Jan. 23, 1968 M. LOEWENSTEIN 3,364,980

WIDE STRIP MOLD FOR CONTINUOUS CASTING

Original Filed Aug. 5, 1964 3 Sheets-Sheet 1

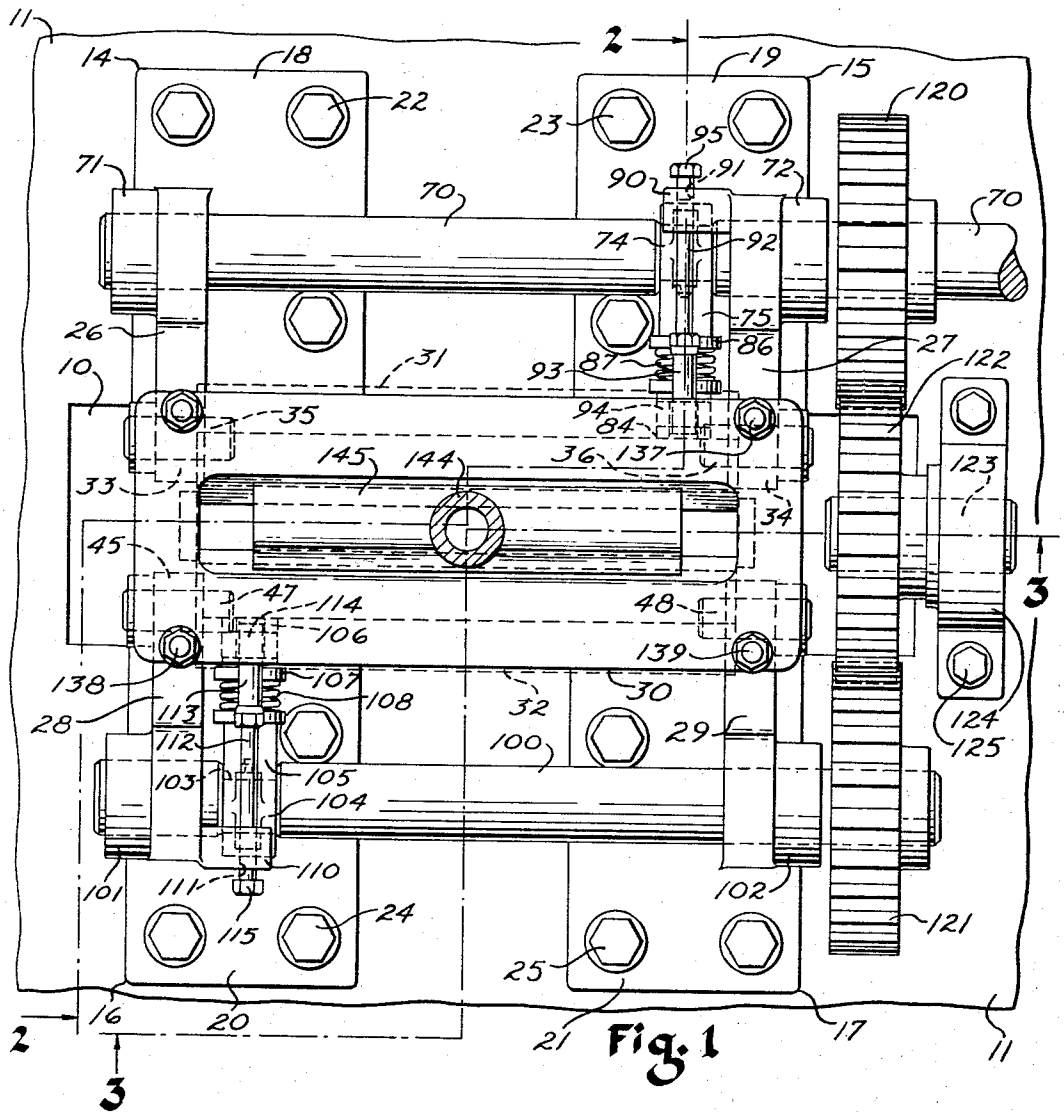


Fig. 1

INVENTOR.
Max Loewenstein
BY
Meyer, Baldwin, Doran & Egan
ATTORNEYS

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Original Filed Aug. 5, 1964 3 Sheets-Sheet 2

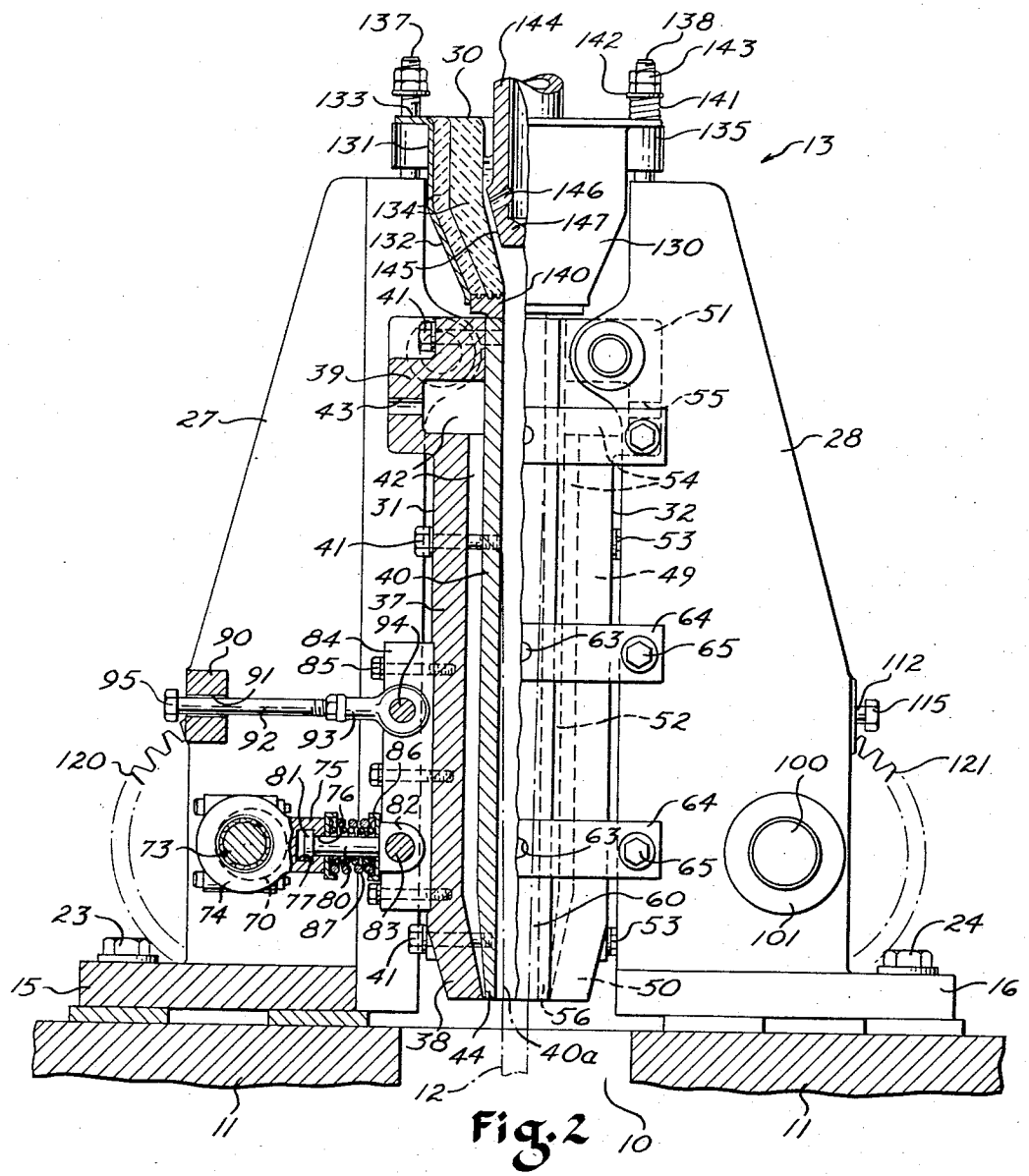


Fig. 2

INVENTOR.
Max Loewenstein
BY
Meyer, Baldwin, Doran & Egan
ATTORNEYS

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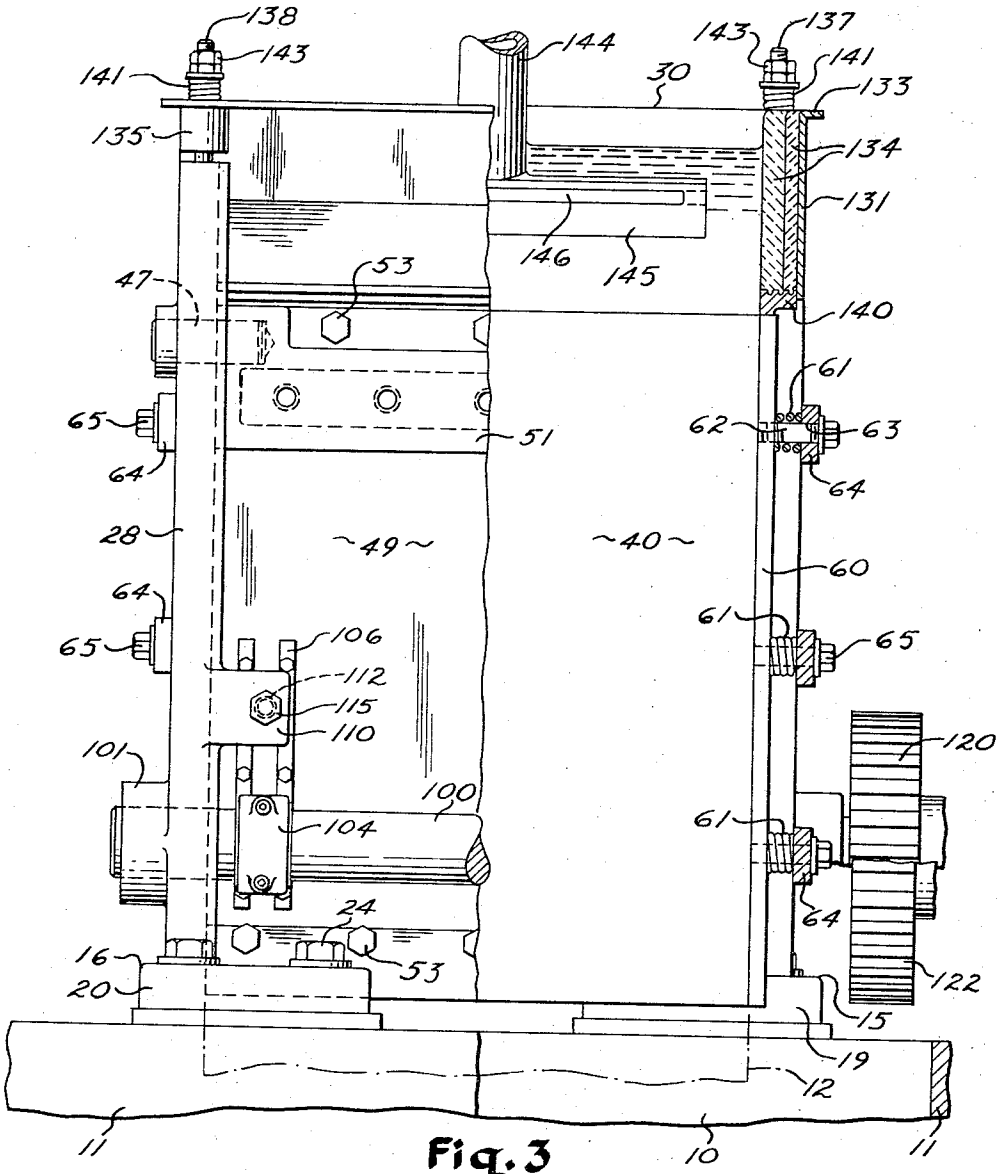


Fig. 3

INVENTOR.
Max Loewenstein
BY
Meyer, Baldwin, Doran & Egan
ATTORNEYS

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3,364,980

WIDE STRIP MOLD FOR CONTINUOUS CASTING

Max Loewenstein, New York, N.Y., assignor to Loma Machine Manufacturing Co., Inc., New York, N.Y., a corporation of Delaware

Continuation of application Ser. No. 387,573, Aug. 5, 1964, This application May 5, 1967, Ser. No. 636,559
7 Claims. (Cl. 164—281)

This is a continuation of application Ser. No. 387,573, filed Aug. 5, 1964, now abandoned.

This invention relates to improvements in a mold for forming wide metal strips by a continuous casting process. More particularly, it relates to a continuous casting mold which is open at the top and bottom, into which the molten metal is poured at the top while a solidified or partially solidified strip is continuously removed at the bottom, which has a cross section that is much wider than it is thick with provision for swinging the wider sides of the mold walls inwardly and outwardly about pivots located near the top of the mold, and which is arranged in such a fashion that the thickness of the mold, across the smaller dimension of the section, converges downwardly in one position of said mold walls. The ideal condition would seem to be one wherein the convergence of the mold walls corresponds at least roughly to the shrinkage of the cast strip which obviously becomes progressively thinner as it moves downwardly in the mold and becomes cooler. It results from the above construction that the wider mold walls, which are cooled, are kept more closely in contact with the strip being cast whereby heat transfer is greatly accelerated, and the inward movement of the wider mold walls toward the bottom of the mold may be sufficient to mechanically work the congealing metal to some extent so that the strip as discharged from this improved mold will no longer have what is sometimes referred to as "ingot" crystalline structure but instead will have some of the characteristics of a strip which has had a limited amount of hot rolling from a larger section.

An object of the present invention is to provide means for varying the amount of oscillatory movement of the wider mold walls and the frequency of this movement so as to adjust the mold to give the best contact for different metals or for different casting conditions.

A further object of the present invention is to reduce the friction between the metal in the mold and the mold walls. In a stationary mold, this friction causes cracks in the cast section, particularly when the proportion of width to thickness of the section exceeds a certain amount; for instance, when casting brass, experience has shown that due to such friction, the relationship of thickness to width should not be above one to six. With the mold according to the present invention, this limitation does not exist so that it is possible to produce strips of a large width and thin gauge and thus reduce the subsequent rolling process to a minimum.

The fact that the pivot point for the movable, wider mold plate is almost at the upper end of the mold, so that there is practically no oscillating movement in this part of the mold, makes it possible to put on top of the mold a tundish which is much wider than the thickness of the cast strip. Thus, there is sufficient space in this tundish for underpouring.

A further object of the present invention is to provide special means, such as a novel design of tundish, which is provided for underpouring, that is, the introduction of the liquid metal below the top surface level of the metal pool in the tundish. The very small amount of up and down movement of the upper edges of the mold due to the pivoting movement of the wider mold sides permits conveying a lubricant under pressure into the mold along the line where the funnel of the tundish and the mold join. Such lubrication, as is well known for most metals, is extremely desirable to obtain a smooth cast surface on the strips.

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

FIG. 1 of the drawings is a top plan view of the molding apparatus of this invention.

FIG. 2 is a section taken generally along the line 2—2 of FIG. 1.

FIG. 3 is a section taken along the line 3—3 of FIG. 1.

Those skilled in the art of continuous casting of metals, particularly steel, are familiar with the fact that when the liquid metal contacts the cool walls of the mold near the point of entrance, the metal forms a thin skin against the cold wall of the mold which causes a shrinkage of the congealing metal and the newly formed skin will move inwardly away from the cold walls by a slight amount. The hotter or molten central portion of the cast section will then reheat the skin causing it to again contact the mold wall and again shrink away in a continuous congealing process as the metal moves downwardly in the mold. Obviously, the farther the metal travels downwardly in the mold the greater becomes the gap between the newly formed skin on the congealing metal and the mold wall.

The present invention has the wider walls of the strip mold pivoted near the top of the mold, together with means for causing these walls to swing toward and away from each other in a regular manner so as to alternately release and grip the newly formed skin along the wider sides of the strip. The wider mold walls converge toward the bottom of the mold as they swing inwardly, more or less conforming to the increased shrinkage of the cast metal section as it travels downwardly in the mold and thus giving a more efficient heat transfer contact between the newly formed skin of the congealing metal and the cooler mold walls. This counteracts the tendency of the hotter metal in the interior of the cast section to reheat the newly formed skin thus causing "bleeding" or "breakout" which has heretofore been one of the problems in continuous casting of metals by this general process. One attempt to overcome this difficulty in a mold with stationary walls comprises building it in such a way that the side walls converge downwardly, but by this arrangement, the friction between the metal and the mold walls is increased to such an extent that a strong pulling force from pinch rollers below the mold is required to eliminate sticking, and this pull causes cracks in the casting or even complete breakage of the casting. The oscillating movement of the mold in accordance with the invention eliminates this friction between the metal and the mold wall, and a light pull is sufficient to draw the casting downwardly from the mold.

At the same time, the swinging mold walls provided by this invention provide a means for hot working the metal of the strip in a progressively increasing fashion as the metal travels downwardly in the mold so that the strip as finally discharged from the bottom of the mold of this invention has some of the crystalline characteristics of metal which has been hot worked in a rolling mill.

Referring now to the drawings and particularly to FIG. 2 thereof, the continuous casting mold of this invention is bridged across a gap or opening **10** between two horizontally disposed, laterally spaced portions of a base surface means **11**. The mold has means defining a through

cavity and is so positioned as to direct a continuously cast metal strip **12** vertically downwardly through the opening **10**, from where it advances further downwardly by means of rotating pinch rollers (not shown). The mold itself is generally indicated at **13** and comprises pairs of frame members **14–15** and **16–17** (FIG. 1) which are disposed respectively on either side of the gap or opening **10**. The frame members **14**, **15**, **16** and **17** have base portions **18**, **19**, **20** and **21** respectively which are bolted to the base surface means **11** by bolts **22**, **23**, **24** and **25**. The base portions **18**, **19**, **20** and **21** carry upright supports **26**, **27**, **28** and **29** respectively for supporting a tundish **30** and a pair of swingable mold halves or portions **31** and **32**.

The mold half **31** is carried by and pivoted between the supports **26** and **27**. Said supports **26** and **27** are provided with journal portions **33** and **34** respectively which project inwardly over the opening **10** adjacent to the upper ends of said supports and carry stub shafts **35** and **36** upon which the mold half **31** is pivoted.

Said mold half **31** comprises a vertical wall **37** having a short, angled, oblique portion **38** at its lowermost end and an enlarged upper end portion **39** which projects between the supports **26** and **27** and which is suitably apertured at either end to receive the stub shafts **35** and **36**. A copper cooling plate **40** of substantial thickness is carried at the inner side of the mold half **31** inwardly beyond the journal portions **33** and **34**, said plate **40** being bolted to the wall **37**, the oblique portion **38**, and the enlarged upper end portion **39** by suitable bolts **41**. Said mold half **31** is hollowed out to form coolant passage means **42** whereby a coolant introduced into an aperture **43** of the upper end portion **39** is circulated downwardly between the vertical wall **37** and the plate **40** to be exhausted at the lower end of the mold half **31** between the oblique portion **38** and a tapered, lower end portion **44** of said plate.

The mold half **32** is similarly carried by and between the upright supports **28** and **29** which said last mentioned supports are provided with inwardly projecting journal portions **45** and **46** respectively. The journal portions **45** and **46** carry stub shafts **47** and **48** to which the mold half **32** is pivoted at its upper end. Said mold half **32** is substantially similar to the mold half **31** having a vertical wall **49**, an oblique lower end portion **50**, and an enlarged upper end portion **51** which is suitably apertured to receive the stub shafts **47** and **48**. The mold half **32** carries a copper cooling plate **52** at its inner side opposite the plate **40**, said plate **52** being secured by suitable bolts **53**. Coolant passage means are provided at **54** into which a suitable coolant may be introduced through an aperture **55** in the enlarged upper end portion **51**. The coolant introduced at the aperture **55** passes downwardly between the vertical wall **49** and the plate **52** to be exhausted at the lower end of said mold half **32** between the oblique portion **50** and a tapered lower end portion **56** of the plate **52**.

The innermost, facing surfaces of the plates **40** and **52** define, generally, the thickness of the strip **12** being cast, the width of said strip extending substantially the distance between a pair of upright supports **26** and **27** or **28** and **29**. The vertical end edges of the mold halves **31** and **32** are closed by copper cooling plates **60** which are biased tightly against said end edges by coil springs **61** disposed over pins **62** which said pins are carried by the copper plates **60**. The pins **62** project outwardly away from the interior of the mold and extend through suitable apertures **63** in a plurality of horizontal braces **64** which are bolted at the ends thereof to the upright supports by bolts **65**. The braces **64** are disposed parallel with the upright supports **26** to **29** and are connected across the outer surfaces of the supports **26** and **28** or **27** and **29**. The pins **62** slidably engage the apertures **63**, and the springs **61** firmly bias the plates **60** against the end edges of the mold halves **31** and **32**.

The mold halves **31** and **32** are provided with substantially identical eccentric means for swinging said mold halves about the stub shafts **35–36** and **47–48** respectively, the means associated with the mold half **31** being best illustrated in FIG. 2. A drive shaft **70** is journaled in lower end portions of the supports **26** and **27** through bosses **71** and **72** respectively. The drive shaft **70** extends outwardly beyond the boss **72** to a suitable rotary driving power source (not herein illustrated). The drive shaft **70** is provided with an eccentrically positioned, diametrically reduced portion **73** upon which is freely rotatably mounted a bearing member **74**. Said bearing member has an integrally formed, laterally projecting shank **75**, said shank having a bore **76** opening at its distal end and an enlarged opening **77** which is concentric with the bore **76**.

The bearing member **74** is resiliently connected to the mold half **31** by a rod **80** which is slidable in the bore **76** and which carries a piston **81** at one end and a bearing **82** at the other end. The piston **81** is disposed within the opening **77** which said cylinder affords a substantial amount of axial movement of said piston. The bearing **82** is pivoted upon a pin **83** which is carried between a pair of elongated pin mounting members **84**. The mounting members **84** are secured to the vertical wall **37** of the mold half **31** by suitable means such as bolts **85**. The rod **80** carries a pair of cupped washers **86**, one of said washers being disposed against the distal end of the shank **75** and the other of said washers being disposed against the bearing **82**. A compound coil spring **87** is compressively interposed between the washers **86** whereby the rod **80** is normally biased in the right-hand direction as seen in FIG. 2 with the piston **81** being bottomed in the right-hand end of the opening **77**. The parts connecting shaft **73** with pin **83** from a thrust link wherein the power is applied to the mold half **31**, and **32**, through compression spring **87**.

In normal operation, the drive shaft **70** is rotated thereby causing eccentric movement of the bearing member **74** and substantially lateral, reciprocating movement of the pin **83**. This swings or pivots the mold half **31** about the stub shafts **35** and **36** thereby causing the inner surface of the cooling plate **40** to swing arcuately between the full line position of FIG. 2 and the broken line position indicated at **40*a***. Note that the movement of plates **40** is substantially at right angles to the axis of the mold cavity and in no other direction.

Limit means are provided for limiting the swing of the mold half **31** to that which is less than the swing indicated by the broken line position **40*a***. Said limiting means comprises a heavy block of steel **90** which is welded to the inner surface of the support **27** adjacent to its outer edge and above the drive shaft **70**. The block **90** has a horizontal bore **91** through which a shank **92** of an adjustment screw projects. The threaded end of the screw is directed toward and is threaded into a bearing member **93** which is journaled upon a pin **94** carried between the mounting members **84**. The opposite end of the shank **92** has an enlarged head **95** which is disposed outwardly beyond the block **90**. It will be readily appreciated that by turning the shank **92** to cause inward movement of the adjustment screw, the head **95** can be brought closer to the block **90** thereby limiting the inward swinging movement of the mold half **31**. If the inward swinging movement is limited to something less than the throw of the eccentric as determined by the reduced portion **73**, lost motion is permitted between the shaft **80** and the shank **75** of the bearing member **74** by the piston moving toward the left, as illustrated in FIG. 2, within the opening **77**. Under these circumstances, the compound spring **87** merely becomes slightly more compressed.

Eccentric means are provided for swinging the mold half **32** in identically the same manner as that provided for the mold half **31**. Similarly, said mold half **32** is provided with adjustment means for adjusting the extent of the swinging movement of the mold half **32** in exactly the same manner as provided for said mold half **31**.

Referring to FIG. 1, the supports **28** and **29** carry, adjacent to their lower end portions, an idler shaft **100** journaled through bosses **101** and **102** of said supports respectively. The idler shaft **100** is disposed horizontally opposite the drive shaft **70** as well shown in FIG. 2. Said idler shaft has an eccentrically positioned, circumferentially reduced portion **103** which is disposed adjacent to the support **28** and which is identical with the reduced portion **73** of the drive shaft **70**. All of the like parts of the identical eccentric means and adjustment means associated with the mold half **32** are not shown, but a sufficient number of them are illustrated to show their identity with like parts associated with the mold half **31**. The reduced portion **103** carries a bearing member **104** having an integral shank **105**. Mounting members **106**, identical with the mounting members **84**, are provided for pivotally connecting the eccentric means and the adjustment means to the mold half **32**. A compound spring is shown at **108** interposed between cupped washers shown at **107**. At **110** there is provided a block identical with the block **90** which has a bore **111** to receive a shank **112** of an adjustment screw. The adjustment screw is threaded into a bearing member shown at **113** and journaled upon a pin **114**. The distal end of the shank **112** has a head **115** for abutting against the block **110** in the same manner that the head **95** is adapted to abut against the block **90**. In all respects, the eccentric means and adjustment means associated with the mold half **32** operate in the same manner as that associated with the mold half **31**.

The mold halves **31** and **32** are synchronized to swing inwardly and outwardly in unison by a gear train comprising a drive gear **120** carried by the drive shaft **70**, a driven gear **121** carried by the idler shaft **100**, and a synchronizing gear **122** which rotates upon an idler shaft **123** journaled in a bearing support **124**. Said bearing support is, in turn, mounted upon the base surface means **11** by bolts **125**. It will be readily seen that the synchronizing gear **122** is driven by the drive gear **120** of the drive shaft **70** and causes the driven gear **121** to rotate in the same direction as said drive shaft. The gears **120** and **121** are of identical size thereby the movements of both mold halves are synchronized.

The molten metal is introduced at the entrance end of the mold, between the plates **40** and **52** at the upper edges thereof, by the tundish **30**. Said tundish comprises an elongated, metal vessel **130** which is adapted to fit between the upper ends of the pairs of upright supports **26–27** and **28–29**. The vessel **130**, as herein illustrated, has a metal outer shell **131** which has a downwardly convergent portion toward the bottom thereof as best seen in FIG. 2. The upper edge of the shell **131** has a horizontally outwardly directed flange **133**, and the inside of the shell is lined with refractory material as indicated at **134**. Adjacent to the four corners of the vessel **130**, there are provided axially vertical bushings **135** which are mounted under the flange **133**. The upright supports **26**, **27**, **28** and **29** carry vertical posts as indicated at **136**, **137**, **138** and **139** respectively in FIG. 1. Said vertical posts project upwardly through the bushings **135** and through suitable apertures in the flange **133** whereby the tundish **30** is positioned directly over the mold halves **31** and **32**. The bottom discharge opening from the tundish is substantially of the cross section of the mold cavity between plates **60** and the plates **40** of mold halves **31** and **32**. The lower end of the tundish is provided with a heavy, rectangular frame **140** which is rigidly fixed with the shell **131** and the refractory material **134** and is seated upon the upper edges of the plates **40** and **52** and the end plates **60**.

The entire tundish is resiliently urged downwardly against the mold halves to effect a tight seal between the frame **140** and said plates. The means for urging the tundish downwardly comprise coil springs **141** which are telescoped over threaded upper end portions of the vertical posts **136** to **139** and are compressively tensioned beneath washers **142** and lock nut means **143**. It will be readily appreciated that this arrangement allows for the slight movement of the upper edges of the plates **40** and **52** which will occur as the mold halves pivot about the stub shafts **35–36** and **47–58**. The axes of said stub shafts are so closely associated with the upper edges of said plates that the movement between the mold halves and the tundish is extremely slight. This arrangement allows for such movement but at the same time holds the tundish tightly downwardly against the mold halves to insure a continuous seal against leakage of the molten metal.

The molten metal is introduced into the tundish through a vertical pipe **144** having a horizontally disposed, elongated pouring spout **145** connected to its lowermost end. The pouring spout **145** extends a substantial distance lengthwise along the tundish **30** and is provided with elongated, horizontal slots **146** in its sides for releasing the molten metal into the tundish. It will be noted that due to the fact that the tundish is enlarged at its upper portion and due to downwardly convergent side walls **147** being provided at the pouring spout **145**, said pouring spout can be disposed downwardly within the tundish below the level of the molten metal for underpouring.

In operation of the continuous casting apparatus hereinabove described, the molten metal is introduced into the tundish **30** and passes downwardly between the mold cooling plates, emerging from the bottom, exit end of the mold in a solidified or partially solidified condition. As the strip of metal moves downwardly and shrinks away from the walls of the mold due to cooling and congealing of the metal, the larger side walls of the mold as defined by the plates **40** and **52** are oscillated inwardly and outwardly by the eccentric means. The oscillation increases in horizontal movement in a downward direction through the mold whereby there is greater inward movement in the areas where there is greater shrinkage of the metal. The eccentric stroke adjustment means makes it possible to vary this stroke to conform to the particular metal or alloy being cast. By the mold walls moving in farther in the area of greatest shrinkage, there is more continuous contact between the metal strip and the cooled mold walls thereby hastening the solidification of the strip and effectively offsetting the tendency for it to reheat from the interior outwardly and again become molten. As hereinabove mentioned, the oscillating walls of the mold also provide a means for hot working the metal strip in a progressively increasing fashion as it moves downwardly through the mold.

It will be understood that many changes in the details of the invention as herein described and illustrated may be made without, however, departing from the spirit thereof or the scope of the appended claims.

What is claimed is:

1. An apparatus for continuous casting comprising means defining a through cavity having an entrance end for receiving a molten substance and an exit end for discharging said substance in at least a partially solidified state; said means including two side mold portions disposed opposite each other in spaced vertical planes and having mutually facing inner wall surfaces extending generally parallel with each other and with the axis of said cavity; means pivotally mounting said mold portions respectively on parallel horizontal pivots at said entrance end of said cavity for swinging movement arranged so that said mutually facing wall surfaces are swingable toward and away from each other to a greater extent adjacent to said exit end than at said entrance end of said cavity; and power means connected to said mold portions for effecting a predetermined swinging movement of said mold portions during casting, whereby the thickness of the mold cavity becomes progressively less toward its discharge end as said two mold portions converge so as to hot work the metal and offset its shrinkage due to cooling at the discharge end of the mold.

2. An apparatus for continuous casting as set forth in claim **1**; said means for effecting a swinging movement

of said mold portions including synchronizing means causing said mold portions to swing toward each other and away from each other in unison.

3. An apparatus for continuous casting comprising mold means defining a vertical through cavity for introducing molten metal into the upper end thereof and for discharging the metal from the bottom thereof in at least a partially solidified state; said means including two movable side portions of the mold means; and power means for swinging said side portions a predetermined amount about horizontal, parallel axes disposed adjacent to their upper edges including between said power means and each of said side portions a thrust link including a compression spring through which the thrust of said power means is transmitted to said side portions; whereby their lower edges move toward and away from each other in unison during casting to hot work the metal and offset the shrinkage of the metal due to cooling thereof.

4. An apparatus for continuous casting of metal comprising a pair of side mold portions disposed opposite each other in generally parallel, spaced, vertical planes, each said mold portion carrying a flat cooling plate at its inner side facing the other mold portion; means pivotally mounting said mold portions adjacent to their upper edges on axes parallel with said upper edges whereby the lower portions of said mold portions are swingable toward and away from each other; end plates disposed over the end edges of said mold portions and being slidable relative thereto; means biasing said end plates against the end edges of said mold portions; a tundish disposed above said cooling plates and said end plates and having a lower exit edge portion in slidable contact with the upper edges of all of said plates; mean biasing said tundish downwardly against all of said plates; said tundish adapted to receive said metal in a molten state and direct it downwardly between said cooling plates, the discharge opening from said tundish being substantially of the cross section between said plates, said metal being cooled and discharged from between the lower edges of said cooling plates in at least a partially solidified state; and means connected to said mold portion for effecting synchronous swinging movement of said mold portions toward and away from each other during casting; said means for effecting synchronous swinging movement of said mold portions comprising eccentric means including a shaft disposed outwardly from the lower end portion of each said side mold portion; each said shaft having an eccentrically disposed journal portion; a bearing mounted on each said journal portion; lost motion means connecting said bearing with the adjacent mold portion; spring means biasing each said bearing and the associated mold portion away from each other; and adjustable stop means connected to each said mold portion for limiting the swinging movement of the mold portion to less than the throw of said eccentric means.

5. An apparatus for continuous casting as set forth in claim 4; each said lost motion connection comprising a rod; a pivot member carried at one end of each said rod; means mounting each said pivot member to the adjacent mold portion; a piston carried by the other end of each said rod; means providing a captive cylinder of larger axial dimension than said piston carried by said bearing, said piston being disposed within said cylinder; means mounting said spring means between said pivot member and said bearing and biasing them apart.

6. An apparatus for continuous casting of metal comprising a pair of side mold portions disposed opposite each other in generally parallel, spaced, vertical planes, each said mold portion carrying a flat cooling plate at its inner side facing the other mold portion; means pivotally mounting said mold portions adjacent to their upper edges on axes parallel with said upper edges whereby the lower portions of said mold portion are swingable toward and away from each other; end plates disposed over the end edges of said mold portions and being slidable relative thereto; means biasing said end plates against the end edges of said mold portions; a tundish disposed above said cooling plates and said end plates and having a lower exit edge portion in slidable contact with the upper edges of all of said plates; means biasing said tundish downwardly against all of said plates; said tundish adapted to receive said metal in a molten state and direct it downwardly between said cooling plates, the discharge opening from said tundish being substantially of the cross section between said plates, said metal being cooled and discharged from between the lower edges of said cooling plates in at least a partially solidified state; and means connected to said mold portions for effecting synchonous swinging movement of said mold portions toward and away from each other during casting.

7. An apparatus for continuous casting comprising means defining a through cavity disposed on a vertical axis and having an upper entrance end for receiving a molten substance and a lower exit end for discharging said substance in at least a partially solidified state; said means including at least two mold portions having means providing mutually facing, flat inner wall surfaces disposed on opposite sides of the axis of said cavity and disposed generally parallel with said axis; means pivotally mounting said mold portions adjacent to their upper ends near the upper end of said cavity for swinging movement about parallel, horizontal axes whereby said flat surfaces are swingable flatwise toward and away from each other at their nonpivoted ends; and means connected to said mold portions for effecting synchonous swinging movement of said mold portions toward and away from each other during casting; said means for effecting a synchronous swinging movement of said mold portions including an eccentric means connected to each said mold portion for swinging said mold portion a predetermined distance; adjustable stop means connected to each said mold portion for limiting the swinging movement of said mold portion to less than said predetermined distance; each said eccentric means including lost motion means allowing continued movement of said eccentric means when said predetermined distance is limited by said stop means.

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J. SPENCER OVERHOLSER, *Primary Examiner.*

R. S. ANNEAR, *Assistant Examiner.*