Dec. 31, 1963 R. BAIER 3,115,686

POURING MECHANISM FOR CONTINUOUS CASTING

Filed Oct. 21, 1959 7 Sheets-Sheet 1

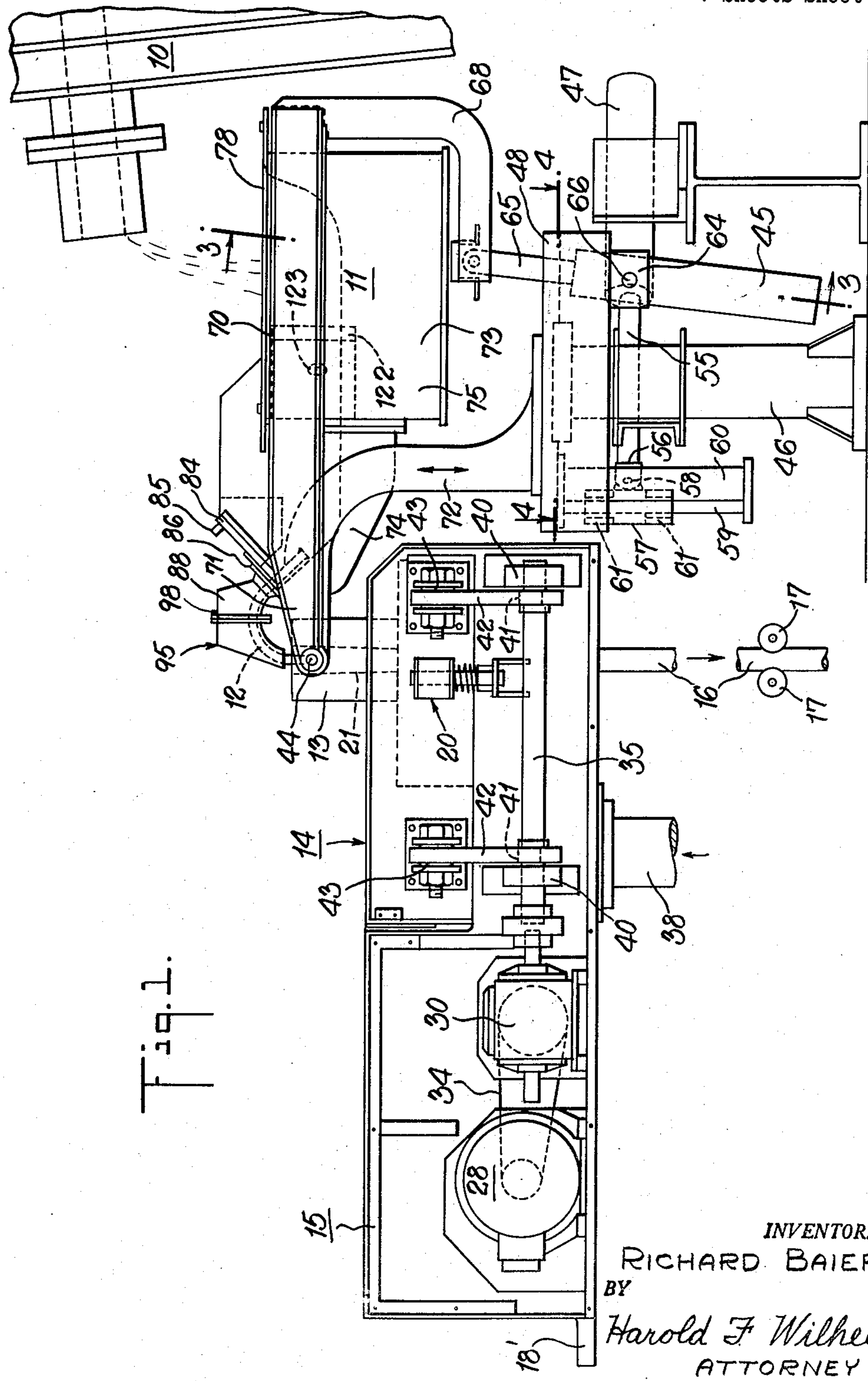

Fig. 1.

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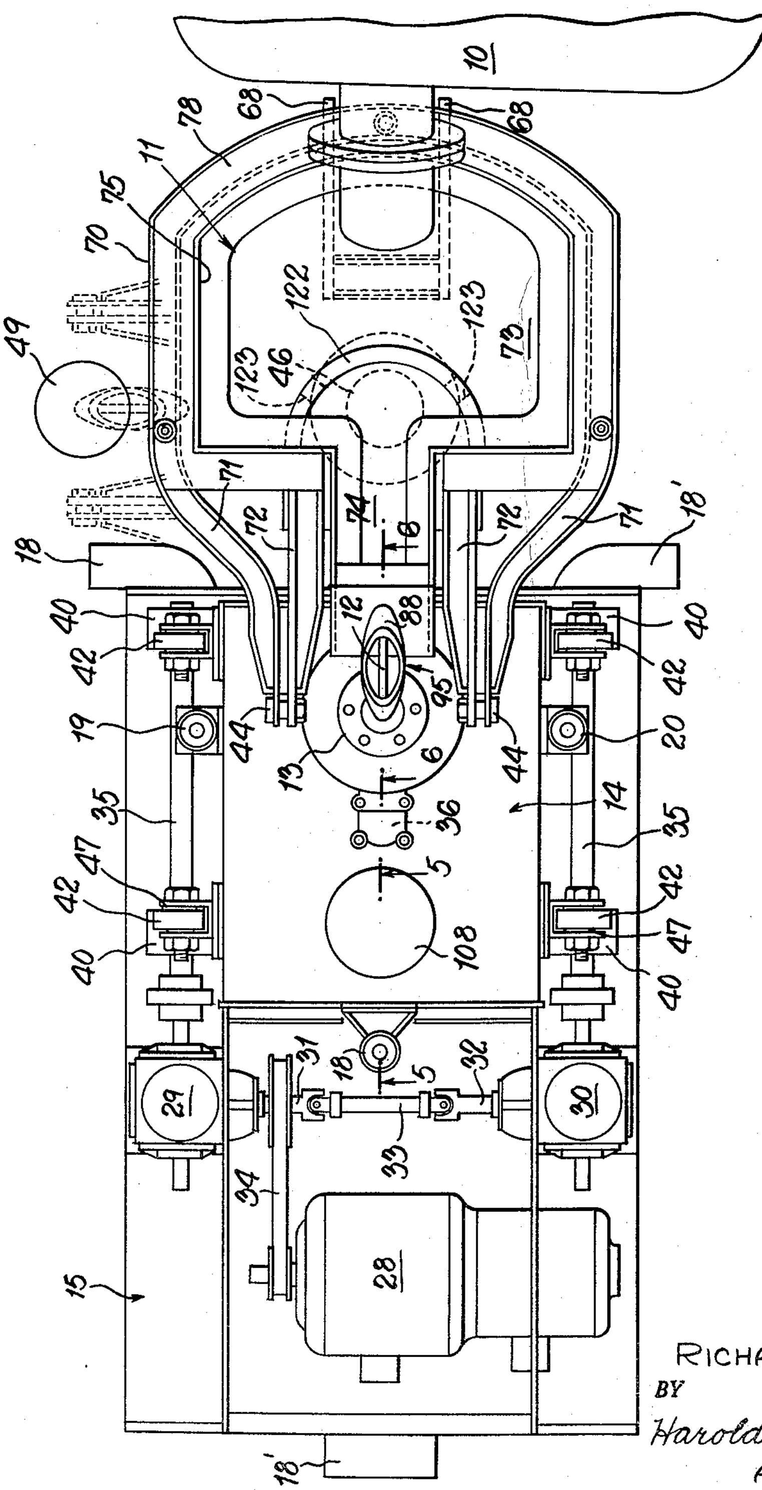

Fig. 2

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Filed Oct. 21, 1959 7 Sheets-Sheet 3

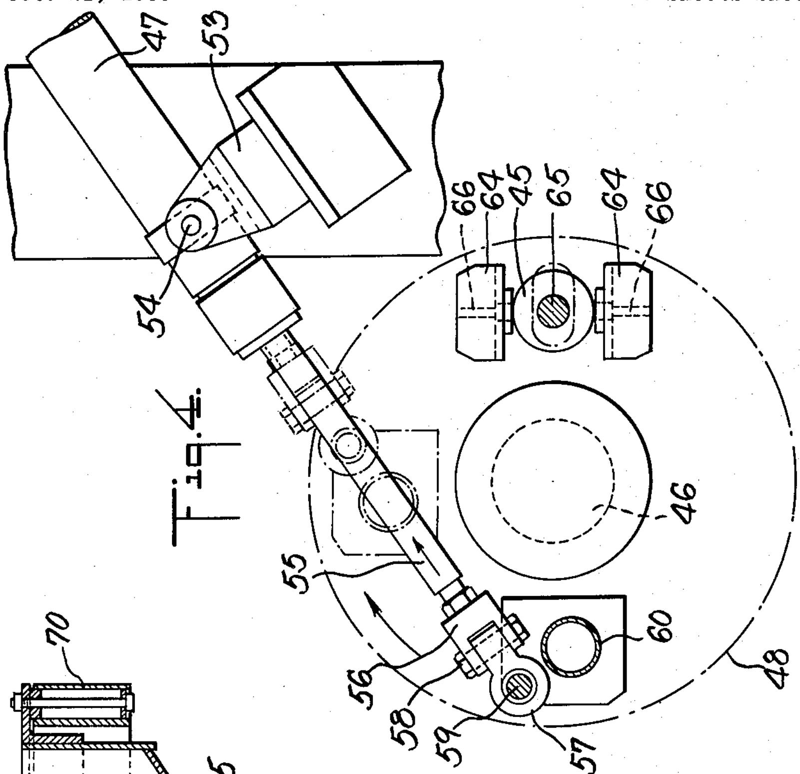

Fig. 4

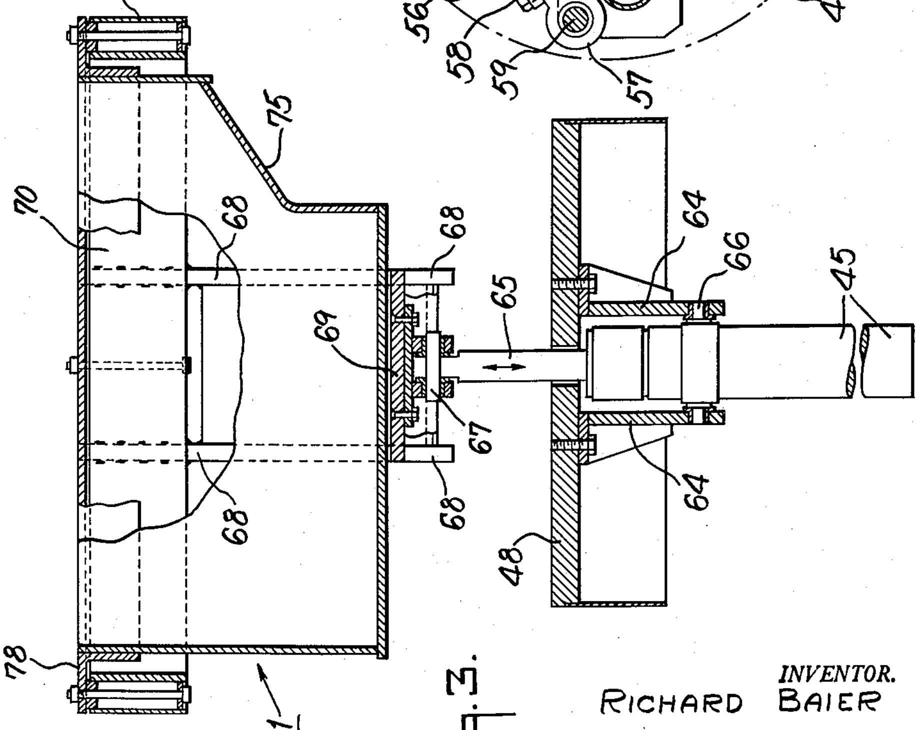

Fig. 3

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POURING MECHANISM FOR CONTINUOUS CASTING

Filed Oct. 21, 1959 7 Sheets-Sheet 4

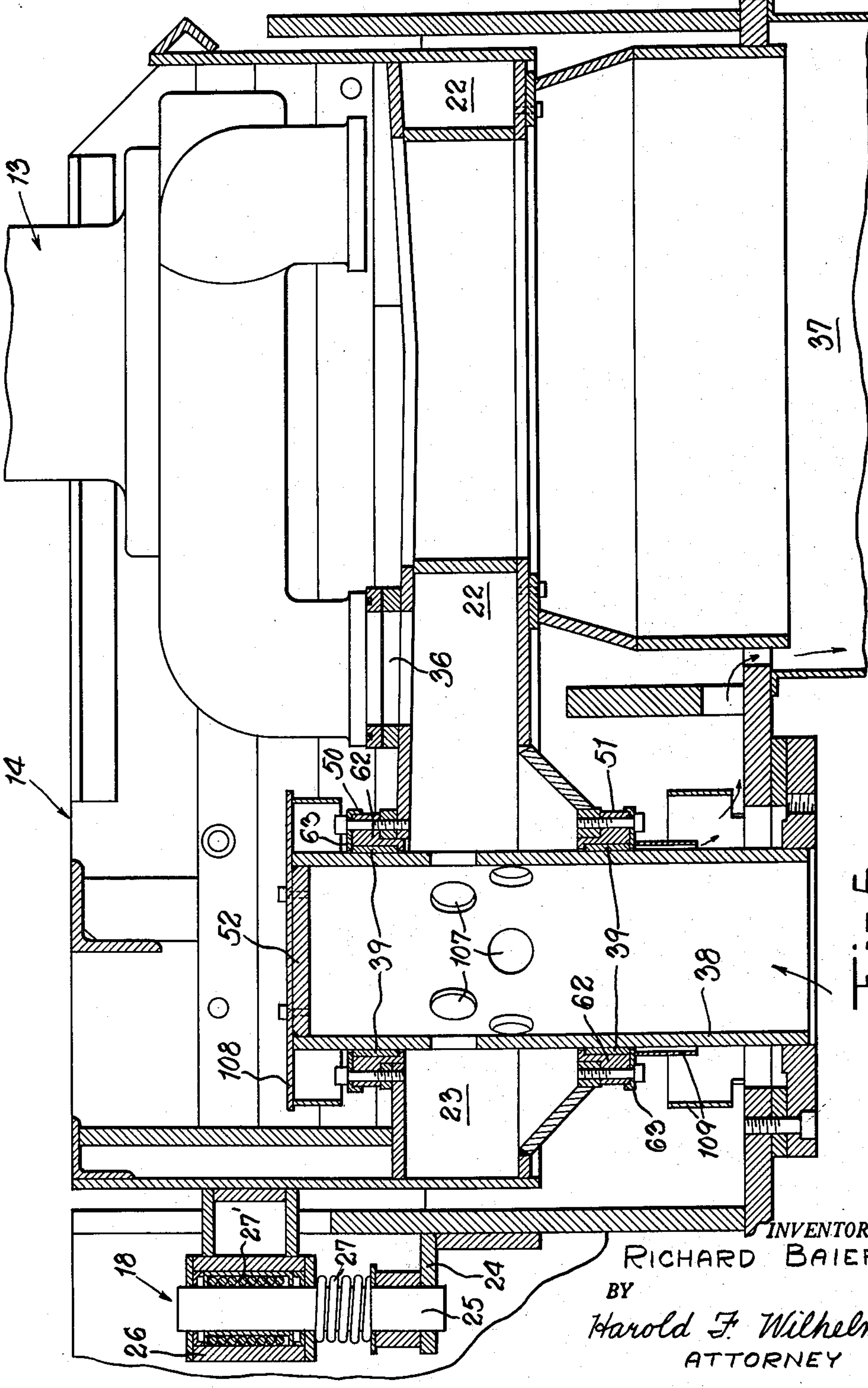

Fig. 5.

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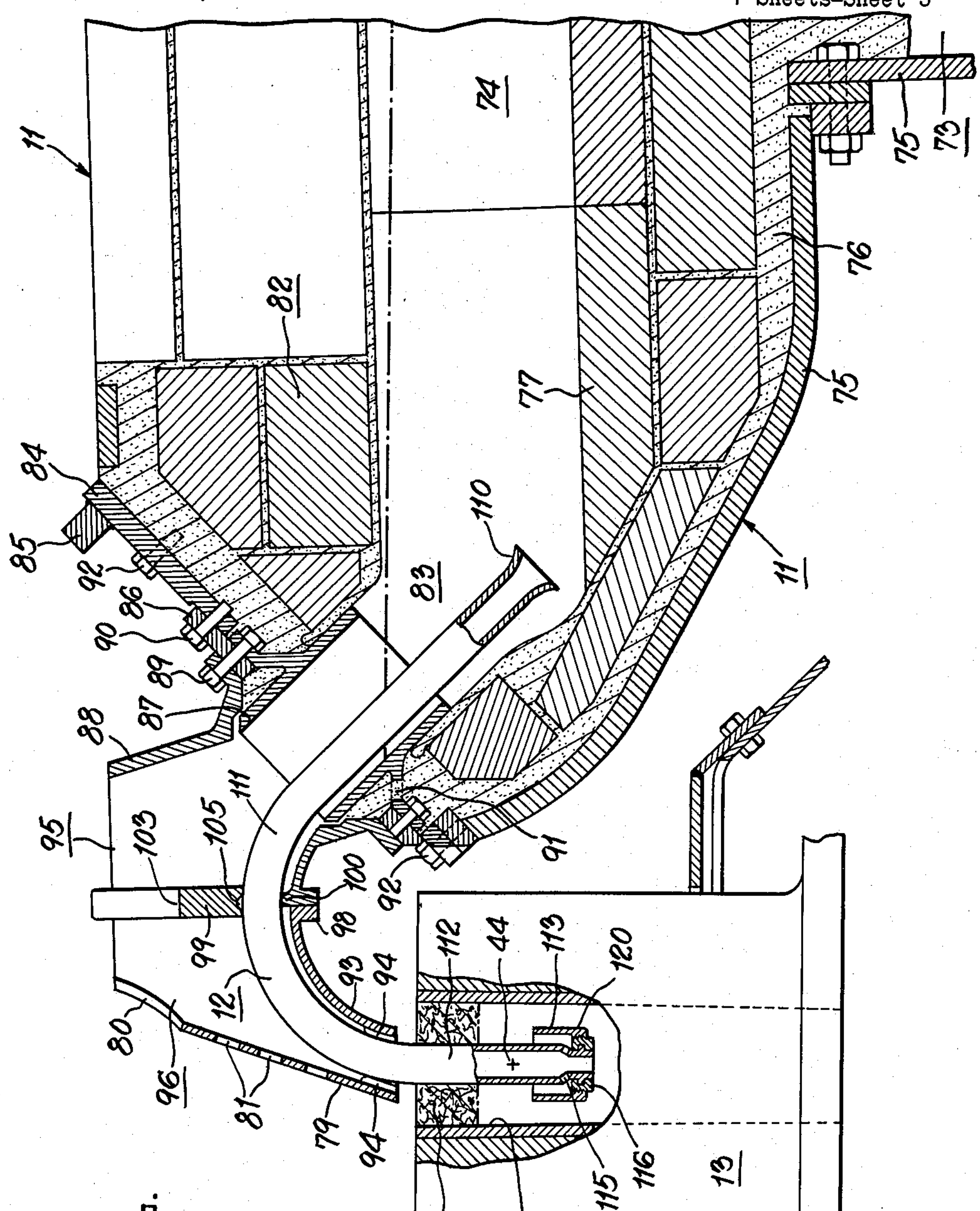

Fig. 6.

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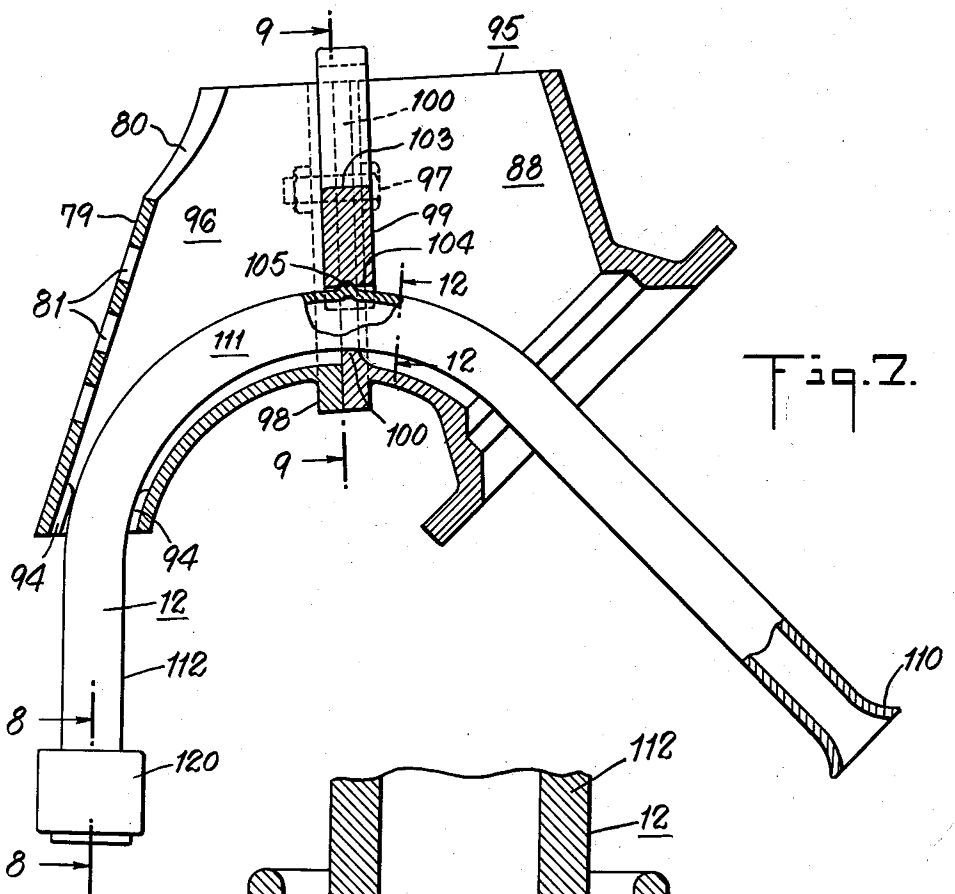

Fig. 7.

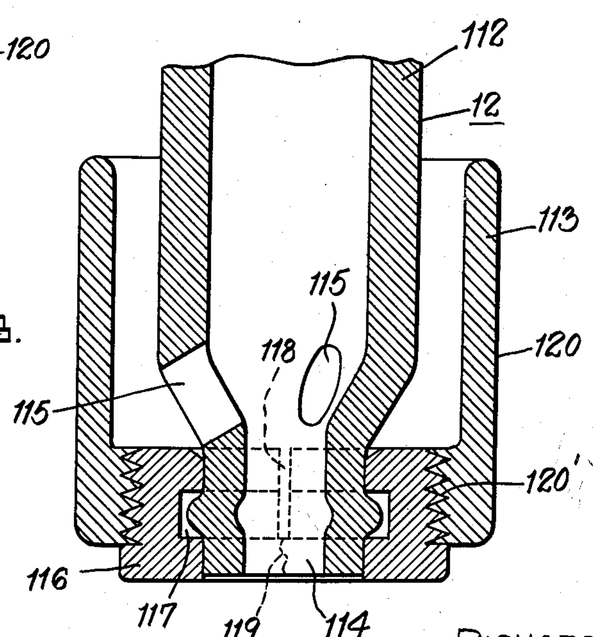

Fig. 8.

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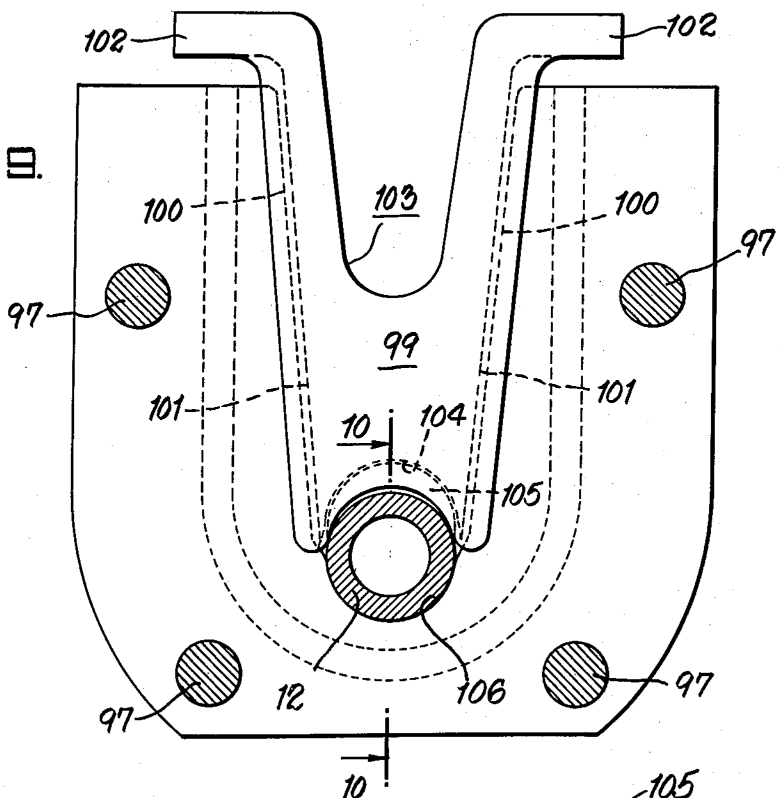
Dec. 31, 1963 R. BAIER 3,115,686

POURING MECHANISM FOR CONTINUOUS CASTING

Filed Oct. 21, 1959 7 Sheets-Sheet 7

Fig. 9.



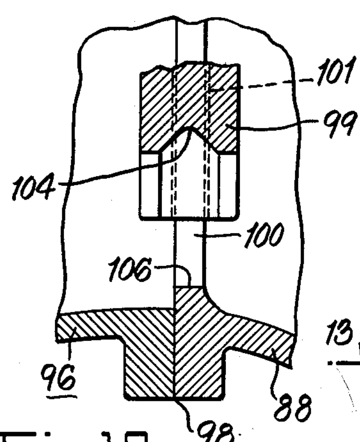


Fig. 10.

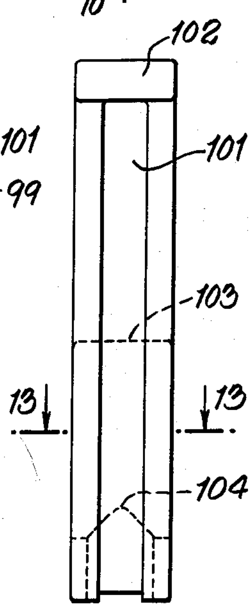


Fig. 11.

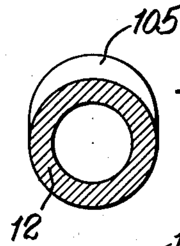


Fig. 12.

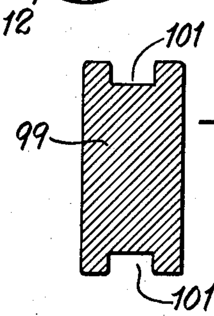


Fig. 13.

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1

3,115,686
POURING MECHANISM FOR CONTINUOUS CASTING

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Filed Oct. 21, 1959, Ser. No. 847,748
15 Claims. (Cl. 22—82)

The invention relates to continuous casting of metals and more particularly to improved pouring mechanism for the continuous casting of copper shapes. This invention constitutes an improvement over the pouring mechanism disclosed in application Serial No. 845,386, filed October 9, 1959, now Patent No. 3,066,364, as a division of application Serial No. 724,114, filed March 26, 1958.

According to a preferred form of the present invention the pouring mechanism comprises a ladle having an enlarged reservoir at the back and a siphon tube at the front. The siphon tube is made of a special material adapted to withstand the wearing effect of hot copper. This material is a metal ceramic comprising a powdered metal, such as chromium, and a ceramic such as aluminum oxide. These substances are slip cast to form the siphon tube, and then sintered to form a composite wear-resistant, brittle refractory tube.

The siphon has a special overflow cup for sealing the discharge tip of the siphon to prevent loss of suction when starting up a pouring operation. In its preferred form the cup comprises a split ring surrounding the reduced end of the siphon tube with a wall member surrounding and threaded to the ring to hold the ring in position.

According to the said preferred form of the invention, a shroud surrounds the siphon to aid in melting out the siphon if the metal should become accidentally frozen therein. The shroud also provides for easy removal of the siphon tube to substitute a new one. The front wall of the ladle is provided with a throat tube to which is attached a shroud entrance casting and a shroud exit casting. The two castings are separable. At the junction of the two castings there is provided a removable dam member which acts to hold the siphon in position and prevents escape of the molten metal during normal pouring operations.

According to the preferred form of the invention, special operating mechanism is provided for handling the ladle. A turntable is supported on a vertical lift cylinder. A swivel cylinder operates to rotate the turntable 90°. The turntable has a depending post, and the piston rod of the swivel cylinder has a sleeve slidable on the post to permit raising the turntable without raising the swivel cylinder. The turntable has arms adapted to be disposed on either side of the mold. The ladle also has arms adapted to be positioned on either side of the mold. Corresponding arms are pivoted together, the pivot axis passing through the vicinity of the discharge tip of the siphon. The turntable has a depending tilting cylinder whose piston rod connects with the ladle to tilt the ladle about the siphon tip pivot axis.

According to the preferred form of the invention, the mold is mounted on a platform which, in turn, is mounted on an adjustable base frame. A special three-point spring

2

ball-bushing support is located between the carriage and the platform. The carriage has motor-driven shafts on either side, carrying eccentrics. Connecting rods connect the eccentrics with the platform to vertically reciprocate the platform and its supported mold.

According to the preferred form of the invention, a special slip joint arrangement connects a stationary supply pipe and the reciprocating mold to supply the latter with the great volume of water at high pressure necessary to extract tremendous quantities of heat from the mold. The platform has an annular duct having three ports feeding the mold. The duct connects with an offset well through which the stationary supply pipe projects. Seals, having bronze bushings having slidable engagement with the supply pipe, are provided in the upper and lower walls of the well.

General objects of the invention are to cast metals, particularly phosphorized copper billets, at higher casting rates; to provide a pouring technique for closely controlling and maintaining the desired pouring rate; to provide reliable equipment for handling the molten metal; to increase the useful life of vital parts; to increase safety by handling great volumes of water at high pressure without coming into contact with molten metal; to provide methods and equipment for continuous casting having one or more of the above-recited features and capable of accomplishing one or more of the aforesaid objects.

Other objects and features of the invention will be more apparent from the following description and claims when considered with the accompanying drawings, in which:

FIG. 1 is an elevation of the new pouring mechanism;

FIG. 2 is a plan view of the new pouring mechanism. Dotted lines indicate the starting position of the ladle;

FIG. 3 is a vertical section, taken on the line 3—3 of FIG. 1, illustrating the ladle shell and the cylinder for tilting the ladle;

FIG. 4 is a horizontal section, taken on the line 4—4 of FIG. 1, illustrating the swivel cylinder for swinging the ladle;

FIG. 5 is a vertical section, taken on the line 5—5 of FIG. 2, illustrating the spring support for the mold platform and the slip joint for feeding water to the reciprocating platform and mold;

FIG. 6 is an elevation, mostly in section, through the front of the ladle and through the siphon, taken on the line 6—6 of FIG. 2;

FIG. 7 is an elevation, partly in section, of just the siphon and shroud;

FIG. 8 is a section, taken on the line 8—8 of FIG. 7, illustrating the construction of the discharge end of the siphon;

FIG. 9 is a transverse section, taken on the line 9—9 of FIG. 7, illustrating the removable dam of the shroud and showing how the dam holds the siphon in place;

FIG. 10 is a fragmentary section through the dam and shroud, with the siphon omitted, taken on the line 10—10 of FIG. 9;

FIG. 11 is an end elevation of the removable dam;

FIG. 12 is a section, on the line 10—10 of FIG. 9, illustrating the protuberance on the arch of the siphon which assists in positioning the siphon in the shroud;

FIG. 13 is a section, taken on the line 13—13 of FIG. 11, illustrating the grooved ways of the dam.

In the accompanying drawings and in the description forming part of the specification certain specific disclosure of the invention is made for purposes of explanation, but it will be understood that the details may be modified in various respects without departure from the broad aspects of the invention.

Referring to the drawings and more particularly to FIGS. 1 and 2, a melting furnace, not shown, supplies holding furnace **10** with the molten metal to be cast. The furnace supplies pouring ladle **11** which, in turn, supplies siphon **12**; the latter supplies mold **13** which is mounted on platform **14** which, in turn, is mounted for vertical reciprocation on carrier **15**.

It will be understood that a suitable starting and lowering mechanism, not shown, is located under the mold **13**. This mechanism includes a starting plug which projects up inside the mold and form the bottom closure of the mold pocket when initiating the pour. As molten metal is fed into the mold, it freezes around the starting plug and the frozen product **16** is pulled downwardly at uniform speed by a conventional roll drive indicated diagrammatically by **17** and forming no part of the present invention. This roll drive may include cut-off mechanism and handling equipment such as disclosed in Betterton and Poland Patent No. 2,291,204, granted July 28, 1942.

Mold Mounting

The carrier **15** comprises a suitable framework supported on the building structure at three points, as indicated by **18'**. The end of the carrier adjacent the ladle has projecting arms and the end of the carrier remote from the furnace has a projecting arm. Associated with these arms are adjustable devices by which the carrier may be adjusted horizontally in two directions so that the mold may be properly aligned with the roll drive **17** which pulls the cast product out of the mold. Vertical adjustment is also provided to properly position the tip or overflow cup **120** of the siphon **12** in the mold **13**, as will be apparent as the description proceeds.

The platform **14** is supported on the carrier **15** by three spring supports **18**, **19**, **20**, as indicated particularly in FIGS. 2 and 5. Since these spring supports are substantially identical, it is only necessary to describe one in detail. In FIG. 5 the adjacent part of the carrier has a bracket **24** which supports a post **25**. The platform has a bracket secured to a sleeve **26**. A helical spring **27** surrounds post **25** between sleeve **26** and bracket **24**. A suitable ball bushing **27'** is interposed between sleeve and post.

The platform **14** and mold **13** are vertically reciprocated by a suitable drive mechanism. The drive comprises an electric motor **28** mounted on the carrier **15**. The motor **28** drives two gear units **29**, **30**, also mounted on the carrier. The gear units have drive shafts **31**, **32** connected by an intermediate shaft **33** and universal joints. A pulley is mounted on shaft **31** which is driven by belt **34** from motor **28**. Each of the gear units **29**, **30** drives a shaft **35**. Since these shafts are of similar construction, only one will be described in detail.

The shaft **35** is journaled in bearings **40** on the carrier. The shaft carries two eccentrics **41**. Each eccentric drives a connecting rod **42**. The connecting rods are connected to bearings **43** supported by brackets on the platform **14**.

It will thus be seen that the motor **28** drives the eccentrics **41** which impart a vertical reciprocating movement to the mold platform. The frequency of reciprocation is determined by the speed of the motor **28** and the amplitude of reciprocation is determined by the throw of the eccentrics **41**. In the form shown the amplitude of reciprocation is about ⅛ inch (3 mm.) and the frequency is about 600 complete cycles per minute when casting a 3-inch diameter circular billet of phosphorized copper at about 55 inches per minute.

The mold pocket wall **21** is especially tapered. It is provided with what may be called for convenience a "forced" taper, to distinguish it from tapers which may be called "natural" tapers. With a forced taper the steepness of taper is so related to linear casting speed that the shrinkage taper on the cast product is forcibly wedged against the taper on the mold pocket so as to plastically deform the red hot tube comprising the crater shell enclosing the liquid core.

The forced taper operation, in a sense, is similar to wire-drawing. It requires the establishment of a crater shell with a long and deep V, with a strong but plastic shell wall surrounding a soft liquid center, a combination that is readily deformed by pulling it through the tapered mold.

A natural taper may be defined as that taper which corresponds to the shrinkage pattern of the congealing casting at any particular casting speed, that is to say, the casting will move through the mold without any external force applied. A forced taper is steeper (i.e. at a larger angle to vertical) than a natural taper for the same linear casting speed and requires a positive pull on the cast product to pull it from the mold. It should be noted that a taper which is a natural taper for any given casting speed and rate of heat extraction becomes a forced taper if that casting speed is increased.

The ball bushings **18–20** hold the mold pocket **21** in register with the pulling rolls **17** and provide smooth vertical movement. The springs **27** counterbalance the weight of the platform and mold.

When the eccentrics **41** are moving the mold **13** upwardly, they must overcome the downward pull exerted by the pulling rolls **17** against the forced taper. The frequency of reciprocation is so related to normal billet speed that the maximum downward speed of the mold, in executing its simple harmonic motion, is greater than the normal billet speed. When the eccentrics are moving the mold downwardly, they must overcome the force necessary to disengage the tapered mold wall from the taper being formed on the billet.

Referring to FIG. 5, the slip joints for supplying the reciprocating mold with water from a stationary pipe will be described. The platform **14** has an annular duct **22** connecting with a well **23**. The annular duct has three equi-spaced ports **36** communicating with three inlet ports on the mold **13**. The mold is supplied with cooling water through these ports, the water being discharged from the mold into the space **37**.

A stationary pipe **38** is mounted on carrier **15**. This pipe passes through seals **50**, **51** in the upper and lower walls of the well **23**. Each seal comprises a bronze bushing **39** having slidable contact with the stainless steel pipe **38**. The bronze bushing **39** is held in place between a flange on a bearing ring **62** and a cap plate **63**. Bolts hold the bearing assembled and to the frame of the carrier.

The upper end of the pipe **38** is closed by wall **52**. Holes **107** connect the inside of pipe and well **23**. An upper anti-spatter shield **108** confines water leaking through the upper seal. Lower anti-spatter shields **109** confine water leaking through lower seal **51**. The leak water flowing to discharge is indicated by the arrows.

These seals handle expeditiously the large volume of water at high pressure used to extract tremendous quantities of heat from the mold. For example, in one installation for continuously casting a 3-inch diameter phosphorized copper billet at a rate of about 55 inches per minute, about 700 gallons of water per minute at about 180 pounds per square inch pressure was applied to pipe **38**. The water lubricates the bronze bushings, the end pressures are canceled, there are no thrusts in any direction. The small leaks through the seals are easily handled by the shields to keep water away from the molten metal.

Ladle Operating Mechanism

The mechanism for operating the ladle **11** will first be briefly described. The ladle is so mounted that it may be moved in several directions for accomplishing the pouring operation. The ladle may be tilted by tilting cylinder 45 about the axis 44 which is approximately in line with the tip of the siphon 12. The ladle 11 may be raised and lowered bodily by lift cylinder 46 without tilting. The ladle may be swivelled horizontally by swing cylinder 47 about the vertical axis of lift cylinder 46. The ladle swings between a point where the siphon tip is in register with the mold 13 to the point shown in dotted lines in FIG. 2, where the ladle may discharge into a waste pot 49, as described hereinafter.

The ladle is mounted on a turntable 48 which, in turn, is mounted on the piston of lift cylinder 46. This cylinder is suitably supported and braced on a structural part of the building. The lift cylinder 46 raises and lowers the turntable 48 and permits the turntable to swivel about the axis of the cylinder.

The swivel cylinder 47 (see also FIG. 4) is pivoted to a clevis 53 mounted on a suitable structural part of the building. The clevis 53 has parts located both above and below the cylinder. Suitable trunnions 54 connect the clevis 53 and a ring surrounding the swivel cylinder. The swivel cylinder has a piston rod 55 which carries a clevis 56 at its free end. The clevis 56 is pivoted to a slide sleeve 57 by a pivot bolt 58. Sleeve 57 is slidably mounted on a shaft 59 depending from the turntable 48. The lower end of shaft 59 is supported by a depending bracket 60. The slide sleeve 57 has ball bushings 61 at either end which have sliding contact with the vertical shaft 59.

The swivel cylinder 47 is double-acting in that its piston rod 55 can be operated in either direction. In FIG. 4 the swivel cylinder 47 is shown in its fully extended position, in which position the siphon tube is in register with the mold 13. When the swivel cylinder is operated to retract its piston rod, the turntable 48 is swung 90° to place the siphon tip over the slag pot 49 in the position shown in FIG. 2.

It will be noted that the axes of swivel bolt 58 and slide sleeve 57 are perpendicular and thus this connection acts as a universal joint to insure ease of operation, regardless of any slight mis-alignment of connecting parts. It will be understood that the swivel cylinder 47 operates in a fixed horizontal plane and that the slidable connection between vertical shaft 59 and slide sleeve 57 permits the lift cylinder 46 to raise and lower the turntable 48 without imparting vertical movement to the swivel cylinder 47 and connected parts.

Referring now also to FIG. 3, the tilting cylinder 45 is pivoted by trunnions 66 between hangers 64 supported by turntable 48. Its piston rod 65 has pivot connection 67 with the bottom plate 69, as explained below. Tilting cylinder 45 is double-acting to permit upward and downward tilt of the ladle 11.

Ladle

The ladle assembly comprises a banjo-shaped support or cradle 70 having outer arms 71. The turntable 48 has inner arms 72. The pivot shafts 44 connect the respective arms as shown. The axis of aligned pivot shafts 44 passes through the vicinity of the tip of the siphon tube 12, as shown in FIG. 6. When the ladle 11 is in normal running position, the turntable 48 is in its lowermost position (as shown in FIG. 1), the pivot shafts 44 are located on either side of the mold 13 (as shown in FIG. 2), and the tip of the siphon 12 is located in proper position in the mold cavity (as shown in FIG. 6).

The ladle 11 has a reservoir comprising a wider portion or bowl 73 at the back and a narrower trough or spout 74 at the front. The ladle, referring also to FIGS. 3 and 6, comprises a steel body shell 75 lined with suitable insulation 76 and refractory 77. The ladle shell 75 has a rim 78 resting on the cradle 70 and is suitably bolted thereto. The brackets 68 connect the back of the banjo frame 70 and the bottom plate 69.

As shown in FIG. 6, the ladle 11 is provided with a front wall 82 having a throat opening 83 through which the siphon tube 12 passes. The front wall of the ladle has a rectangular main front plate 84 having a top bar 85 suitably welded thereto; this plate is bolted to the ladle shell 75 by bolts 92.

The front wall 82 also has an adapter plate 86, a flanged throat tube 87 and an entrance casting 88; these members are bolted together by bolts 89. The adapter plate 86 is bolted to main plate 84 by bolts 90. The flange of the throat tube 87 has openings 91 for the lodging of cement.

For melting out a frozen siphon tube, a shroud 95 is provided. The shroud comprises the entrance casting 88 and an exit casting 96, see FIG. 7. These castings are connected by a flange coupling 98 through which bolts 97 pass.

A removable dam or plate 99 is located at the flange coupling 98 and engages the siphon tube 12 to removably hold it in place. The entrance casting 88 has internal upright flanges 100 providing sliding ways. The dam has upright grooves 101 in its ends engaging flanges 100. The removable dam has top wings 102 and an overflow notch 103; it also has a grooved curved seat 104 engaging a top protuberance 105 on the siphon tube. The entrance casting 88 has a curved seat 106 in which the arch of the siphon tube rests.

The exit casting 96 has a front wall 79 provided with a top notch 80. Below the top notch are a series of holes 81. The exit casting has a depending tubular portion 93 having spaced inner ribs 94 for centering the vertical part of the siphon tube. The siphon tube 12 has a flared inclined inlet portion 110, a top arch portion 111 supporting protuberance 105 and a depending vertical portion 112 having an overflow cup 120.

Referring more particularly to FIG. 8, the lower end of the siphon tube 12 has a reduced neck having a lower opening 114; the siphon tube also has three lateral upper openings 115 connecting with cup 120.

The overflow cup 120 comprises a cup member 113 having threaded engagement 120′ with a split ring 116. The split ring has an annular internal groove 117 engaging an annular bead on the end of the siphon tube. The split ring 116 has a diametral fabricated slot 118 and also a diametral broken edge indicated by line 119.

It will be understood that the split ring 116 is made in the form shown with the fabricated slot 118 formed therein but connected at the line 119; this is for convenience of manufacture and shipping. To apply the ring to the siphon, it is split to break along the line 119, as indicated. The halves can then be applied around the annular bead on the siphon tube. The two halves of the ring are held in position by the cup member 113 being threaded thereon.

The parts of the shroud 95 are preferably made of stainless steel. The siphon tube 12 is preferably made of the type of metal-ceramic discussed below. The split ring 116 and overflow cup member 113 are preferably made of steatite, as discussed below. These parts, when made of these materials, are highly resistant to the wearing action of phosphorized copper, but they are vulnerable to heat shock due to alternate heating and cooling. Consequently, even with these special materials, it is usually necessary to replace the split ring and cup member at the beginning of every start-up after a continuous casting operation has been shut down; and to replace the siphon tube sometimes as often as every three start-ups, although somewhat less frequently on the average. Consequently, it is important to be able to remove the siphon tube readily and to replace the split ring and cup member readily.

To replace a siphon tube, it is only necessary to lift out the removable dam 99 and unbolt the exit shroud casting 96 by removing the bolts 97 at the flange coupling 98. The siphon tube and exit casting can then be easily lifted out of the ladle. The cup member and split ring are then removed. The siphon tube can then be separated from the exit casting. Merely to replace the split ring and cup member it is not necessary to remove the siphon tube from the ladle.

The shroud 95 and siphon tube 12 are assembled cold. Both shroud and tube are heated to high temperature by blow torches prior to a start-up. During continuous casting the siphon remains at elevated temperature but the shroud drops to a somewhat lower temperature. The shroud 95 and siphon tube 12 have different rates of expansion with temperature change and both expand and warp in use; hence the siphon tube must be supported in such manner as not to subject it to cracking strains in use. The support of the arch by the opposed seats 104, 106 at the dam is made liquid-metal-tight by addition of asbestos cement or the like; this support prevents displacement of the tube both lengthwise and transversely of itself. The support by the ribs 94 at the front of the shroud prevents any tendency of the tube to rotate about the axis of opposed seats 104, 106. Yet these supports (even if the fits are snug) permit both shroud and tube to change length and warp under temperature changes independently of each other without breaking the brittle siphon tube. Actually the fits at these supports are deliberately made slightly loose, so as to give the siphon and shroud maximum freedom to lengthen and warp, while holding the tube in correct operative position.

The siphon tube 12 is made from a material which will withstand the erosive action of phosphorized copper and oxides of copper at high temperatures. Certain powdered metals, such as chromium, suitably molded or pressed into shape and then sintered, may be used. Metals or other materials which have protective coatings of, for example, chromium oxide, may also be used.

A material which has performed satisfactorily is a metal-ceramic comprising powdered chromium and aluminum oxide. A particular composition which has given satisfactory service comprises, by weight, 77% metallic chromium and 23% aluminum oxide (Al_2O_3). These materials may be made by the well-known slip casting process and then sintered.

The exact composition varies within wide limits. In general there should be sufficient aluminum oxide to inhibit grain growth of the chromium. For example, a composition comprising from 50 to 95% of chromium metal by weight, with the balance aluminum oxide will give satisfactory results for siphoning copper.

Under oxidizing conditions the chromium metal in the metal-ceramic mixture forms a surface layer of chromium oxide which is tightly bonded to the metal phase and serves to protect it from further oxidation. Siphon tubes made from these ceramic materials are both brittle and refractory.

The metal-ceramic is greatly superior to stainless steel as a material for the siphon tube. Copper reacts with stainless steel, resulting in compounds which erode the surface, or build up on the surface and scale off and plug up the siphon.

The cup 120 is made from a steatite variety of talc. Steatite occurs in nature in dense formation and is characterized by its softness. One form of steatite is a hydrated magnesium silicate. It is machined to shape and then fired, resulting in a hard refractory material.

Suitable provision is made for adjusting the ladle 11 so as to accurately align the siphon tip or cup 120 with the center of the mold pocket 21. It will be understood that accurate positioning of the siphon tip in the mold in a horizontal plane is necessary. The crater of the congealing casting is relatively deep and the embryo crater shell closely surrounds the overflow cup 120. Any substantial off center position of the overflow cup adversely affects the distribution of metal delivered by the siphon and the symmetry of the embryo crater shell. Indeed, if the overflow cup is too much off center, it may actually freeze into the congealing crater shell.

The centering adjustments of the overflow cup 120 with respect to the mold pocket 21 are as follows. The adjustment lengthwise of the ladle, that is, in a horizontal direction perpendicular to the axis of pivots 44, is attained by sliding the rim 78 of the ladle 11 on its cradle 70. Suitable provision, not shown, is made for this adjustment after which the ladle 11 may be bolted to its cradle 70 by the bolts indicated in FIG. 3.

The adjustment of the overflow cup 120 with respect to the mold pocket 21 transversely of the ladle, that is, in a direction tangential to the arc of swing of the cup around the axis of lift cylinder 46, is obtained by the adjusting clevis 56 (FIG. 4) on piston rod 55 when the swing cylinder 47 has operated the turntable 48 to its furthermost extended position, as shown in FIGS. 2 and 4.

The looseness of the mounting of the brittle siphon tube 12 in the shroud 95 must be commensurate with the leeway permitted in the accuracy of centering of overflow cup 120 in the mold pocket. The looseness of this mounting must be sufficiently small that, together with changes in dimension due to expansion of shroud and siphon, the swing cylinder 47 will not position the overflow cup 120 further off center from the mold axis than can be tolerated by good casting practice.

Referring to FIGS. 1 and 2, a curved dam 122 is set into the refractory ladle lining 77 to prevent a direct wash of metal from the furnace spout 10 into front trough 74 and into the flared end 110 of the siphon tube. The dam 122 is convex toward the wider end of the ladle into which the metal stream falls. The dam has a hole 123 at each side near the bottom of the lining and the dam extends above the highest liquid level.

Thus, the metal stream entering the ladle 11 is forced to take a tortuous path through the dam openings 123 to the siphon 12. In the absence of such tortuous path non-uniform temperatures and non-uniform quality can result. By the use of the dam the metal flow from the holding furnace 10 is confined to the ladle bowl 73 and causes a thorough intermixing of the newly entering metal with the metal already in the bowl. This provides for uniform temperature and metal quality by the time the flow passes to the siphon through the two offset holes 123 at the floor of the ladle. These holes are submerged at all times and the top of the dam performs the usual skimming action on the surface of the molten metal.

The dam 122 therefore performs a two-fold purpose: it skims as any submerged skim plate and insures thorough intermixing of metal already in the bowl and metal flowing into the bowl from the holding furnace 10. This results in metal which is clean and of uniform temperature and quality delivered to the siphon.

Operation

For convenience of explanation, the opening in the reduced end of the siphon will sometimes be refererd to as lower orifice 114 and the overflow opening from cup 120 will sometimes be referred to as upper orifice 120.

One procedure for starting the pouring operation will be, first, only briefly described after which the starting will be described more in detail. The siphon 12 must be first primed; an excess flow rate is required for priming. Before delivering metal to the mold 13 the priming flow is reduced to a volume more suitable for starting the casting operation. Then the siphon cup 120 is registered over the mold 13 and lowered into the mold. When the mold fills and the metal covers the cup, the operator starts downward movement of the starting plug at reduced starting speed. The reducing priming flow rate automatically decreases, when the cup becomes submerged, to a rate corresponding to the downward movement of the starting plug. The operator then increases the speed of the starting plug to full running speed and at the same time raises the liquid level in the ladle to provide sufficient head to deliver metal at the increased rate.

The starting procedure will now be described more in detail. Because of the small volume of a three inch billet mold and because it is desired to employ a high casting rate, special precautions must be taken both in starting up and in maintaining normal running conditions.

As stated, the casting operation is first started at a reduced pre-set rate after which the casting rate is increased to normal running speed. In commercial operation, successful casts are being made at normal running speeds of about 124 pounds per minute; this is equivalent to a linear billet casting speed of about 55 inches per minute in a three inch billet mold. A suitable reduced pre-set starting rate is about 45 pounds per minute, which is equivalent to a linear billet casting speed of about 20 inches per minute.

As the first step in the starting procedure, the entire siphon and open top shroud is preheated by a heating torch to bright red heat approaching the melting point of copper to prevent accidental freeze-up. It will be understood that, in order to prime the siphon and establish stable flow conditions, as much as several hundred pounds of molten copper may be run into a separate container; priming is therefore done with the ladle 11 pushed around to the position shown in dot and dash lines in FIG. 2, where siphon 12 can discharge into slag pot 49. This constitutes one extreme position of swing cylinder 47. The other extreme position is when overflow cup 120 registers with the pocket of mold 13.

To prime the siphon, the holding furnace 10 is tipped and metal is poured into the ladle 11. When the ladle is nearly full of copper, it is tilted forward, causing the molten metal to flow toward the siphon 12. The ladle is tilted enough to bring the molten metal level higher than the highest part of the arched siphon tube 111, the dam 99 serving to retain the molten metal. This supplies a hydrostatic head to the siphon tube and produces a copious metal flow through lower orifice 114 and upper orifice 120.

After the spihon has been primed, the ladle is tilted backward to reduce the priming flow to a rate suitable for starting; this will be greater than the above-mentioned pre-set reduced starting rate. A free flowing pouring rate of about 60 pounds per minute has proven satisfactory. This rate can be checked visually very easily; when the flow from the top orifice 120 is reduced to an intermittent, or very small, trickle (while full flow from the bottom orifice 114 is continued), proper pouring rate is indicated.

Having adjusted the ladle to discharge at the free pouring rate of 60 pounds per minute, the ladle 11 is then raised if necessary to clear the mold 13 (but without substantially changing the angle of tilt). Then, with metal still flowing, the siphon 12 is swung about the vertical axis of lift cylinder 46 from over slag pot 49 to register over mold 13. The cup 120 is then rapidly lowered into the mold cavity (again without substantially changing the angle of tilt) until the turntable 48 reaches its lowermost point. This places the siphon cup 120 at proper level in the mold, as shown in FIG. 6.

With the above-mentioned free pouring rate of 60 pounds per minute, a period of about 10 to 12 seconds is about all the time that can be allowed, after registration of the siphon cup 120 with the mold cavity, in which to lower the siphon 12 into the mold and to start downward movement of the starting plug, without overfilling the three-inch billet mold.

As soon as siphon cup is in line with the mold 13, the mold starts filling with molten metal; and when the level in the mold reaches normal level of about 1½ inches below the top of the mold (above the top of siphon cup 120), the operator starts the lowering mechanism to withdraw the starting plug at the pre-set starting rate of 20 inches (45 pounds) per minute.

With the ladle tilt angle adjusted to give a free pouring rate of 60 pounds per minute, the construction is such that, with the ladle originally filled to the proper level, the level of molten metal in the ladle 11 will be automatically located no higher than about one-half inch below the top of the mold 13 when the turntable 48 reaches lowermost position.

This constitutes a safety device since, if the starting plug is not lowered out of the mold soon enough, the molten metal in the mold can rise only to the same level as the level in the ladle (which is about one-half inch below the top of the mold) and thus cannot overflow the mold.

When the molten metal level in the mold rises to above the top of siphon cup 120, the rate of flow through the siphon automatically decreases to a rate corresponding to the rate at which the starting plug is withdrawn. The flow rate being proportional to the square root of the difference in head, the metal level in the mold will rise until the difference in head corresponds to the withdrawal rate of the starting plug.

The operator may continue pouring and withdrawing at the pre-set reduced starting rate of 20 inches (45 pounds) per minute until he is sure everything is in order. When the operator is ready, he then tilts the ladle 11 forward, or adds metal to the ladle from the holding furnace 10, to raise the molten metal level in the ladle above the top of the mold so as to increase the pouring rate to the normal running rate of 124 pounds per minute. At the same time that the operator increases the pouring rate to 124 pounds per minute, he increases the downward velocity of the starting plug to the corresponding casting speed of 55 inches per minute. The metal level in the mold then reaches equilibrium about 1½ inches below the top of the mold.

In the following discussion, it will be understood that by effective area is meant the area which controls the rate of flow through the several parts of the siphon, namely, the siphon tube 12, the lower discharge orifice 114 and the overflow orifice 120.

The effective area of the bottom orifice 114 is governed by the flow rate desired by the operator for the particular mold and the desired starting conditions. There is a definite relationship between the effective areas of the bottom orifice 114 and of the cross section of the siphon tube 12 in order to build up sufficient velocity head in the cup 120 to keep the level of molten metal in the cup above the end of the siphon tube during priming. The combined effective area of the overflow orifice 120 and bottom orifice 114 is greater than the effective cross sectional area of the siphon tube 12, so that maximum flow and velocity are obtained in the tube 12 in order to flush out gases. If the lower orifice 114 is too small, during the time when the metal is only trickling from the top orifice 120, the velocity through the siphon tube will be too low, allowing gas separation at the top of the arch of the siphon tube and loss of siphoning action or possible freezing of the metal in the siphon tube.

For example, in a siphon for feeding a three inch billet mold, it is necessary to limit the size of the bottom orifice 114 to no greater than 80% of the effective area of the siphon tube 12. The best operating ratio was found to be between 30% and 60%. The effective area of the overflow orifice 120 should be no less than 50% of the effective siphon tube area, but no critical relation exists here since the main function of the ports 115 is to assist in obtaining easy priming by rapidly flushing the trapped gases from the siphon tube. It therefore follows that the sum of the effective areas of the lower orifice 114 and of the overflow orifice 120 should be nearly equal to (not less than 80%), or preferably greater than, the effective area of the siphon tube 12.

It will be understood that, if the lower discharge orifice 114 is too small, the flow through the siphon will not be fast enough to flush entrapped gases from the siphon tube. The cross section of the siphon tube at the top of its arch must be small enough to cause the velocity at this point to be sufficiently high to prevent entrapped gases from remaining. On the other hand, there must be sufficient flow through the overflow orifice 120 to seal the end of the siphon conduit, particularly when the molten metal does not wet the siphon conduit.

It is important too that the area of bottom orifice 114 be accurately maintained; it has been found that the metal ceramic used withstands the wearing action of hot molten copper very well so that the starting flow rate, when once established at the desired value, can be reliably maintained.

With high linear billet withdrawal rates of the order of three feet to five feet and higher per minute, very accurate pouring control and withdrawal control is necessary.

For uniform mold casting conditions, the free metal level in the mold should be held to less than plus or minus one inch (preferably within plus or minus one-half inch) from normal level; normal level is about 1½ inches below the top of the mold.

Furthermore, to prevent inclusion of the carbonaceous mold cover 121 in the surface of the casting, the metal level must be kept above the top of the siphon cup 120; also, the metal level must not change too rapidly or else the carbonaceous cover adhering to the mold wall (on top of the metal surface at the meniscus) will be cast into the surface of the molten metal if it rises rapidly. A slow rate of rise is apparently not harmful since the reciprocation of the mold works any excess of carbonaceous cover away from the meniscus if given a finite time of about 30 seconds.

To obtain accurate pouring control, the ladle body 11 has a horizontal area many times the cross sectional area of the mold cavity. For example, in commercial operations, the ladle body has a horizontal area of well over 300 square inches as compared with the cross sectional area of the three inch billet mold which is about seven square inches. This represents a ratio of over forty to one. This means that each one inch of metal depth in the ladle contains over 100 pounds of metal, in contrast to about 2¼ pounds for each one inch of metal depth in the mold.

It will be apparent that any given variation in pouring rate from furnace 10 into the ladle 11 will cause a much less change in level than the same variation would cause if applied directly to the billet mold. This follows because the ladle acts as a large area reservoir which can absorb relatively large variations in supply without materially affecting molten metal level.

As shown above, there is no problem in accurately controlling the liquid level in the ladle 11. Thus, with liquid level in the ladle and the billet withdrawal speed both maintained approximately constant, the liquid level in the mold must stay within the permissible limits. The pouring and withdrawal apparatus has a built-in automatic correction device in that, if the liquid level in the mold rises, the liquid head automatically decreases, thus decreasing metal flow; on the other hand, if the liquid level in the mold drops, the liquid head automatically increases, thus increasing metal flow.

The operation of the shroud in case of a freeze-up will now be described.

The function of the shroud 95 and overflow notch 80 and holes 81 is to remelt a frozen siphon tube 12. Due to error in preheating causing freeze-up, or in event of a foreign body becoming lodged in the siphon tube, the flow of copper during priming may cease before full metal flow can be established. If this condition occurs, the ladle is tilted to an elevation permitting molten metal to flow over the dam 99 and around the siphon tube.

Freezing can also occur between the shroud 95 and the tube 12, and progressive melting is required to remelt this metal. This is accomplished by allowing the molten metal to overflow the front wall of the shroud 95 and flow, in succession, from the openings 80 and 81 in the front of the shroud. The frozen metal is quite rapidly remelted and in a few minutes any frozen area in the siphon tube becomes remelted and flow conditions are established.

I briefly discuss some of the difficulties overcome by the overflow cup 120 as shown in tests. To prevent freezing of the initial metal it is necessary to establish a high flow rate through the siphon for priming and starting. Upon reducing the flow rate to a more desirable stream velocity, without the cup the heavy liquid copper would run down one side of the open-ended siphon tube and allow air to enter the opposite side of the tube, breaking the siphoning action. The cup prevents this loss of siphoning action.

After the siphon tip is once submerged in the molten metal in the mold and kept there, a steady and controlled flow is easily maintained even without a cup. Under these casting conditions the cup then serves the additional purpose of distributing the metal through both its upper and lower orifices. It is important to balance this distribution because a disadvantageously long V crater is created when all of the hot metal is delivered downwardly at the center.

While certain novel features of the invention have been disclosed herein, and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. In a device for pouring molten metal, a ladle having a reservoir to receive metal, a siphon having an inlet communicating with said reservoir and a discharge end projecting from said ladle, a shroud surrounding said siphon in position to receive molten metal from said reservoir when said ladle is sufficiently tilted, to melt out a frozen siphon, a dam separating the back and forward portions of the shroud to permit a hydrostatic head of metal to be built up in back of the dam for priming the siphon, said shroud comprising separable sections, said shroud having a seat in which the arch of the siphon tube rests, said dam having a seat fitting the top of said arch, said dam being removable and said sections being separable to permit easy removal of the siphon tube from said ladle.

2. In a device for pouring molten metal, a ladle having a front opening, a siphon tube having an arched intermediate portion and passing through said opening, a shroud surrounding said tube and comprising an entrance section and an exit section, means detachably connecting said sections, means connecting said entrance section to said ladle, said shroud having a curved lower seat for said tube and having upstanding ways, a dam having upstanding ways slidably engaging said shroud ways, the bottom of said dam having a curved seat complementary with said lower seat to surround said tube, said dam seat having a groove running lengthwise of the curvature of said dam seat, said tube having a protuberance seatable in said groove, said exit section having a front wall, a forward portion entirely surrounding said tube, said forward portion having spaced inner projections to center said tube.

3. In a device for pouring molten metal, a ladle having a front wall, said front wall having an opening, a throat tube in said opening, a siphon tube passing through said throat tube, a shroud surrounding said siphon tube and comprising an entrance section and an exit section, means detachably connecting said sections, means connecting said entrance section to said throat tube, said entrance section having a lower seat for said siphon tube and having upstanding ways, a dam having upstanding ways slidably engaging said first ways, the bottom of said dam having a curved seat complementary with said lower seat to surround said siphon tube, said dam seat having a groove in its face, said siphon tube having a protuberance seatable in said dam groove, said exit section having a front wall and a forward portion

entirely surrounding said tube, said front wall and forward portion having an upright line of openings, said forward portion having spaced inner projections to center said siphon tube.

4. In a device for pouring molten metal, a siphon having a depending conduit, a split collar surrounding the end of said conduit, a sleeve surrounding said collar, said conduit having openings connecting the interior of the conduit and the inside of said sleeve, abutment means interlocking said collar and conduit, and abutment means interlocking said collar and sleeve, said collar and sleeve forming an overflow cup.

5. In the device of claim 4, said first-mentioned abutment means comprising a bead on said conduit and a recess on said collar, said second-mentioned abutment means comprising screw threads.

6. In a system for casting, a mold, a reservoir to receive molten metal and to deliver it to said mold, a turntable supporting said reservoir, a lift cylinder under said turntable and resting on a stationary support, a piston in said cylinder and attached to said turntable, swing mechanism comprising a horizontal swivel cylinder, pivot means connecting said swivel cylinder and support, a post depending from said turntable, a slide sleeve on said post, said swivel cylinder having a piston rod, pivot means connecting said rod and slide sleeve, whereby said swing mechanism may rotate the turntable about the axis of said lift cylinder at any elevation of said turntable.

7. In the system of claim 6, the axis of said last-mentioned pivot means being perpendicular to said post.

8. In a system for casting, a mold having a vertical axis and an open top, a ladle having a reservoir to receive molten metal and deliver it to said mold, a turntable, brackets projecting from said turntable for disposition on opposite sides of said mold, a cradle having arms projecting alongside said brackets, pivots, one said pivot passing through each bracket and associated arm, said ladle having a rim resting on said cradle, said cradle having a downwardly projecting bracket extending under said ladle; tilting mechanism comprising brackets depending from said turntable, a tilting cylinder, means pivoting said tilting cylinder between said last-mentioned brackets, a piston rod in said tilting cylinder, pivot means connecting said piston rod and said downwardly projecting bracket.

9. In a system for continuous casting, a mold having a vertical axis and an open top, a ladle having a reservoir to receive molten metal, a siphon having an inlet in said reservoir and a discharge tip projecting from said ladle, a turntable, a lift cylinder under said turntable and resting on a stationary support, said cylinder having a piston rod attached to said turntable, brackets projecting from said turntable for disposition on opposite sides of said mold, a cradle having arms projecting alongside said brackets, pivots, one said pivot passing through each bracket and associated arm, said ladle having a rim resting on said cradle, said cradle having a downwardly projecting bracket extending under said ladle; tilting mechanism comprising brackets depending from said turntable, a tilting cylinder, means pivoting said tilting cylinder between said depending brackets, a piston rod in said tilting cylinder, said turntable having an opening through which said tilting piston rod projects, pivot means connecting said tilting piston rod and said downwardly projecting bracket; swing mechanism comprising a horizontal swivel cylinder, pivot means connecting said swivel cylinder and said support, a post depending from said turntable, a slide sleeve on said post, said swivel cylinder having a rod, pivot means connecting said swivel rod and slide sleeve.

10. In a system for continuous casting, a platform, a mold resting on said platform, means for vertically reciprocating said platform, a duct on said platform, said mold having cooling passages connected to said duct, said duct having a well reciprocable with said mold, a fixedly mounted feed conduit, said well having seals in its upper and lower walls surrounding said feed conduit, said feed conduit having a closed upper end and an open lower end for connection to a coolant supply, said feed conduit having openings into said well.

11. In a system for casting, a mold, a reservoir to receive molten metal and to deliver it to said mold, a turntable supporting said reservoir, a lift cylinder assembly under said turntable, said assembly comprising a cylinder member and a piston member, one of said members resting on a stationary support, the other member being attached to said turntable, swing mechanism comprising a horizontal swivel assembly, said swivel assembly comprising a swivel cylinder member and a swivel piston member, pivot means connecting one of said swivel members and said stationary support, a post depending from said turntable, a slide sleeve on said post, pivot means connecting the other said swivel member and said slide sleeve, whereby said swing mechanism may rotate the turntable about the axis of said lift cylinder assembly at any elevation of said turntable

12. In a device for pouring molten metal, a metal support having a container to receive the molten metal, a brittle metal-ceramic siphon tube comprising an arch having an inlet end communicating with said container and a discharge end projecting from said container, first means on said support engaging a local area on said siphon tube to hold said tube against appreciable movement both lengthwise of the siphon tube and transversely of the siphon tube, second means on said support engaging said siphon tube at a local area removed from said first local area, said second means holding said siphon tube against appreciable movement transversely of its length but permitting movement of the siphon tube lengthwise of itself, said first means comprising interengaging abutments on said siphon tube and on said support.

13. In the device of claim 11, said first means comprising inter-engaging separable abutments on the arch of the siphon tube and on the support.

14. In a system for cooling a mold for continuous casting, a mold support, a mold resting on said support, said mold having a mold cavity with an open top and open bottom, said mold having cooling passages in the wall thereof, a stationary support, means on said stationary support for mounting said mold support for vertical reciprocation, the direction of reciprocation being axial of said mold cavity, a slip seal comprising an outer chamber with upper and lower walls, said walls having slip openings, an inner chamber within said outer chamber and having walls engaging said slip openings and having reciprocating relation thereto, said inner chamber having openings communicating with said outer chamber, said outer chamber having a connecting conduit member, said inner chamber having a connecting conduit member, one of said conduit members being mounted on said mold support and connected to said cooling passages, the other conduit member being mounted on said stationary support for connection to a source of coolant under pressure, whereby end thrusts applied to the reciprocating parts of the seal by pressure of the coolant are balanced.

15. In a system of continuous casting, a vertical mold having a mold cavity with open top and open bottom, a ladle having a reservoir to receive molten metal, a siphon secured to the wall of said ladle and having an inlet in said reservoir and a discharge tip projecting from the ladle, a support, a table, means for mounting said table on said support for rotation about a vertical axis, elevating means for raising and lowering said table, brackets secured to said table for positioning on opposite sides of said mold, said ladle having arms disposed alongside said brackets, pivots, one pivot connecting each arm and corresponding bracket, said pivots having a common axis passing through said tip, means on said support for tilting said ladle about said pivots, said elevating means serving to position said tip selectively in said mold cavity or

above said mold, said pivots being disposed on opposite sides of the mold when said tip is in said mold cavity.

References Cited in the file of this patent

UNITED STATES PATENTS

853,754	Bechman	May 14, 1907
925,687	Danver et al.	June 22, 1909
1,666,910	Poske	Apr. 24, 1928
1,983,579	Ennor et al.	Dec. 11, 1934
2,131,955	Johnson	Oct. 4, 1938
2,305,477	Junghans	Dec. 15, 1942
2,601,615	Jordan	June 24, 1952
2,631,343	Hunter	Mar. 17, 1953
2,683,294	Ennor et al.	July 13, 1954
2,772,517	Bowes	Dec. 4, 1956
2,789,327	Corley	Apr. 23, 1957
2,810,169	Hofer	Oct. 22, 1957
2,837,428	Brown	June 3, 1958
2,909,834	Modl	Oct. 27, 1959
2,946,100	Baier et al.	July 26, 1960

FOREIGN PATENTS

219,902	Australia	Feb. 27, 1958
549,238	Great Britain	Apr. 10, 1942