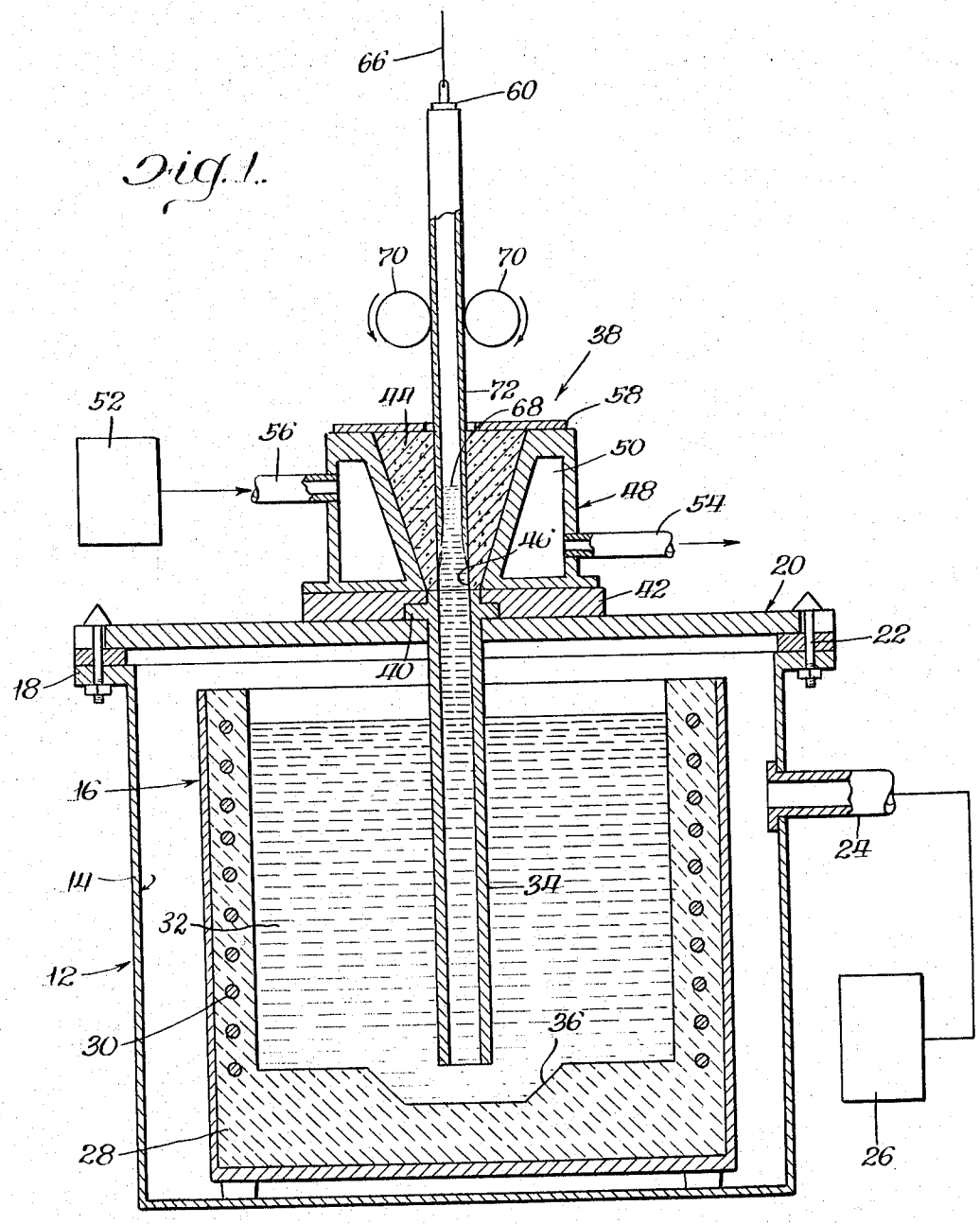
Feb. 7, 1967 J. WOODBURN, JR 3,302,252

APPARATUS FOR CONTINUOUS CASTING

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Fig. 1.



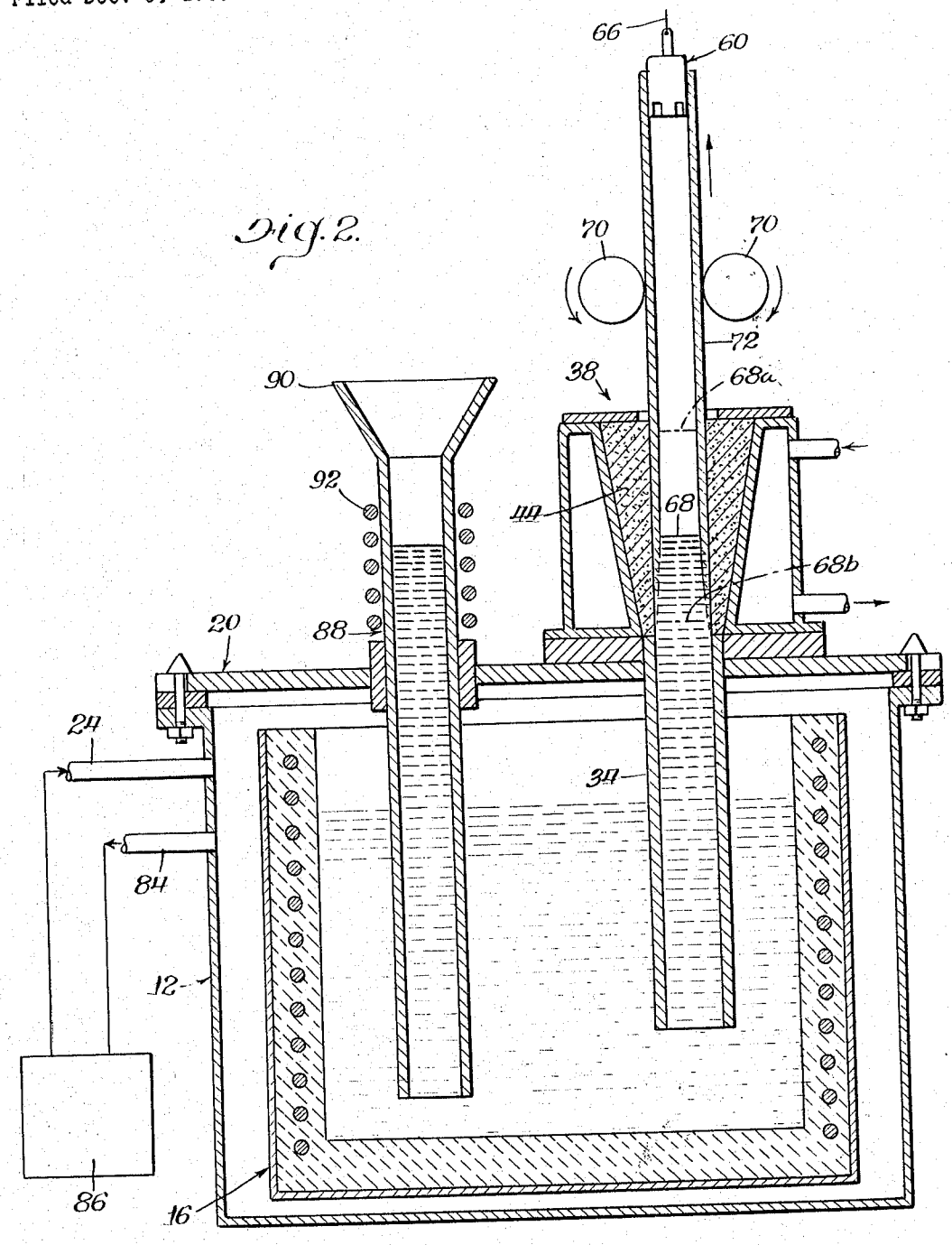

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APPARATUS FOR CONTINUOUS CASTING

Filed Dec. 3, 1963 3 Sheets-Sheet 2

Fig. 2.




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Fig. 3.

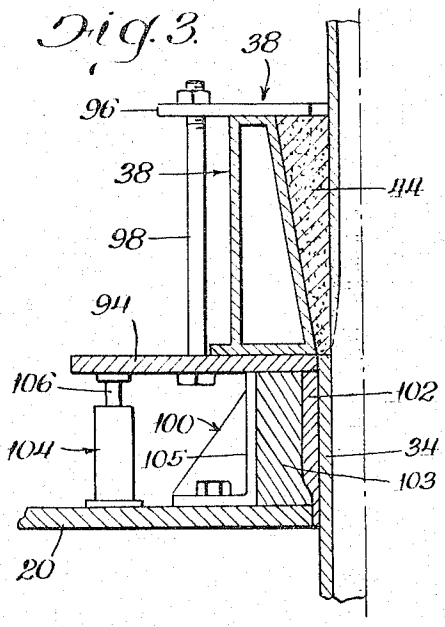



Fig. 4.

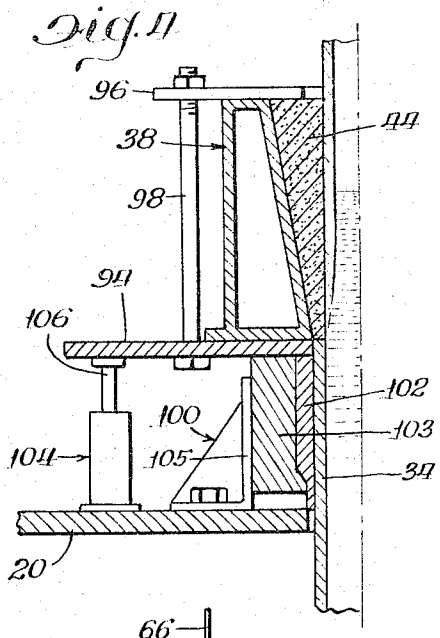
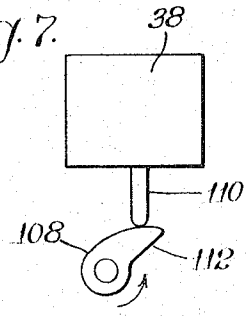



Fig. 7.



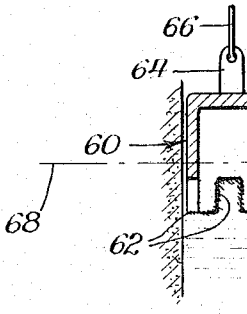
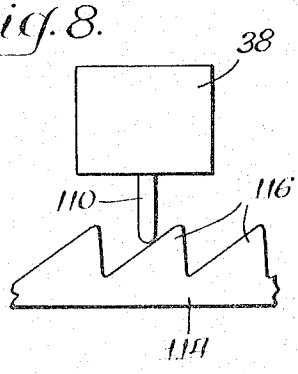




Fig. 5.

Fig. 8.



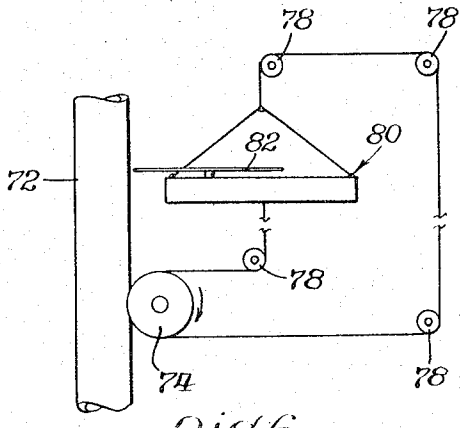




Fig. 6.

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# APPARATUS FOR CONTINUOUS CASTING

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2 Claims. (Cl. 22—57.2)

The present invention relates to apparatus for and method of continuous casting.

A broad object of the invention is to attain advantages resulting from continuous casting, the method including continuously adding molten metal and continuously withdrawing the cast article at a corresponding rate, both of indefinite duration within practical limits, with consequent economy in the molded product.

The invention relates more particularly to casting apparatus and method wherein the cast product is formed in an upward movement through a mold and from which the molded product continues to move in an upward direction and is withdrawn in that direction from the mold.

A principal advantage of the invention is related to the upward withdrawal of the molded product in that there is no necessity for providing means for preventing stray passage of molten metal through the mold, as would be the case where the molded product is withdrawn downwardly.

Another and more specific advantage of the invention is that due to the advantage just mentioned, namely the elimination of the necessity for preventing stray passage of the molten metal, the molded product may be in hollow or tubular shape, such as pipe, and upon withdrawal of the pipe the molten metal remains below the top of the mold due to gravity.

Another object of the invention is to provide a novel apparatus containing a heated ladle and a cooled mold closely associated, both in function and physically, whereby the molten metal in the ladle remains molten until it passes into the mold where it is gradually cooled and freezes, forming the desired molded product.

Another object is to provide apparatus including means for oscillating the mold, relative to the rate of withdrawal of the molded product, whereby to facilitate movement of the molded article through the mold, and more specifically to provide greater efficiency with respect to the frictional engagement and relative movement between the molded product and mold.

A still further object is to provide means for oscillation of the molten metal in the mold whereby to provide a more precise or clearly defined inner surface of a hollow molded product such as pipe.

Still another object is to provide apparatus for and method of continuous casting wherein novel means is provided for continuously adding molten metal to the apparatus to enable indefinitely continuous casting.

Other objects and advantages of the invention will appear from the following detailed description taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a vertical sectional view of one form of apparatus embodying the features of the invention;

FIGURE 2 is a vertical sectional view of another form of apparatus;

FIGURE 3 is a fragmentary sectional view of a portion of mold apparatus including means for oscillating the mold, with the mold in retracted position;

FIGURE 4 is a view similar to FIGURE 3, but with the mold in advanced position;

FIGURE 5 is a detail sectional view of a starter section, located in the mold, utilized for starting withdrawal of the molded product;



FIGURE 6 is a diagrammatic view of a means for cutting the molded product in lengths;

FIGURE 7 is a diagrammatic view of another means for oscillating the mold; and

FIGURE 8 is a diagrammatic view of still another means for oscillating the mold.

Referring now in detail to the drawings, attention is directed first to FIGURE 1 showing one form of apparatus embodying the features of the invention. The apparatus includes a pouring tank **12** which may be of any suitable construction, defining a cavity **14** in which is disposed a ladle **16**. The tank **12** may have an opening at any location such, for example, as at the top in the present instance, and is provided with a flange **18** around the open top, for use in securing a cover **20**. The cover **20** may be secured in place by any suitable means such as clamps **22**, there being a sealing gasket interposed between the cover and the flange **18** for sealing the interior of the tank against the escape of air which is introduced into the tank for pressure pouring.

Communicating with the interior of the tank is a suitable conduit **24** leading from a conventional pump or other air pressure developing apparatus indicated here diagrammatically which, upon controlled operation thereof, develops air pressure in the tank for pressure pouring of the molten metal.

The ladle **16** includes bounding elements composed of insulating refractory material **28**, and embedded in the upright wall elements thereof is an induction coil **30** for connection with a suitable source of current (not shown) for induction heating the ladle and the molten metal **32** therein, and maintaining it in molten form.

A pouring tube **34** leads from adjacent the bottom of the ladle, such as in or adjacent a cavity **36** in the bottom of the ladle, upwardly out of the ladle and through the top cover **20** where it communicates with the mold indicated generally at **38**, which will be described in detail below herein. For convenience in supporting the pouring tube in position, the upper end thereof is provided with a flange **40** which engages and rests on the outer surface of the cover **20**. A plate **42** is disposed on the cover **20** for supporting and adapting the mold **38**, the plate having a recess for receiving the flange **40** and the upper extremity of the tube **34** which projects above the flange. The mold **38** includes a central sleeve portion **44** provided with a central vertical bore **46** forming a cavity in which the molding of the product takes place. Preferably, the inner diameter of the pouring tube **34** is the same as the diameter of the cavity **46** to facilitate flowing of the molten metal.

The sleeve **44** is of high heat conductivity for conducting the heat from the molten metal therein for freezing it and producing the molded product. Preferably, the sleeve is made of graphite, and its outer surface is preferably conical in shape tapering downwardly and supported in a cooling packet **48** which may be of copper. The cooling jacket **48** has an annular internal space **50** for circulation of a cooling liquid, such as water, for hastening the cooling action of the molten metal. Water is forced therethrough by suitable means indicated diagrammatically at **52** which may withdraw water from a tap, and force it through an inlet conduit **56**, and after passing through the interior space **50**, it passes through the outlet conduit **54** to waste. A suitable top plate **58** may be utilized for retaining the graphite sleeve **44** in the cooling jacket.

The molten metal **32** is placed in the ladle **16** in any suitable manner, and then the ladle is placed in the tank **12** and the induction coil **30** connected with a suitable source of electrical supply. In the present instance, it is lowered through the open top of the tank, after which the cover **22** is secured in place, the mold **38** being carried by

the cover or later applied thereto, as desired. After the ladle is thus introduced in the tank, air pressure is developed in the tank by the means **26**, and due to the sealed condition of the tank the air pressure forces the molten metal **32** downwardly in the ladle and upwardly through the pouring tube **34**, and thus into the mold.

I have provided novel means for starting the molded product in the withdrawing action, namely a starter section **60**, shown in detail in FIGURE 5. This starter section may be in the form of an inverted cup having an open lower end with a plurality of cutouts or notches **62** in its lower marginal edge, and is provided with an extension **64** by which a line or cable **66** may be secured. It is lowered into the mold to a position indicated in FIGURE 5, in which its lower end is immersed in the molten metal, the level of the latter being indicated by the line **68**. The starter section **60** may be made of a metal having a melting point higher than that of the metal being cast, e.g., steel having a melting point of in the neighborhood of 500° F. higher than cast iron. The cooling action on the molten metal in the mold will already have been started, and the metal being cast when it freezes will grip the starter section **60** with sufficient mechanical force to be withdrawn by the starter section when the latter is raised. The cooling water passed through the cooling jacket continues the freezing operation, the outermost portion of the column of molten metal in the mold cavity being frozen first in an annular or pipe form. The starter section is then withdrawn by suitable hoist means (not shown) withdrawing the molten product or pipe.

After the molded product or pipe has been thus started, the withdrawing action is continued with a plurality of extraction rollers **70** frictionally engaging the pipe, which upon rotation thereof (by suitable means not shown) in the directions indicated, withdraw the molded product or pipe now identified at **72**. It will be understood that the peripheral speed of the extraction rollers is such as to withdraw the molded product at the desired rate according to the desired rate of molding, taking into consideration all other factors affecting the molding operation. The rate of withdrawal of the molded product or pipe **72**, together with the temperatures involved, determines the wall thickness of the pipe, it being understood that a slower rate of withdrawal results in a thickner-walled pipe, other factors being equal. Similarly, a different temperature of molten metal will result in different wall thickness, other factors being equal, and the same is true with respect to the temperature of the cooling water in the cooling jacket **48** and the rate of flow thereof.

It is desired to cut the molded pipe in lengths and to do so without stopping or otherwise interfering with the constant withdrawal of the molded product. To accomplish this end, the cut-off device is arranged to move upwardly with and at the same rate as the molded pipe. Any of various arrangements may be utilized for this purpose, one being shown diagrammatically in FIGURE 6, where a pulley **74** is driven at a peripheral speed equal to that of the extraction rollers **70**. A cable **76** is trained over that pulley and over a series of other pulleys **78**, the opposite ends of the cable being connected above and below respectively to a cutting means indicated generally at **80**, including a cutting element **82** for cutting the pipe. Upon rotation of the pulley **74** in the appropriate direction, clockwise in the arrangement shown, the cutter means **80** is elevated with the pipe. The cutter element **82** during this operation is operated and moved against the pipe, cutting the latter. Suitable means may be employed for controllably operating the pulley **74**, such as mounting it on a common shaft with one of the extraction rollers, and providing a clutch means for controllably elevating the cutter means. The cutter means may be lowered by any suitable means such as by gravity.

The embodiment illustrated in FIGURE 2 includes the principal features included in the apparatus of FIGURE 1, with additional features described below. The apparatus of FIGURE 2 includes the tank **12**, ladle **16**, pouring tube **34**, and mold **38**. Instead of the single inlet conduit **24**, there is in addition an outlet conduit **84** for controlling the flow of compressed air in and out of the tank **12**. Suitable pump means **86** is provided for pumping compressed air into the tank through the inlet conduit **24** and controllably removing it therefrom through the outlet conduit **84** for controllably varying the air pressure in the tank.



In addition to the various structural elements incorporated in the apparatus of FIGURE 1, there is also a vertical filling tube **88** which extends through the cover **20** and terminates closely adjacent the bottom of the ladle, and has a filling hopper element **90** at the top exteriorly of the tank. The filling tube is, of course, sealed in the cover **20** to prevent escape of air from the tank therepast. An induction coil **92** surrounds the upper exposed portion of the filling tube for heating and maintaining in the molten state the portion of the molten metal that extends up into the tube, as it does in the normal operation of the apparatus.

In the operation of the apparatus of FIGURE 2, the molten metal is poured into the filling tube **88** until the level in the ladle rises to the desired height, such as adjacent the top thereof. Then air pressure is developed in the tank, which forces the molten metal up through the pouring tube **34** and into the mold **38**, and the molding operation is performed and continued as described above in connection with FIGURE 1. The molten metal also rises in the filling tube **88**, due to the air pressure, to a level effectively equal to the level of the liquid portion of the molten metal in the mold, and as the molding or casting operation is continued, the withdrawal of the metal from the mold is compensated by additional molten metal forced thereinto by the air pressure which is constantly increased to maintain the desired level of molten metal in the mold.

An advantage of the invention is that oscillation of the molten metal can be effected. This is done by varying the air pressure in the tank. For example, if the air pressure is increased to a predetermined value, it may raise the level of the metal in the mold to a height indicated by the line **68***a*, and upon release of that pressure to a second and lower predetermined value, the level of the molten metal descends to a position, for example, indicated by the line **68***b*. This lowering of the level is done relatively rapidly, causing a washing effect of the molten metal in the center of the pipe against the inner surface thereof, producing a more refined and clean-cut inner surface of the pipe. It will be understood that the lower limit indicated by the line **68***b* would be above the lowermost limit of any freezing effect in the molded product.

The upper end of the filling tube **88** is at least as high as the upper extremity of the mold so as to prevent overflow of the molten metal through the filling tube in the normal operation of the apparatus. The arrangement enables continuous filling or replenishment of the apparatus; for example, given a constant air pressure in the tank, molten metal may be introduced into the filling tube and the level resulting therein forces the metal up into the mold, and at the same rate at which the metal is introduced in the filling operation.

The apparatus is also adapted for reciprocation of the mold relative to the other portions of the apparatus and relative to the rate of withdrawal of the pipe. FIGURES 3 and 4 show a fragmentary portion of the apparatus incorporating means for oscillating the mold. In these figures, the mold **38** is provided with a surrounding flange **94** or a plurality of extensions at its lower end and another flange **96** or extensions at its upper end. Tie bolts **98** interconnect these two flanges for forming a rigid assembly of the various components of the mold, and the lower flange **94** provides means for securing the pouring tube **34** to the mole.

This rigid mold assembly is detachably supported on an extension **100** which is annular in form and mounted on the top **20** of the tank. This extension **100** receives the upper end portion of the pouring tube **34** for reciprocating movement therein, a suitable bushing **102** being secured as by welding to the pouring tube for sealing around it against the escape of the compressed air. The bushing **102** is secured to an outer bushing **103** and the two together rise and fall with the pouring tube and mold assembly. The bushing **103** has bearing engagement with a surrounding wall element **105** included in the extension **100**.

Power means, such as a plurality of hydraulic ram means **104**, is provided for raising the mold. These ram means are mounted on the cover **20** and have pistons **106** engageable with the lower flange **94**. Upon extension of the rams **106** through suitable power means (not shown) the flange **94** and thus the mold assembly is raised, carrying also the pouring tube **34** therewith.

The mold assembly is raised to its upper limit at a rate equal to that of the withdrawal of the molded pipe, and then abruptly lowered while the pipe continues to be withdrawn at its normal rate. This oscillating action frees the pipe from the mold, thus minimizing the static friction adherence of the pipe to the mold. This action results in greater average freeing action relative to a fixed mold and constant movement of the molded product or pipe.

It will be understood that the power ram means **104** is exemplary of various means that may be utilized for oscillating the mold. For example, as shown in FIGURE 7, cam means **108** may be provided for engaging a suitable element **110** of the mold **38**, and upon rotation of the cam in the direction indicated, the mold will be raised. The cam is provided with a drop-off surface **112** enabling an abrupt lowering of the mold, it being understood that the surface **112** may have a slight inclination to prevent an entirely free fall of the mold.

FIGURE 8 diagrammatically illustrates still another form of means for oscillating the mold. Instead of the cam **108**, a saw tooth member **114** may be utilized, each tooth **116** having a slope such that upon movement of the member **114** in the direction indicated and at a predetermined rate, the teeth will engage the element **110** and raise the mold at a rate equal to the withdrawal of the molded product or pipe, and upon the tooth passing beyond the element **110**, the mold drops, as described in connection with FIGURE 7.



While I have herein shown certain preferred forms of the invention, it will be understood that changes may be made therein within the scope of the appended claims.

I claim:

**1.** Apparatus for continuous casting comprising a ladle, a mold above the ladle and having a vertical passage therethrough forming a cavity, means forming a passage from said ladle to and communicating with said mold cavity at the lower end thereof, said mold being of high heat conductivity relative to the ladle and passage forming means, means for applying pressure on the molten metal in the ladle for forcing the molten metal through said passage and into said mold, means for continuously withdrawing the cast product at a constant rate from the upper end of the mold, and means for oscillating the molten metal and thereby raising and lowering the level thereof in and relative to said mold, said last mentioned means being operative for raising that level at a rate substantially equal to the rate of withdrawal of the cast products and abruptly lowering the level independently of and during the constant withdrawal of the cast product.

**2.** The apparatus set out in claim **1** wherein the pressure applying means includes means for controllably varying the pressure so as to oscillate the molten metal and thereby raise and lower the level thereof in the mold.


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