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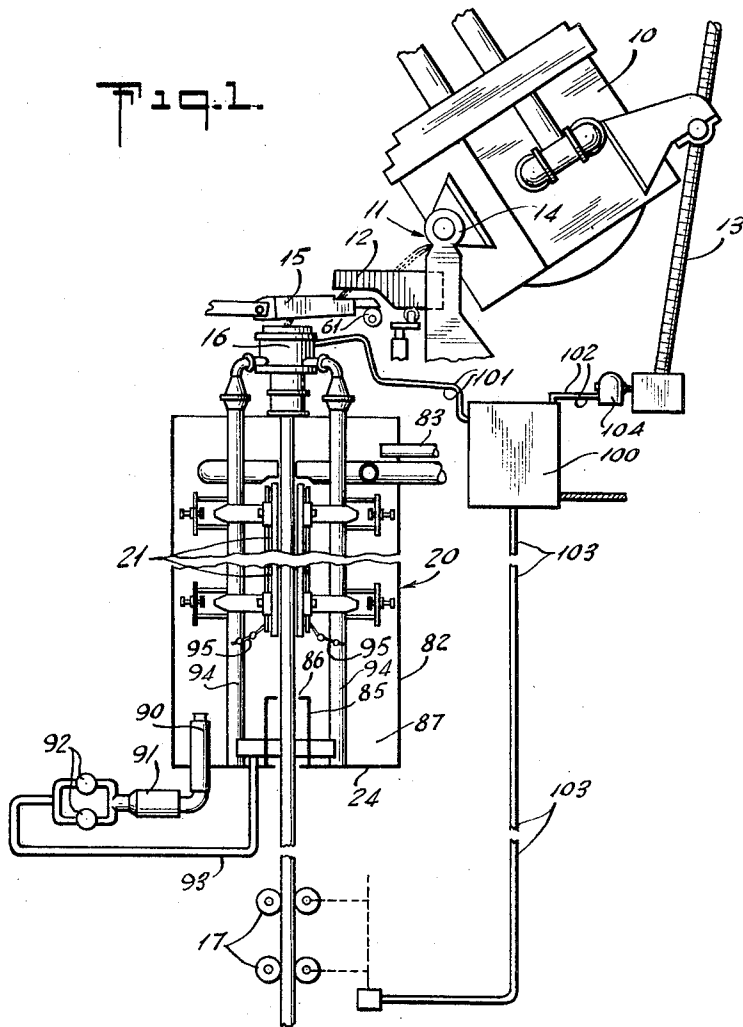
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2,804,665

METHOD OF AND APPARATUS FOR CONTINUOUSLY CASTING METAL

Filed Sept. 22, 1955

4 Sheets-Sheet 1



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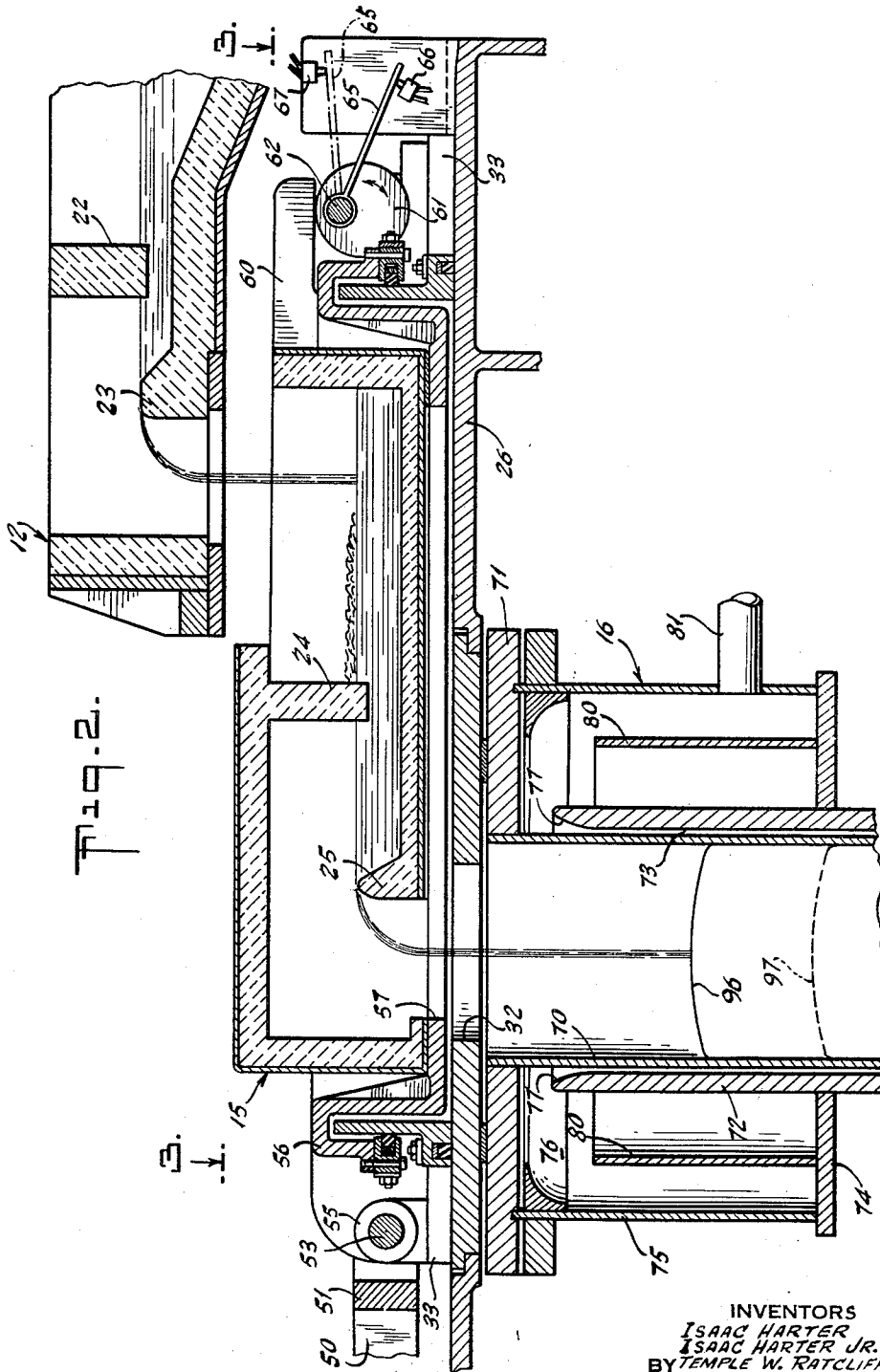
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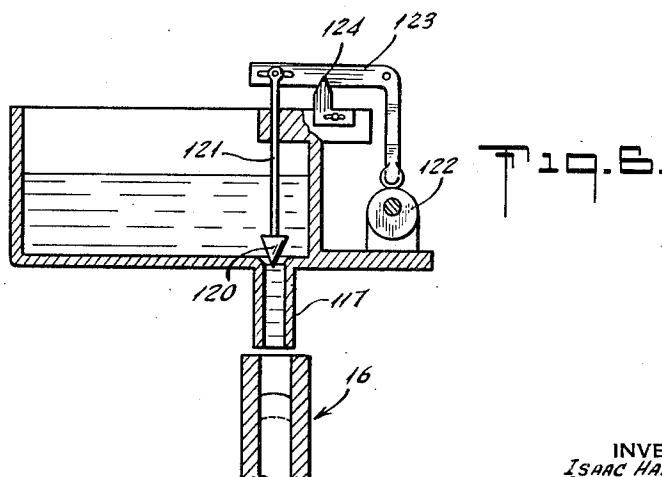
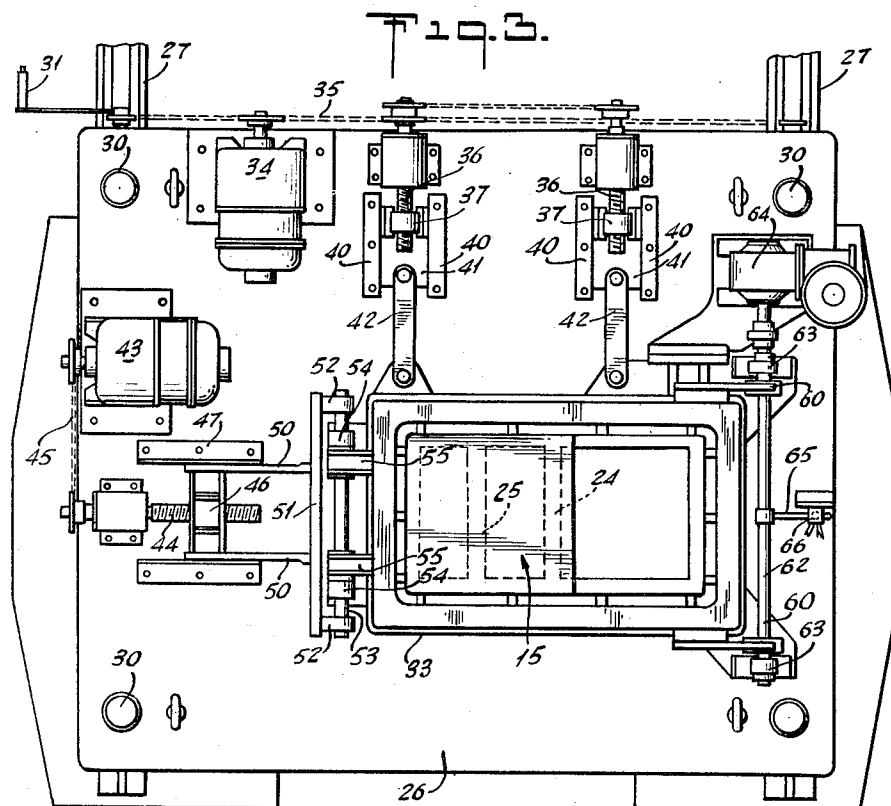
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Fig. 4.

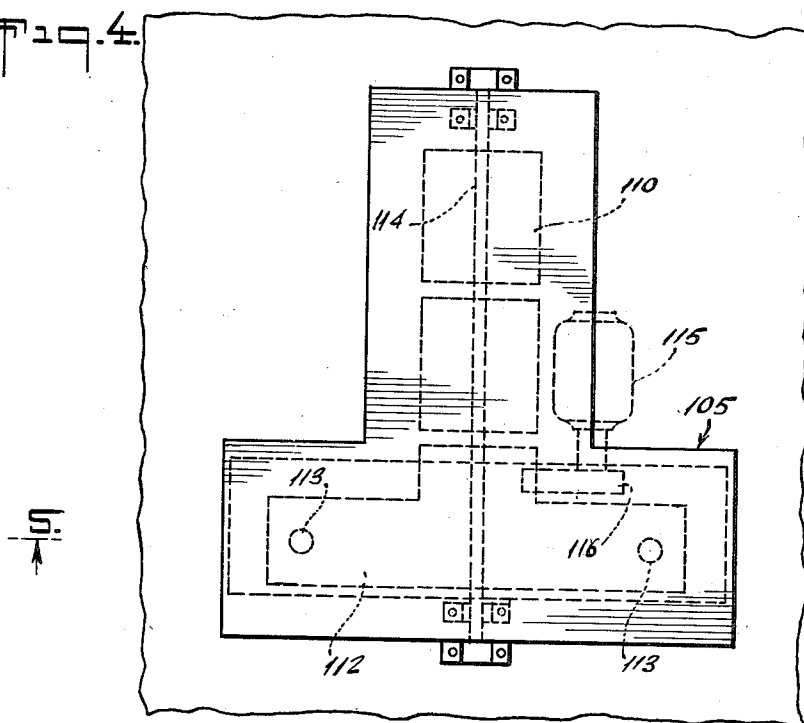
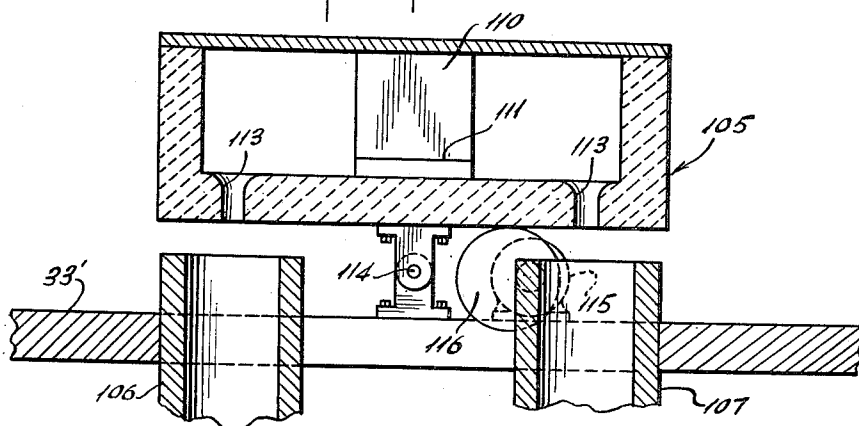


Fig. 5.



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METHOD OF AND APPARATUS FOR CONTINUOUSLY CASTING METAL

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9 Claims. (Cl. 22—57.2)

The present invention relates generally to the continuous casting of metal products, and more particularly to a process of and apparatus for the continuous casting of high melting temperature metals such as ferrous metals and alloys in semi-finished products of various cross-sections.

In the continuous casting of high melting temperature metals it is customary to provide an open ended substantially upright fluid cooled casting mold which is supplied with molten metal at its upper end, and an embryo casting is withdrawn from the lower end thereof. Since the economic justification for a continuous casting system is dependent upon the casting production rate, it is necessary to provide high cooling capacity in the mold for the rapid freezing of the metal within the mold. As pointed out in United States Patent 2,682,691 it is of advantage in increasing the cooling rate of the molten metal to provide for a cyclic variation of the molten metal level within the mold in a predetermined pattern. Actually, with an efficient heat transfer mechanism from the mold wall to the cooling fluid the rate of heat removal from the mold can be greater than the rate of heat exchange through the molten metal to the mold wall. It is for this reason that a varying molten metal level is provided since such a scheme of operation provides intimate heat exchange contact between molten metal and the cold wall of the mold. This mode of operation moreover, provides an opportunity to use the heat storage capacity of the mold wall to increase the heat transfer effect from the molten metal, and to periodically remove small amounts of slag and oxides with the casting before such slag or oxide can accumulate in large amounts in the cavity of the mold.

In Patent 2,682,691 provision is made for molten metal level variation by changing the withdrawal rate of the casting from the mold in a predetermined timed cycle. In the present invention a molten metal variation is also attained, but it is attained by a controlled variation in the molten metal delivery rate to the mold. This has an advantage in that the hereinafter disclosed mode of operation can readily be applied to either a single casting mold or to multiple molds.

In accordance with the invention molten metal is delivered at a substantially continuous rate from a reservoir or source of molten metal which may take the form of a melting furnace or may be a heated metal holding vessel. This vessel may be of the tilting, lip pour type or may be of the bottom discharge type where molten metal is discharged through an orifice positioned in the bottom of the vessel. The molten metal discharged from the reservoir is intercepted in a tun dish which is arranged to provide means for retaining the slag and is also constructed and arranged for single or multiple discharge of molten metal therethrough for delivery to the continuous casting mold or molds. The tun dish is advantageously constructed and arranged for an intermittent delivery to each of the molds.

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The embryo casting produced in the mold or molds is withdrawn at a substantially uniform rate with the speed of the withdrawal advantageously coordinated with the rate of pour from the molten metal storage reservoir.

In the system hereinafter described the rate of production of the casting unit is advantageously maintained at a high and substantially uniform rate which is dependent upon the cooling capacity of the mold, or molds. With the tun dish constructed and arranged for an intermittent delivery of molten metal to each casting mold the high production of continuously cast metal is assured.

The various features of novelty which characterize our invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which we have illustrated and described preferred embodiments of the invention.

Of the drawings:

Fig. 1 is an elevation view, partly in section, of a continuous casting unit constructed and arranged in accordance with the present invention;

Fig. 2 is an enlarged elevation view of a part of the apparatus shown in Fig. 1;

Fig. 3 is a plan view taken on the line 3—3 of Fig. 2;

Fig. 4 is a plan view of a modified arrangement of a tun dish;

Fig. 5 is a section taken on the line 5—5 of Fig. 4; and

Fig. 6 is an elevation, in section, of a further modified construction of the tun dish.

As shown in Fig. 1 the continuous casting unit includes a reservoir or source of molten metal which, in the embodiment shown, comprises a tilting type of arc furnace 10. From the reservoir, molten metal is discharged through a lip 11 into a tun dish 12 which is arranged to receive the molten metal and to skim the slag from the molten metal stream moving through the tun dish. The arc furnace 10 is provided with a tilting mechanism which includes a motor driven screw 13 which operates to tilt the furnace about trunnions 14 positioned to form a horizontal axis corresponding generally with the lip 11 of the reservoir. The molten metal discharging from the tun dish 12 is delivered to a second tun dish 15 which is arranged for intermittent discharge of metal into the upper end of a continuous casting mold 16.

An embryo casting is formed in the mold and is drawn downwardly by pairs of pinch rolls 17 which are spaced at a position well below the lower end of the mold 16. Between the lower end of the mold 16 and the pinch rolls 17 an after-cooling zone or section 20 is provided for the final solidification of the embryo casting. As shown in Fig. 1, a series of guide rolls 21 are arranged within the after-cooling section to support the weak walls of the embryo casting while streams of cooling water are directed against the surface of the casting to solidify the molten core of the casting.

Below the pinch rolls 17 the casting is cut to length, and the ingots are removed to storage for subsequent processing. The ingot cutting mechanism is not shown, but may be of the form disclosed in U. S. Patent 2,590,311.

In the form of the invention shown in Figs. 1, 2, and 3 a single continuous casting mold 16 is utilized. As shown particularly in Fig. 2, the molten metal passing through the tun dish 12 flows beneath a depending baffle 22 which serves as a slag skimmer and thereafter discharges over a weir 23. It is customary to adjust the tun dish 12 so that its position is fixed, with molten metal discharge over the weir at a rate controlled by the rate of delivery of molten metal from the reservoir 10. The tun dish 12 is covered and sealed against the infiltration of oxygen con-

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tained gases so as to reduce oxidation of the molten metal while it is in transit.

The molten metal discharged over the weir of the tun dish falls by gravity into a second tun dish 15 where the metal again passes beneath a depending baffle 24 for movement toward and over a discharge weir 25 which is positioned immediately above the upper end of the continuous casting mold 16.

As shown particularly in Figs. 2 and 3, the tun dish 15 supporting mechanism includes an adjustable platform 26 which is mounted on wheels (not shown) resting upon rails 27. The rails are in turn supported on the structural framework which also supports the continuous casting mold 16, so that the vertical relationship between the rails and the mold is fixed. The platform 26 is provided with means for leveling and vertical adjustment relative to the rails, as for example by screw jacks 30, operated by a hand crank 31 or the like, and can be adjusted in a horizontal direction by movement along the rails.

The platform 26 is provided with a central opening 32 (see Fig. 2) which is located directly above the mold 16, when in an operative position. Immediately above the opening and resting on the platform 26 is a platelike table 33 which is slidable on the surface of the platform. To shift the table on the platform top two mechanisms are provided, one of which moves the table in a direction parallel to the rails, while the other moves the table in a direction transverse to the rails. The first mechanism includes a gearmotor 34, rigidly attached to the table 26 and operatively connected by a chain drive 35 with a pair of rotating screw shafts 36 which are likewise attached to the table 26. Each of the rotating screws is arranged with its axis parallel to the rails 27, and engages a threaded nut 37 which is guided in its movement by fixed guides 40. A slide member 41 is connected with the nut 37 and linked to the table 33 by an arm 42 for movement of the latter in a direction parallel with the rails.

A second gear motor 43 is connected with a rotating screw shaft 44 by a chain drive 45, with rotation of the screw shaft moving a threaded nut 46 between fixed guides 47. The threaded nut is attached by a pair of arms 50 to a bar 51 which is provided with sleeve bearings 52 at opposite ends thereof engaging a shaft 53. The shaft 53 is keyed to the bearings 52 so that operation of the gear motor moves the shaft 53 in a direction transverse to the axes of the rails.

The shaft 53 is fitted with bearings 54 which are attached to the table 33. The bearings 54 are spaced inwardly along the shaft 53 from the keyed bearings 52 so that relative movement of the table 33 in a direction parallel to the rails 27 by operation of the gear motor 43 can occur. A third pair of bearings 55 are slidably mounted on the shaft 53 inwardly of the bearings 54 and are rigidly attached to a tun dish frame or box 56 in which the tun dish 15 is supported. The box 56 has an open top and a partially open bottom with a lower flange 57 upon which the tun dish rests. A pair of arms 60 are attached to the sides of the box 56 and extend outwardly in the direction opposite to the end engaging the shaft 53, each to bear upon the surface of a corresponding eccentric cam 61. The cams are mounted for rotation about a shaft 62 which is supported by spaced bearings 63 attached to the table 33 and rotated by a reversing gear motor 64.

In the embodiment shown, the gear motor 64 is operated to rotate the shaft 62 in alternately reversing directions so as to raise and lower the molten metal receiving end of the tun dish and to thereby vary the discharge of metal therefrom in a controlled pattern of flow. The amplitude of tilting movement of the tun dish 15 can be adjusted by adjusting the position of a contact arm 65 which is clamped on the shaft 62 and makes contact with limit switches 66 and 67.

As shown in Fig. 2, the continuous casting mold consists

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of an inner mold liner 70 which is positioned upright with the mold liner pendently supported from its upper end by a horizontally disposed flange 71 which is in turn supported on the structural steel of the apparatus. The mold liner 70 is externally enclosed by a skirt member 72 which is spaced therefrom to provide a surrounding flow passageway 73 of narrow cross-section. The skirt member is supported and positioned by a flange member 74 which is downwardly spaced from the flange 71 and connected thereto by a cylindrical shell 75 which is outwardly spaced from the skirt 72 and forms the outer boundary of a water inlet chamber 76. The upper end of the skirt 72 is spaced downwardly from the flange 71 and is shaped to form a converging annular inlet 77 for the entrance of cooling water into the annular passageway 73. Advantageously, an intermediate upright cylindrical member 80 is positioned between the skirt and the outer shell 75 of the cooling water inlet chamber. The cooling water is admitted to the chamber 76 through a plurality of water inlet pipes 81 (one shown) which are positioned to open into the lower portion of the chamber 76. With this construction, the incoming water is deflected upwardly in the chamber 76 for substantially a uniformly distributed flow into the confined cooling water flow passageway 73. To attain high cooling rates of the continuous casting mold, the water flow velocity through the annular cooling flow passageway 73 will also be at a high rate, as described in U. S. Patent 2,590,311.

The after-cooling zone or section 20 shown in Fig. 1 is enclosed by an exterior housing 82 which is closed at the top, and provided with an outlet duct 83 in the upper portion thereof for the escape of gases such as hydrogen which may be produced by dissociation of water spray in contact with the outer hot surface of the casting. The lower end of the housing 82 is closed by an annular plate 84 and provided with a central sleeve 85 having an axial opening 86 therein to accommodate the downward withdrawal of the casting formed in the unit. The lower portion of the housing 82, above the annular plate 84, defines a sump 87 for the collection of the water after its spray contact with the casting. The water is withdrawn from the sump through a pipe 90 by a pump 91, passed through filters 92, and returned to the after-cooling section through a pipe 93. Thereafter the water is delivered to stand pipes 94 and passed to the spray nozzles through pipes 95. The stand pipes 94 provide structural support for the guide rolls 21 which are adjustably mounted to prevent swelling of the casting beyond a predetermined dimension, substantially equal to the cross-section of the mold 16.

In the operation of the apparatus described, the tun dish 15 is tilted in a controlled pattern of rise and fall to cause molten metal delivery to the mold 16 at a varying rate. The average rate of pour will be equal to the delivery rate of molten metal from the vessel 10. With a change in the molten metal delivery rate to the mold the molten metal level within the mold wall vary between determined limits such as 96 and 97 shown in Fig. 2. As pointed out in U. S. Patent 2,682,691, the variation in molten metal level encourages a high rate of heat transfer through the mold wall, and an increased casting production rate.

A variation in the molten metal level within the mold also is of advantage in controlling the rate of pour from the vessel 10. This control can be attained by the method and apparatus disclosed in U. S. Patent 2,709,284. As disclosed in the patent, means are positioned in operative relationship to the continuous casting mold 16 to determine the molten metal level movement within the mold. Indications of the molten metal level positions are transmitted to a control mechanism, indicated at 100, where the actual conditions within the mold 16 are compared with a desired set of conditions to regulate the tilting rate of the vessel 10. As shown in Fig. 1 a control

apparatus such as disclosed in said U. S. patent is indicated schematically by the numeral 100. The electrical lead wires 101 connect the mold 16 with the control apparatus, and the lead wires 102 connect the control with the motor 104 operating the screw 13. While the pinch roll operating mechanism is driven at a substantially uniform rate, this rate can be regulated manually in accordance with the requirements of the particular metal being cast. Such a manual control is conveniently mounted in the control mechanism 100 and connected with the pinch roll operating motor by electrical connections 103.

In the modified form of the invention shown in Figs. 4 and 5 a tun dish 105 is shown for the delivery of molten metal to two horizontally spaced continuous casting molds 106 and 107. In the mechanism shown in these drawings the tun dish 105 is substituted in place of a tun dish 15 shown in Fig. 1, and in addition duplicate continuous casting mold units are arranged where such units are each constructed generally as shown in Fig. 1.

Referring to Fig. 4, molten metal is delivered from the tun dish 12 to the inlet end 110 of the tun dish 105, thereafter the molten metal passes beneath a pair of depending baffles 111 for delivery to a transversely extending trough portion 112 at the opposite end of the tun dish. At each end of the tun dish trough section 112 is positioned downwardly opening orifice 113 which is located immediately above and in alignment with the central axis of one of the continuous casting molds 106 and 107.

As illustrated in the drawings the tun dish is mounted upon a longitudinally extending shaft 114 which is supported directly upon a table 33' such as the table 33 shown in Fig. 3. The shaft 114 is positioned intermediate the continuous casting molds 106 and 107 and is normal to the length of transverse trough section 112 of the tun dish 105. As shown particularly in Fig. 5, a gear motor 115 is disposed beneath the tun dish 105 and arranged to drive an eccentric 116 which is mounted on the surface of the table 33' and oscillates the tun dish 105 about the shaft 114.

In the operation of the apparatus shown in Figs. 4 and 5 a substantially uniform stream of molten metal is delivered to the inlet 110 of the tun dish 105 with the molten metal passing through the tun dish being alternately delivered to each of the continuous casting molds 106 and 107. Thus, the molten metal delivery to each mold is intermittent, and the molten metal level within each mold will rise and fall in a predetermined pattern regulated by the speed of rotation of the eccentric 116.

In the great majority of cases a lip type, or weir, discharge is preferable when handling a molten metal such as steel, due to the erosive action of steel on known refractories. However, when a continuous casting is being formed of small cross-sectional area it is extremely difficult to regulate the delivery of molten metal over a weir to the center of the casting mold. Accordingly it is advantageous when pouring molten metal to a continuous casting mold of relatively small cross-sectional dimensions to use a nozzle or orifice type of feed mechanism. It will be appreciated that the mechanism shown in Figs. 4 and 5 can be constructed with a weir type of discharge such as shown in Fig. 2 of the drawings. Moreover it is possible to deliver molten metal through a tun dish of the type shown in Figs. 4 and 5 to multiple molds, in excess of the two shown.

In the modification shown in Fig. 6 a nozzle type of molten metal discharge device from a tun dish or delivery channel is shown, where instead of rocking or oscillating the tun dish the nozzle or orifice 117 is provided with a plug valve 120 which is raised and lowered relative to the opening of the orifice to change the effective dimensions of the nozzle opening and to thereby change the rate of molten metal flow therethrough. As shown in Fig. 6 the plug valve 120 is mounted on the lower end of an upright rod 121 pivotably attached at its upper end

to a horizontally extending arm raised and lowered by the rotation of an eccentric 122 bearing on a crank arm 123 which is pivoted about a fulcrum 124.

The amplitude and period of the valve 120 movement may be regulated by change in the rotational speed of the eccentric 122 or by changing the horizontal position of the fulcrum 124 as desired, to change the operation of the casting unit.

What is claimed is:

1. The process of continuously casting molten metal in an open-ended vertically elongated stationary mold liner having a laterally confined space therearound for the flow of a cooling medium therethrough and a casting withdrawal mechanism spaced below said mold liner comprising, maintaining a substantially uniform pour rate of molten metal from said source and delivering the molten metal to the upper end portion of said mold liner in a predetermined cycle of changing metal delivery rate, continuously cooling the molten metal within said mold liner to form an embryo casting, and withdrawing said casting from the lower end of said mold liner at a rate coordinated with the delivery of molten metal from said source of molten metal.

2. The process of continuously casting molten metal wherein a pair of open-ended vertically elongated stationary mold liners are laterally spaced apart and are each provided with a casting withdrawal mechanism spaced below the mold liner, the steps comprising maintaining a substantially uniform pour rate of molten metal from a source of molten metal, intercepting the molten metal from said source, and delivering the molten metal to the upper end portion of each of said mold liners in a predetermined cycle of changing metal delivery rate, continuously cooling the molten metal within each of said mold liners to form an embryo casting, and withdrawing said casting from the lower end of each of said mold liners at a combined rate substantially equal to the pour rate of molten metal from said source of molten metal.

3. The process of continuously casting molten metal wherein a plurality of open-ended vertically elongated stationary continuous casting molds are disposed in a group about a central position and a casting withdrawal mechanism is spaced below each of said molds comprising the steps of maintaining a substantially uniform discharge rate of molten metal from a source of molten metal, intercepting the molten metal from said source and delivering molten metal to the upper end portion of each of said molds in a predetermined cycle of changing metal delivery rate, continuously cooling the molten metal within each of said molds to form an embryo casting, and continuously withdrawing the embryo casting from the lower end of each of said molds at a substantially uniform rate, the total weight of casting withdrawn from said molds being substantially equal to the average weight of molten metal delivered to said molds from said source of molten metal.

4. Apparatus for continuously casting molten metal comprising an open-ended vertically elongated stationary fluid cooled mold, a molten metal reservoir, means for discharging molten metal from said reservoir at a controlled substantially uniform rate, a tun dish positioned between said molten metal reservoir and the upper end of said mold, said tun dish constructed and arranged to receive the molten metal discharged from said reservoir and to deliver molten metal to said mold liner, means for changing the rate of molten metal delivery from said tun dish to said mold in a predetermined cycle, and a withdrawal mechanism positioned beneath said mold for the withdrawal of the casting from said mold at a substantially uniform rate equal to the average rate of molten metal delivered to said mold.

5. Apparatus for continuously casting molten metal comprising means forming an open-ended vertically elongated stationary mold, means forming a laterally confined

space around said mold for the high velocity flow of a liquid coolant therethrough, a molten metal reservoir, means for discharging molten metal from said reservoir at a controlled substantially uniform rate, a tun dish positioned above the upper end of said mold, said tun dish constructed and arranged to receive the molten metal discharged from said reservoir and to deliver molten metal to the upper end of said mold, means for changing the rate of molten metal delivery from said tun dish to said mold in a delivery pattern of alternate high and low rates, and a withdrawal mechanism positioned beneath said mold for the withdrawal of the casting therefrom at a substantially uniform rate coordinated with the molten metal discharge rate from said reservoir.

6. Apparatus for continuously casting molten metal comprising an open-ended vertically elongated stationary mold, means for cooling said mold, a source of molten metal, means for discharging molten metal from said source at a controlled substantially uniform rate, a tun dish positioned to receive the molten metal discharged from said source and to deliver molten metal to said mold, means for changing the rate of molten metal discharge from said tun dish to said mold including a shaft attached to one end of said tun dish, and a power driven cam at the opposite end of said tun dish to tilt the position of the tun dish, and a withdrawal mechanism positioned beneath said mold for the withdrawal of the casting from said mold at a substantially uniform rate coordinated with the molten metal delivery rate to said tun dish.

7. Apparatus for continuously casting molten metal comprising horizontally spaced open-ended vertically elongated stationary molds, means for cooling said molds, a source of molten metal, means for discharging molten metal from said source at a controlled substantially uniform rate, a tun dish positioned to receive the molten metal discharged from said source and to deliver molten metal to said mold, means for cyclically changing the rate of molten metal discharge from said tun dish to each of said molds, and a withdrawal mechanism positioned beneath each of said molds for the withdrawal of the casting from said molds at a combined rate substantially equal to the molten metal delivery rate to said tun dish.

8. Apparatus for continuously casting molten metal comprising at least two horizontally spaced open-ended vertically elongated stationary molds, means for cooling said molds, molten metal reservoir at a controlled sub-

stantially uniform rate, molten metal channel means positioned between said molten metal reservoir and the upper end of said molds, said channel means constructed and arranged to receive the molten metal discharged from said reservoir and to deliver molten metal to each of said molds, means for alternately changing the rate of molten metal delivery from said channel means to said molds in a selected cycle, and a withdrawal mechanism positioned beneath each of said molds for the withdrawal of a casting from each of said molds at a substantially uniform rate, the total rate of casting withdrawal from all of said molds being equal to the rate of molten metal delivered to said channel means.

9. Apparatus for continuously casting molten metal comprising means forming an open-ended vertically elongated stationary mold, means for cooling said mold, a molten metal reservoir, means for discharging molten metal from said reservoir at a controlled substantially uniform rate, a tun dish positioned above the upper end of said mold, means forming an orifice discharge opening in the bottom of said tun dish, said tun dish constructed and arranged to receive the molten metal discharged from said reservoir and to deliver molten metal through said orifice to said mold, means for changing the rate of molten metal through said orifice in a predetermined cycle of high and low discharge rates, and a withdrawal mechanism positioned beneath said mold for the withdrawal of the casting therefrom at a substantially uniform rate coordinated with the average rate of molten metal delivery to said mold.

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