

25. An apparatus for continuously casting metal comprising a horizontal mold having an inlet end into which molten metal is adapted to be delivered and a discharge end through which cast metal is adapted to be discharged, a primary chamber located at a lower level than said mold and adapted to store molten metal, means providing fluid communication between the primary chamber and said inlet end of said mold, a secondary chamber adapted to store molten metal, means including valve means for communicating said chambers, means for establishing a pressure in said primary chamber to direct molten metal upwardly from said primary chamber through said means for providing fluid communication to said mold, and means for de-gassing the metal as it flows from said secondary chamber to said primary chamber including means for establishing a vacuum in said primary chamber.

26. The apparatus for continuously casting metal as defined in claim 25 wherein said mold comprises a plurality of generally horizontally oriented walls defining a mold cavity, means mounting certain of said walls for movement and movable to reduce the cross-sectional area of said mold cavity, and means operatively connected to move said movable walls to maintain contact with the casting therein.

27. A continuous casting apparatus for forming a casting from molten metal by introducing the molten metal into one end of an open ended mold cavity and withdrawing the cooled metal from the other end of the mold cavity, said apparatus comprising a plurality of generally horizontally extending walls defining said cavity, conduit means for conducting molten metal to said cavity and vibrator means connected to a bottom wall of said mold for vibrating said bottom wall at a high frequency relative to the other walls of said mold to retard adherence of said molten metal to said bottom wall.

28. A casting apparatus as set forth in claim 27 wherein said other walls of said mold include lubricating means having a relatively low structural strength mounted on metallic reinforcing sections for retarding adherence of said molten metal to said other walls of said mold.

29. A continuous casting apparatus for forming a casting of molten metal by introducing the molten metal into one end of an open ended mold cavity and withdrawing the cooled metal from the other end of the mold cavity, said apparatus comprising a plurality of generally horizontally extending walls defining said cavity, conduit means for conducting molten metal to said cavity, means for mounting a roll of lubricating tape adjacent to said one end of said mold, and dummy bar means mounted for movement away from said one end of said mold to withdraw a casting from said mold, said lubricating tape having an end portion which is adapted to be connected to said dummy bar means to unwind said roll of lubricating tape and move said lubricating tape along a bottom wall of said mold between the molten metal and said bottom wall as said casting is removed from said mold to thereby retard sticking of said casting to said bottom wall of said mold.

30. A continuous casting apparatus as set forth in claim 29 wherein said lubricating tape is formed of stainless steel.

31. A continuous casting apparatus as set forth in claim 29 wherein said lubricating tape includes a plurality of elongated metallic members embedded in a nonmetallic casing.

32. A method of forming a casting comprising the steps of flowing molten metal from a source through a conduit to one end of a horizontally extending mold, vibrating a bottom wall of said mold to retard sticking of the molten metal to the bottom wall as the molten metal cools and at least partially solidifies in said hold, and removing the cooled metal from another end of said mold.

33. A method of forming a casting comprising the steps of flowing molten metal from a source through a conduit to one end of a horizontally extending mold, removing

the cooled metal from another end of the mold, and pulling a lubricating tape through the mold contemporaneously with said removing step with the lubricating tape located between the molten metal and a bottom wall of the mold to thereby retard sticking of the molten metal to the bottom wall of the mold.

34. A method of forming a casting as set forth in claim **33** further including the method step of unwinding said lubricating tape from a roll disposed adjacent to the mold as the lubricating tape is pulled through the mold.

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