March 7, 1967 N. P. GOSS 3,307,230

CONTINUOUS CASTING APPARATUS WITH POSITIVE DRIVE OSCILLATING MEANS

Filed May 9, 1963 3 Sheets-Sheet 1

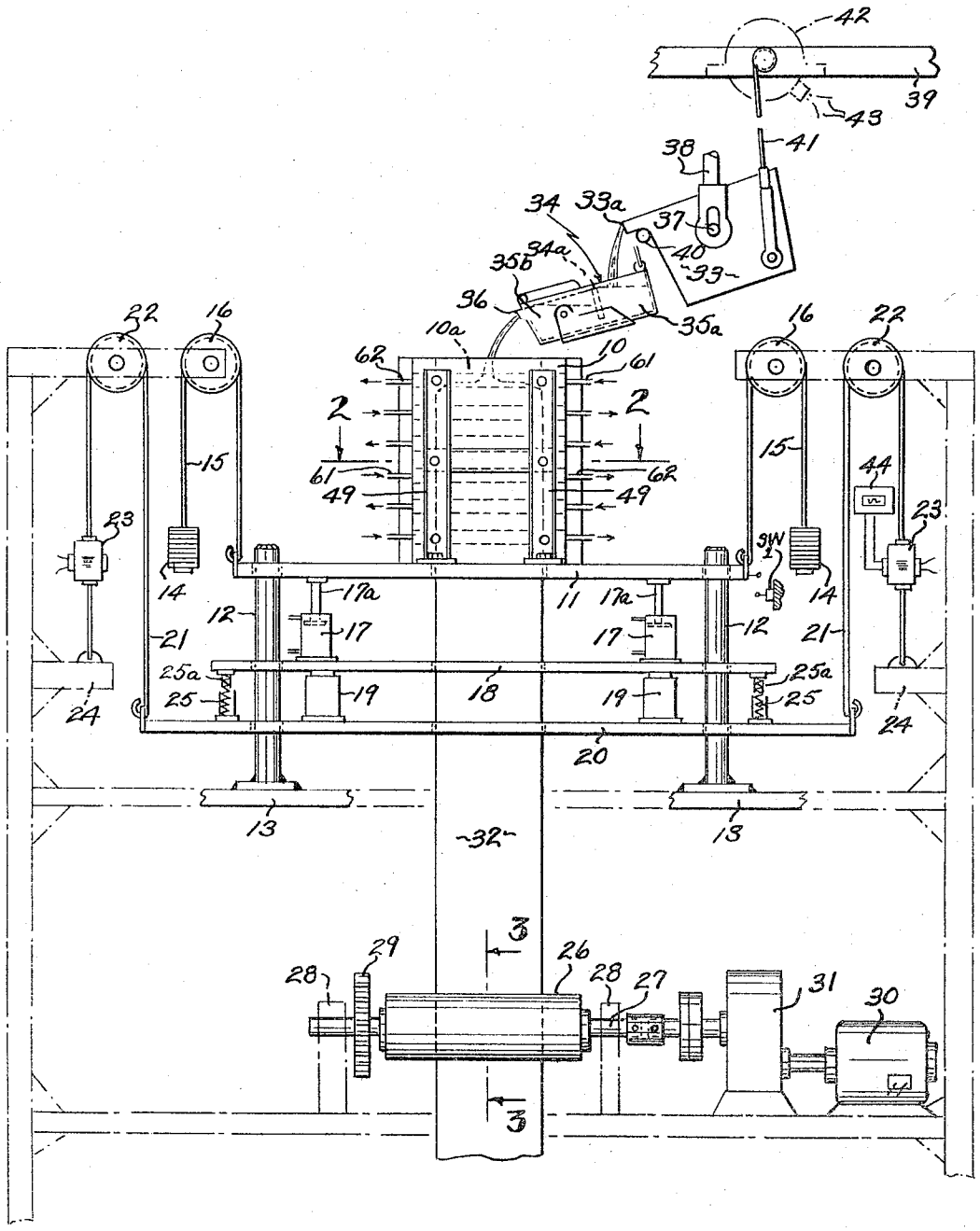


FIG. 1

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Filed May 9, 1963 3 Sheets-Sheet 2

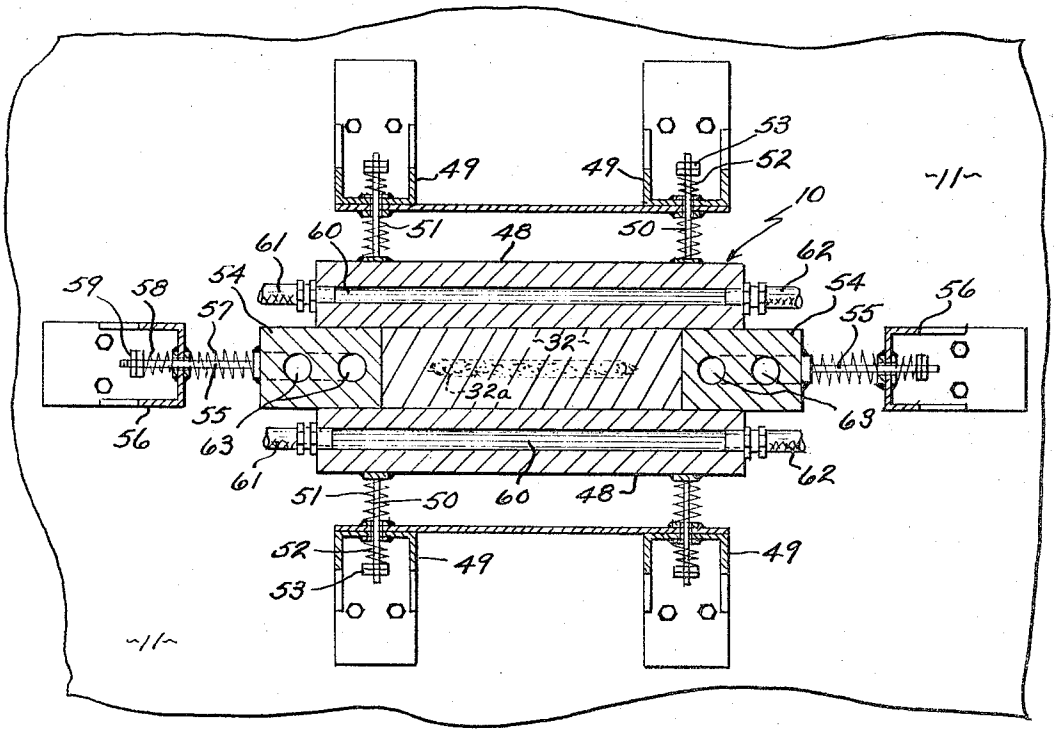


FIG. 2

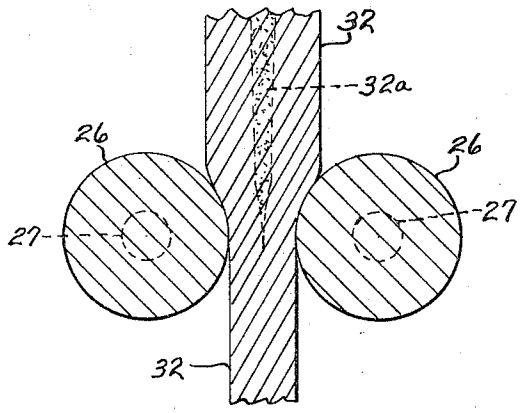


FIG. 3

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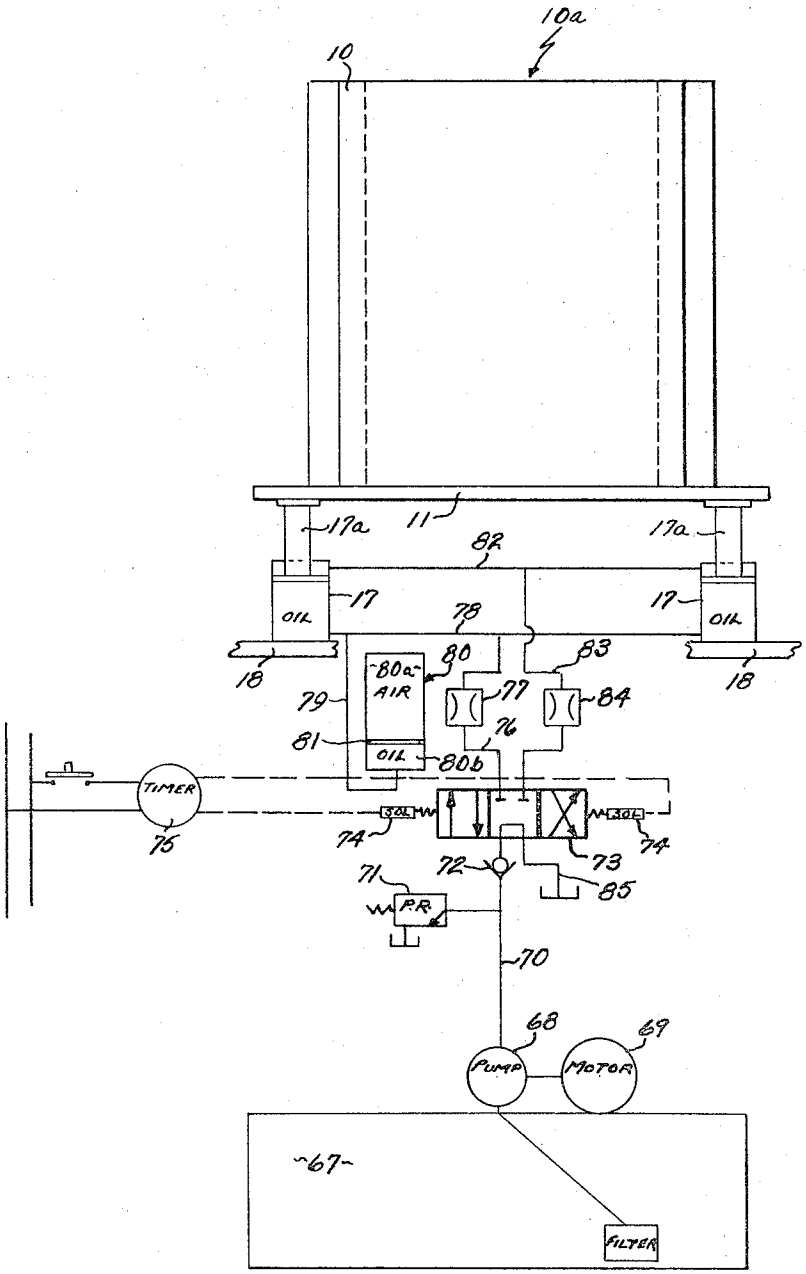


FIG. 4

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CONTINUOUS CASTING APPARATUS WITH POSITIVE DRIVE OSCILLATING MEANS

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4 Claims. (Cl. 22—57.3)

This invention relates to improvements in apparatus for continuously casting metal.

An object of the present invention is the provision of improvements in a metal casting operation wherein a cooled mold is provided having a through passageway generally positioned vertically into which molten metal is introduced at the upper end at a controlled rate and the bar which is formed in the cooled mold is continuously removed through the bottom opening thereof. The improvements set forth herein involve one or more of the following elements either taken separately or in combination. Among these is the provision for continuously oscillating the mold in the direction of bar movement generaly involving movement of the mold downwardly in contact with the bar at a speed not appreciably less than than the speed of bar movement, and then returning the mold upwardly at a rate not substantially greater than the downward rate on the previous half of the cycle. An essential feature of the present invention is that the force available for moving the mold upwardly of the bar is always held at a level insufficient to fracture the embryo skin which is first formed when the molten metal strikes the cool mold wall. It results from this apparatus limitation that even though the oscillatory apparatus is making an upward stroke at the time that the metal sticks to the mold wall, nevertheless, the force available is insufficient to push upwardly with the strength which would cause rupture of the cast bar and, therefore, at such a moment the friction between the bar and mold is capable of carrying the mold downwardly rather than rupturing the newly formed skin on the bar inside the mold.

Another element in the improvement of this invention is the application, preferably continuously, of high frequency vibrations to the mold during the casting operation at an amplitude of vibration in the path of bar movement less than the stroke of the oscillatory apparatus previously mentioned so that the vibratory operation has a tendency to cause a slight necking of the embryo skin on the bar in either direction of the vibratory movement of the vibratory cycle thus continuously tending to free the bar from the mold wall and the vibratory device at no time having sufficient force to cause a rupture of the embryo skin.

Another step in this invention is the introduction of a glass-like layer on top of the molten metal in the mold, together with the use of the vibratory action herein described to aid movement of the glass-like material into the small gap between the cast bar and the mold to further reduce friction there.

Other objects and advantages of this invention will be apparent from the accompanying description and drawings and the essential features thereof will be set forth in the appended claims.

In the drawings,

FIG. 1 is a somewhat schematic view of apparatus adapted to carry out this invention;

FIG. 2 is a sectional view, enlarged, of the mold taken along the line 2—2 of FIG. 1 showing details omitted from FIG. 1 for clarity;

FIG. 3 is a sectional view, enlarged, taken through the pinch rolls along the line 4—4 of FIG. 1;

FIG. 4 is a diagrammatic view illustrating the use of

electricity and various fluids to provide the control operations herein described.

Referring to FIGS. 1 and 2, a mold **10**, open at top and bottom, is fixed to a movable platform **11** which in turn is mounted for guided vertical movement on a plurality of vertical posts **12** which are fixed to a permanent support **13**. The cross-sectional area of the posts **12** and the receiving openings for them in the platform **11** are of sufficient area as to prevent cocking of the platform on the posts **12** so that the platform may move evenly up and down on the posts. For one example, the central opening **10***a* through the mold **10**, as seen in FIG. 2, is approximately 4" wide and 24" long for the purpose of casting a steel slab. It is obvious that this mold opening might have other forms. For ease in manipulating the mold **10** and the platform **11**, as hereinafter described, a counterweight **14** is supplied substantially equal in weight to the platform **11** and all parts carried by it. This counterweight is carried by cables **15** which pass over idler pulleys **16** rotatably mounted on any suitable fixed support.

Means is provided for giving an oscillatory motion up and down to the platform **11** and the mold **10**. Any suitable mechanical means may be used, but, in this case, a preferred form is illustrated as a plurality of hydraulic jacks **17** mounted on a platform **18** which is also mounted for free movement vertically on the posts **12**. The operation of the hydraulic jacks **17** will be later described.

The invention contemplates the application of high frequency vibrations to the molding equipment during its operation and in FIG. 1 this is illustrated as comprising a plurality of high frequency electrically operated vibrators **19** mounted on a platform **20** and adapted to engagement with platform **18**, oscillatory means **17** and platform **11** to produce high frequency vibrations in the mold **10**. The platform **20** is to all intents and purposes fixed in position by means of cables **21** which pass over fixed idler pulleys **22**. The cables **21** have in series strain gauges **23** and the cables are eventually fastened to a fixed bracket **24**. Platform **18** is held in constant engagement with the vibrators **19** by means of a plurality of tension springs **25** suitably held in position by a telescoping housing **25***a* as shown. Other similar high frequency vibratory means might be substituted for that described. By using high frequency vibrations superimposed upon the lower frequency oscillation of the mold, a novel means is provided for reducing the frictional forces between the bar and mold.

As shown in FIGS. 1 and 3, a pair of pinch rolls **26** fixed on drive shaft **27** are mounted in suitable bearings in brackets **28** and geared to rotate together by a pair of pinions **29**. One of the shafts **27** is driven by means of motor **30** through reduction gearing **31**. Those familiar with this art will understand that the slab **32** which is cast in the mold **10** is controlled in its movement through the mold by controlling the speed of motor **30**.

Referring to FIG. 1 the supply of molten metal for the casting operation is provided in a ladle **33** with a pouring lip **33***a* which is normally positioned over a tundish **34** having an internal baffle **34***a* which compels the metal to flow from the rear compartment **35***a* of the tundish under the baffle into the forward compartment **35***b* so as to skim slag and the like in a known manner. The pouring spout **36** of the tundish is normally positioned centrally over the mold opening **10***a*. The ladle **33** is suspended in the usual manner by trunnions **37** supported at **38** from an overhead crane **39**. Preferably, fulcrum **40** is fixed relative to the crane **39** and rests under the pouring lip **33***a*. Then a pair of tension cables or the like **41** are secured to the ladle and wound on a winch **42** carried by the crane **39** and supplied with power from an electri-

cal source connected at 43. This is for the purpose of slowly tilting the ladle 33 during a pouring operation.

Referring now to FIG. 2, the mold specifically discloser herein comprises generally parallel side plates 48 resiliently mounted on brackets 49 which in turn are bolted to the platform 11. The mounting means comprises a plurality of bolts 50 integral with the side plates 48 and passing through suitable openings in the brackets 49. Springs 51 are held in slight compression between brackets 49 and side plates 48, while other springs 52 are held in compression between brackets 49 holding nuts 53 threaded on the outer ends of bolts 50. End walls 54 are provided for the mold which fit snugly between said plates 48 so as to retain metal in the mold while permitting plates 48 to expand and contract independently of the end walls. The end walls are mounted by means of integral bolts or studs 55 which pass through suitable openings in brackets 56 which are in turn secured to the platform 11. Compression springs 57 are held between bracket 56 and members 54 while other springs 58 are held in compression between brackets 56 and securing nuts 59 which are threaded on the ends of studs 55. The control valves may be adjusted so that the endwise expansion of the side walls 48 is substantially held constant. The end walls 54 are suitably cooled by passing a cooling liquid through the internal passageways 63. Manual control of this cooling liquid will normally be sufficient.

Referring now to FIGS. 1 and 4, the oscillatory means 17 comprises hydraulic jacks having their cylinders mounted on the platform 18 and having their piston rods 17*a* connected to the platform 11 so that the platform 11 may be positively moved both upwardly and downwardly by means of the hydraulic jacks. Hydraulic fluid such as oil is stored in reservoir 67 and placed under pressure by pump 68 driven by motor 69 and delivered into outlet pipe 70 under the control of a pressure regulator 71. A check valve 72 is provided in line 70 permitting flow away from the pump only. The output of the pump passes through a reversing valve 73 under the control of solenoid means 74 which in turn is subject to the control of an electrical timer 75 as will presently be described. Other suitable mechanical means may be used in place of solenoid 74. In one position of valve 73 the fluid under pressure passes through line 76, needle valve 77 and line 78 to the lower ends of the hydraulic jacks 17 so as to provide upward movement of the platform 11 and mold 10. The pressure regulator 71 is so set that this upward pressure of the hydraulic jacks 17 is sufficient to overcome the ordinary friction between the bar 32 and the walls of the mold but insufficient to rupture the embryo skin which forms immediately upon the hot metal engaging the cooled walls of the mold 10. The rate of upward stroke is controlled by the needle valve 77. If the bar 32 sticks to the mold walls 10 with an abnormal friction, which the pressure in the lower portion of hydraulic jack 17 is unable to overcome, then the bar 32 moving down under control of the pinch rolls 26 will carry the mold 10 and platform 11 down with it against the insufficient pressure in the lower portion of the jack 17. At this time, the oil expelled from the lower portions of the jacks 17 will pass through line 79 to accumulator 80 having an air cushion in its upper chamber 80*a* and having an internal seal 81 preventing oil in the lower chamber 80*b* from passing upwardly into the air chamber 80*a*. Thus, the air chamber 80*a* acts as a resilient cushion which is loaded as the bar 32 carries the mold 10 downwardly and, upon release of the abnormal friction between the bar and the mold walls, the oil stored in chamber 80*b* will slowly be returned to the hydraulic jack system through the pressure of the loaded air cushion 80*a*. During upward stroke of the hydraulic jacks 17, the displaced hydraulic fluid in the upper portions of the hydraulic jacks passes through line 82, line 83, controlled by needle valve 84, back to the reservoir through discharge line 85.

In another position of the distributor valve 43, hydraulic fluid passes from the pump 68 through lines 70, valve 73, and lines 83 and 82 to the upper ends of the hydraulic jacks so as to cause a downward stroke, the rate of which is controlled by the needle valve 84. Preferably, the speed of the downward stroke is coordinated with the speed of the pinch rolls 26 so that the downward stroke caused by the hydraulic jacks 17 is approximately the same as, or a little greater than, the downward movement of bar 32 so that during the downward stroke there is either no relative movement between the bar 32 and the walls of the mold 10, or the mold will tend to move ahead of the bar.

I visualize that the output from the device herein described for casting a stab 4" by 24" in section will move at the rate of about 30" per minute downwardly. If the various devices hereinbefore described do not release the mold 10 from the bar 32 under abnormal friction conditions, then after a predetermined time, it will be necessary to stop the operation. To this end, I have placed switch SW1 in position adapted to be actuated by downward movement of platform 11 of approximately three inches. This switch is so connected electrically to winch 42 and motor 30 that upon actuation it operates the winch 42 to stop pouring at the lip 33*a* and at the same time stops the motor 30 so that the pinch rolls no longer act upon the bar 32. Under such conditions the abnormal friction situation must be overcome before the apparatus is restarted.

Those familiar with this art will understand that in a casting operation of this sort, a pipe will form at 32*a* in the interior of the bar 32 and a suitable mechanism for eliminating this pipe is illustrated in FIG. 4. The pinch rolls 26 are made of such diameter that they are capable of reducing the cross-section of the bar 32 between them by at least 25 percent by a squeezing action. To get such a squeezing action the diameter of the pinch rolls must be made sufficiently large. In the present illustration, of a bar 32 having dimensions of 4" by 24", I prefer to make the pinch rolls 26 approximately 3 feet in diameter. Then, as the newly formed bar passes between the pinch rolls, the solid metal is pressed together in the center of the bar and welded there and the pipe is eliminated.

I may add a layer of glass-like material on top of the molten metal as taught in my Patent No. 2,825,947, granted March 11, 1958, for Method of Continuous Casting of Metal so that the glass, aided by the vibratory action taught herein, may pass at the meniscus down between the embryo skin and the wall of the mold 10 so as to hold the friction at as low a level as possible. I believe this to be a novel method step in continuous casting of the type taught herein wherein the embryo skin is never fractured. The use of glass in a method wherein fractures occurred in the embryo skin would be deleterious to the casting process because bits of glass would seep into the fracture cracks and spoil the surface of the cast bar. This would be true, for instance, in the method of Junghans which causes a sudden, rapid upward stroke of the mold relative to the cast bar which is sufficient to rupture the embryo skin and permit the glass to enter such cracks. In the improved casting method taught herein, the upstroke of the mold 10 is slower than the upstroke taught by Junghans and, in any case, the power of the hydraulic jacks 17 is preferably held at a point insufficient to cause a rupture of the embryo skin within the mold.

The pressure fluid for jacks 17 might be compressed air instead of oil.

In normal operation, the apparatus of this invention above described operates as follows. The pouring is started using a stop member to close the bottom of the mold and to lead the first portion of the bar to the pinch rolls 26. When the mold 10 is filled for a major portion of its height, the pinch rolls are started by means of the motor 30 and the pouring rate and the pinch rolls are set for the normal operation of 30 inches per minute (assumed) of cast bar. The oscillatory means 17 and vibra-

tory means 19 are placed in operation. Under normal friction conditions the bar moves downwardly without appreciable movement of the mold 10. If abnormal friction occurs between the bar and the mold, then the bar and the mold start down together pushing the hydraulic fluid of the oscillatory means 17 into the accumulator 80. Normally, release of the abnormal friction will occur quickly. Then normal operation begins again with the excess hydraulic fluid in the accumulator 80 moving slowly back into the hydraulic system at the lower ends of the jacks 17. If the strain gauge 23 is stressed above the normal level, the operator will note this on oscillograph 44 and make the proper adjustments.

It should be noted that the high frequency vibrators 19 operate at all times with an amplitude preferably of .005" to .020" and at a rate of 500 to 3600 vibrations per minute. The oscillatory means 17 operates with a greater stroke than the vibratory means preferably a stroke of 0.25" to 1.0", and at a preferred frequency between 60 and 100 times per minute. This operation of the vibratory means at a higher rate and at a smaller amplitude than the oscillatory means results in a slight necking of the embryo skin first formed as the metal chills against the mold walls but the vibratory stroke is so short and of such force that it does not result in a fracture of the embryo skin. At the same time the constant operation of the vibratory means tends to separate the embryo skin from the mold walls so as to hold the friction down to a normal level.

What is claimed is:

1. In apparatus for continuously casting metal from the molten stage, a cooled mold open at both ends, means for introducing molten metal at one end of said mold whereupon it immediately forms a thin skin against said cooled mold, means for controlling the removal of the metal bar formed in said mold out of the other end of said mold at a controlled rate, wherein normal friction exists between said bar and said mold when said bar is moving through said mold at said controlled rate and abnormal friction exists there when said bar sticks to said mold, means mounting said mold for movement back and forth in the direction of bar movement, oscillatory expansible chamber means rigidly connected with said mold and continuously positively driving said mold back and forth in the direction of bar movement, and said oscillatory means yieldingly urging said mold in the direction upstream of said bar movement with a force less than that sufficient to rupture said thin skin and greater than said normal friction.

2. Apparatus as defined in claim 1 wherein said oscillatory means has a frequency of 60 to 100 stroke per minute and an amplitude of 0.25 inch to 1.0 inch.

3. In apparatus for continuously casting metal from the molten stage, a cooled mold open at both ends, means for introducing molten metal at one end of said mold whereupon it immediately forms a thin skin against said cooled mold, means for controlling the removal of the metal bar formed in said mold out of the other end of said mold at a controlled rate, wherein normal friction exists between said bar and said mold when said bar is moving through said mold at said controlled rate and abnormal friction exists there when said bar sticks to said mold, means mounting said mold for movement back and forth in the direction of bar movement, oscillatory means continuously moving said mold back and forth in the direction of bar movement, and said oscillatory means yieldingly urging said mold in the direction upstream of said bar movement with a force less than that sufficient to rupture said thin skin and greater than said normal friction, whereby under abnormal friction said mold moves downstream with said bar, said oscillatory means including expansible chamber means in rigid engagement with said mold for moving said mold upstream of said bar together with a pressure fluid supply therefor, and a resilient pressure accumulator in communication with said chamber for temporarily receiving a portion of said pressure fluid upon decrease in volume of said expansible chamber by movement of said bar and mold downstream, said accumulator adapted to return said temporarily received pressure fluid upon release of said abnormal friction.

4. In apparatus for continuously casting metal from the molten stage, a cooled mold open at both ends, means for introducing molten metal at one end of said mold whereupon it immediately forms a thin skin against said cooled mold, means for controlling the removal of the metal bar formed in said mold out of the other end of said mold at a controlled rate, wherein normal friction exists between said bar and said mold when said bar is moving through said mold at said controlled rate and abnormal friction exists there when said bar sticks to said mold, means mounting said mold for movement back and forth in the direction of bar movement, oscillatory means continuously positively driving said mold back and forth in the direction of bar movement, and said oscillatory means yieldingly urging said mold in the direction upstream of said bar movement with a force less than that sufficient to rupture said thin skin and greater than said normal friction, whereby under abnormal friction said mold moves downstream with said bar, and means for stopping said molten metal introducing means and for stopping said bar removal means responsive to a predetermined movement of said mold downstream.

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