

Oct. 14, 1969

A. CALDERON

3,472,309

METHOD OF AND APPARATUS FOR CONTINUOUSLY CASTING STEEL

Original Filed Oct. 8, 1965

10 Sheets-Sheet 1

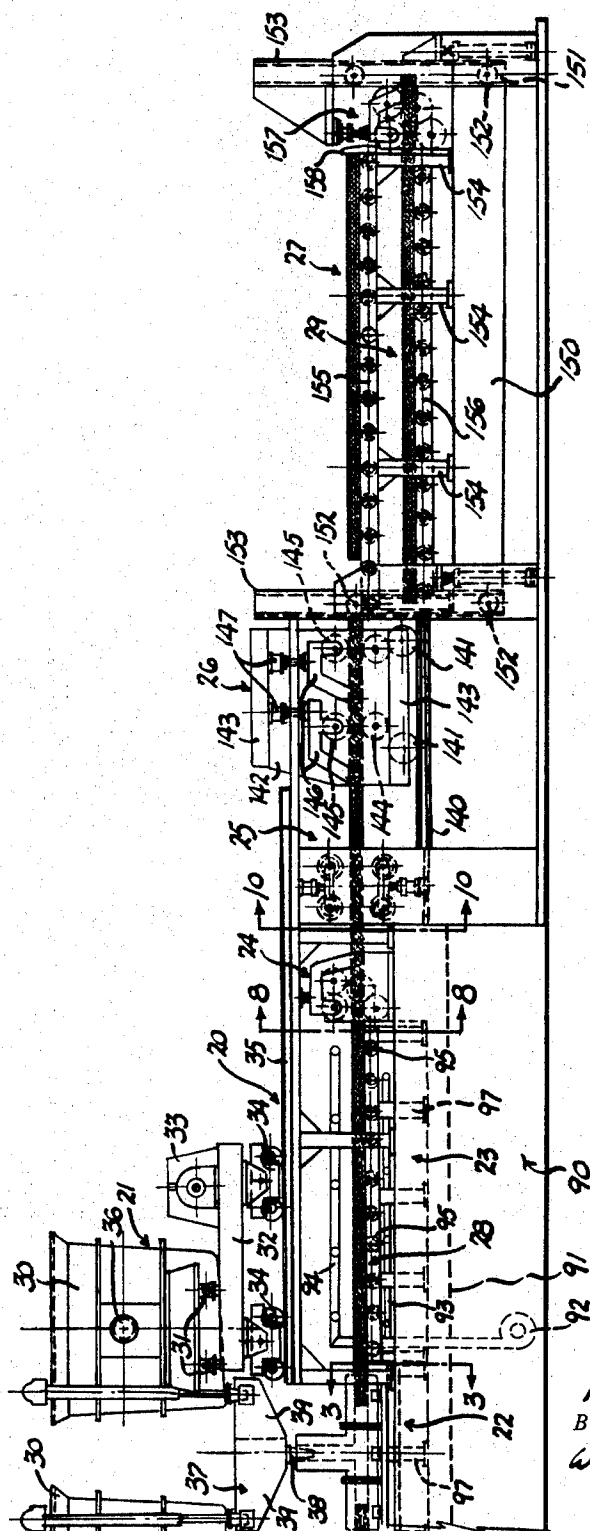


Fig. 1

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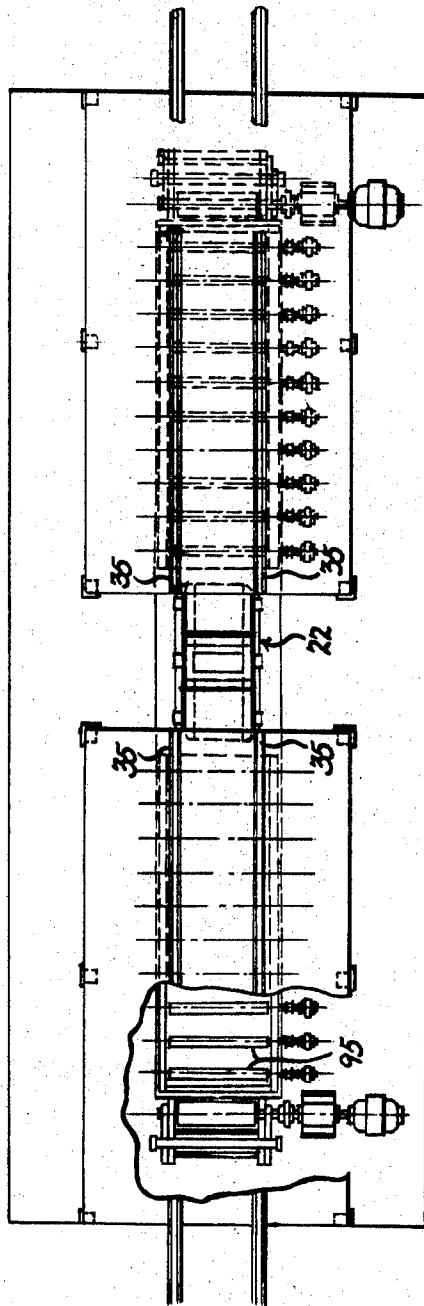


Fig. 2

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10 Sheets-Sheet 3

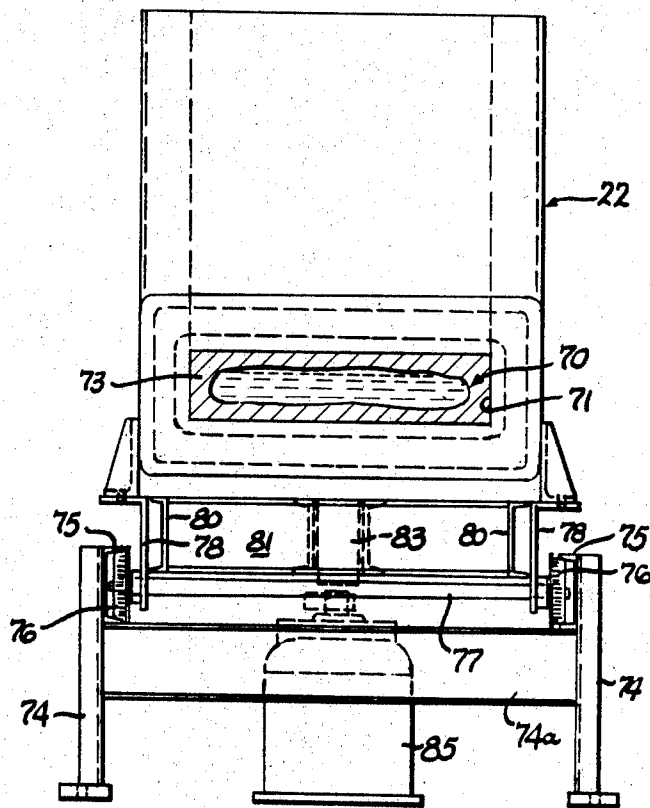


Fig. 3

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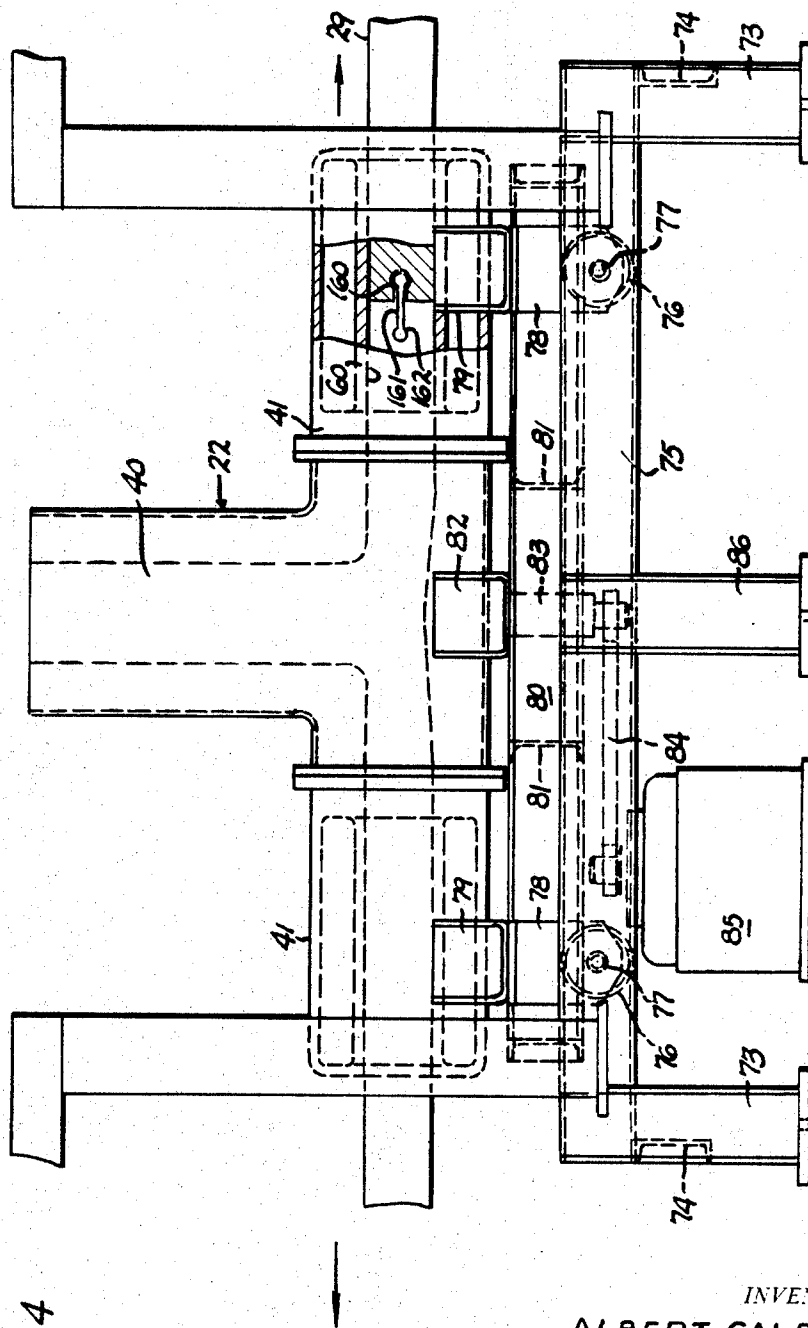


FIG. 4

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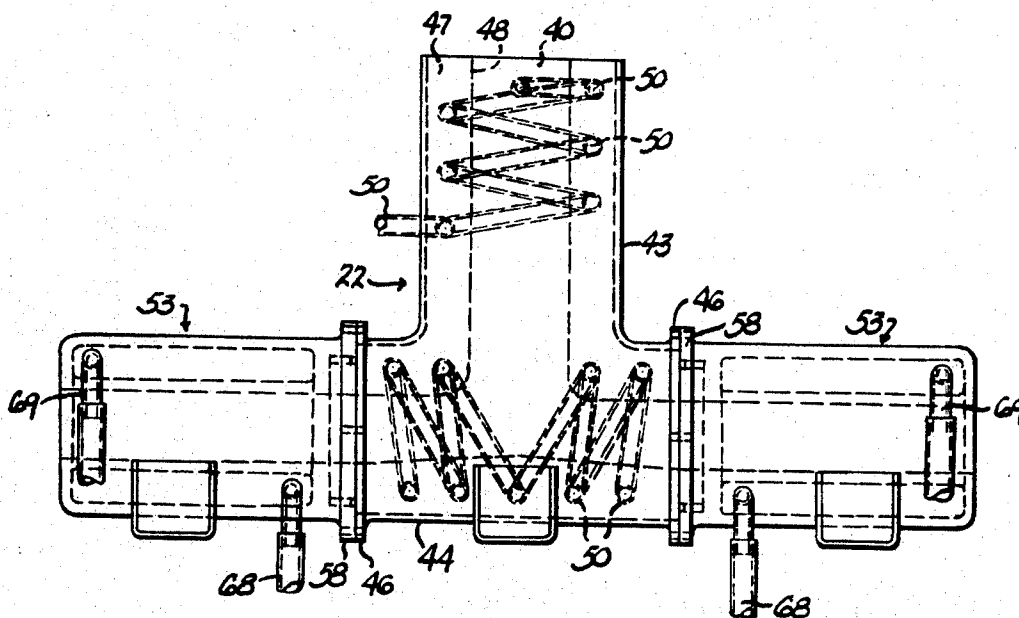


FIG. 5

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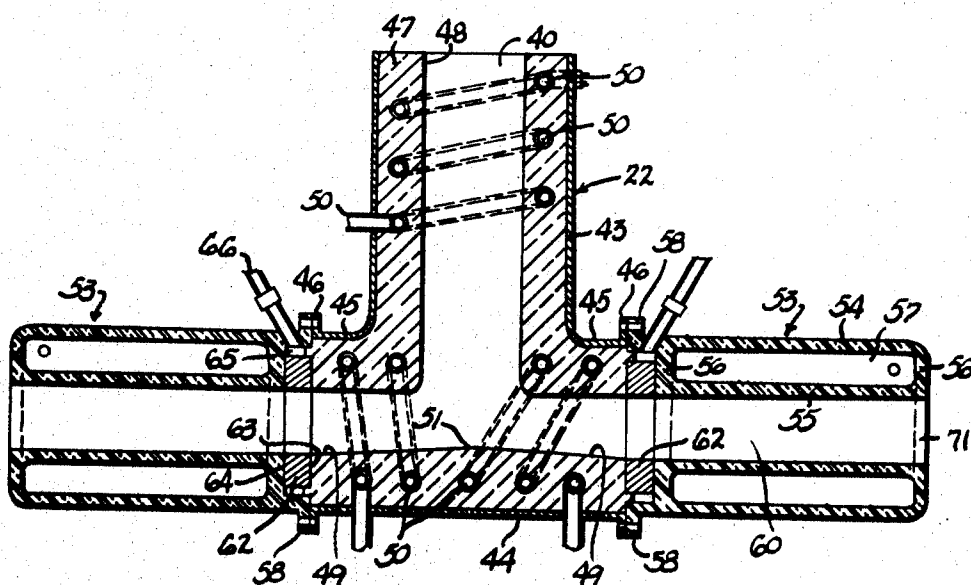


FIG. 6

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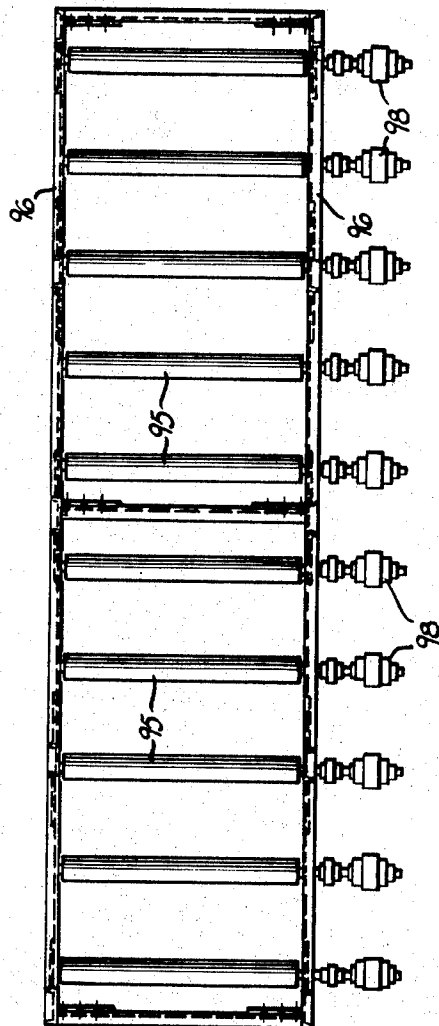


Fig. 7

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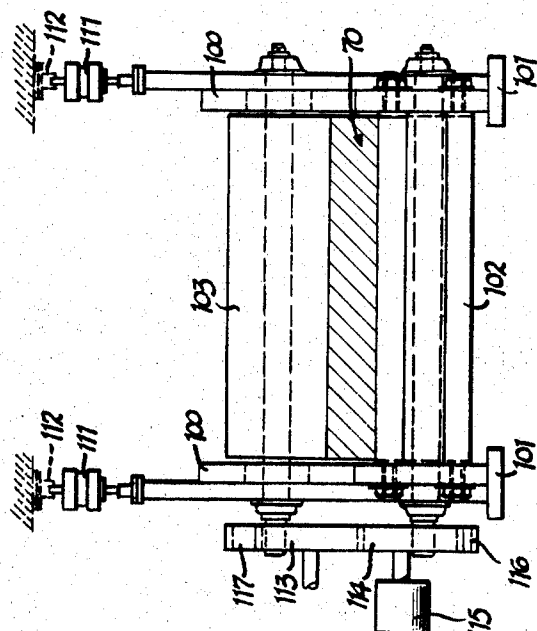


Fig. 8

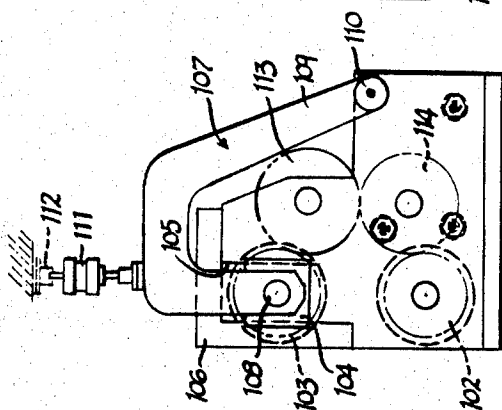


Fig. 9

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FIG. 11

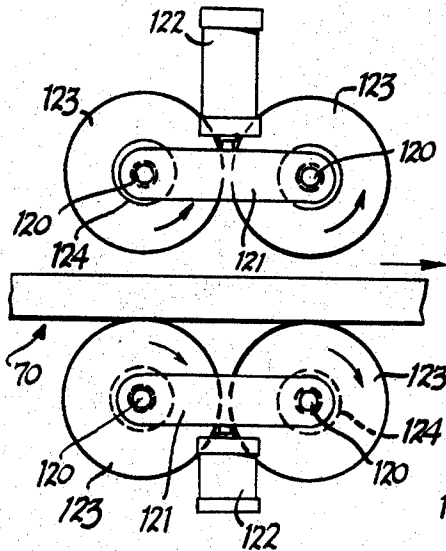


FIG. 10

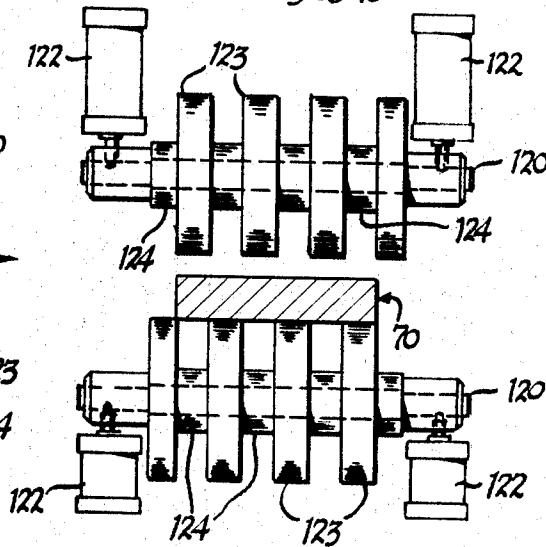


FIG. 13

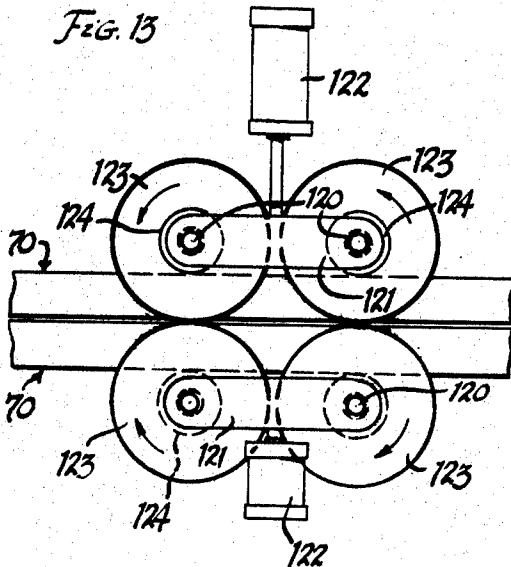
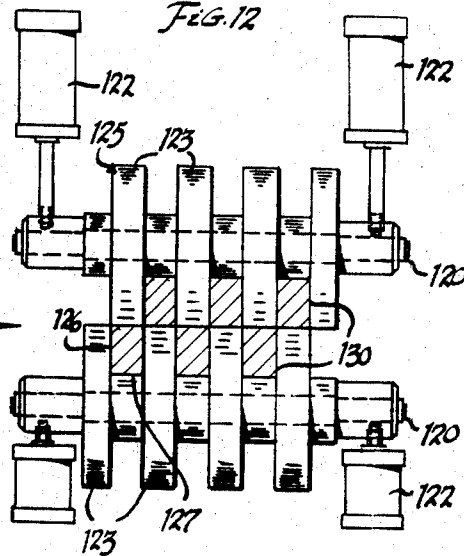


FIG. 12



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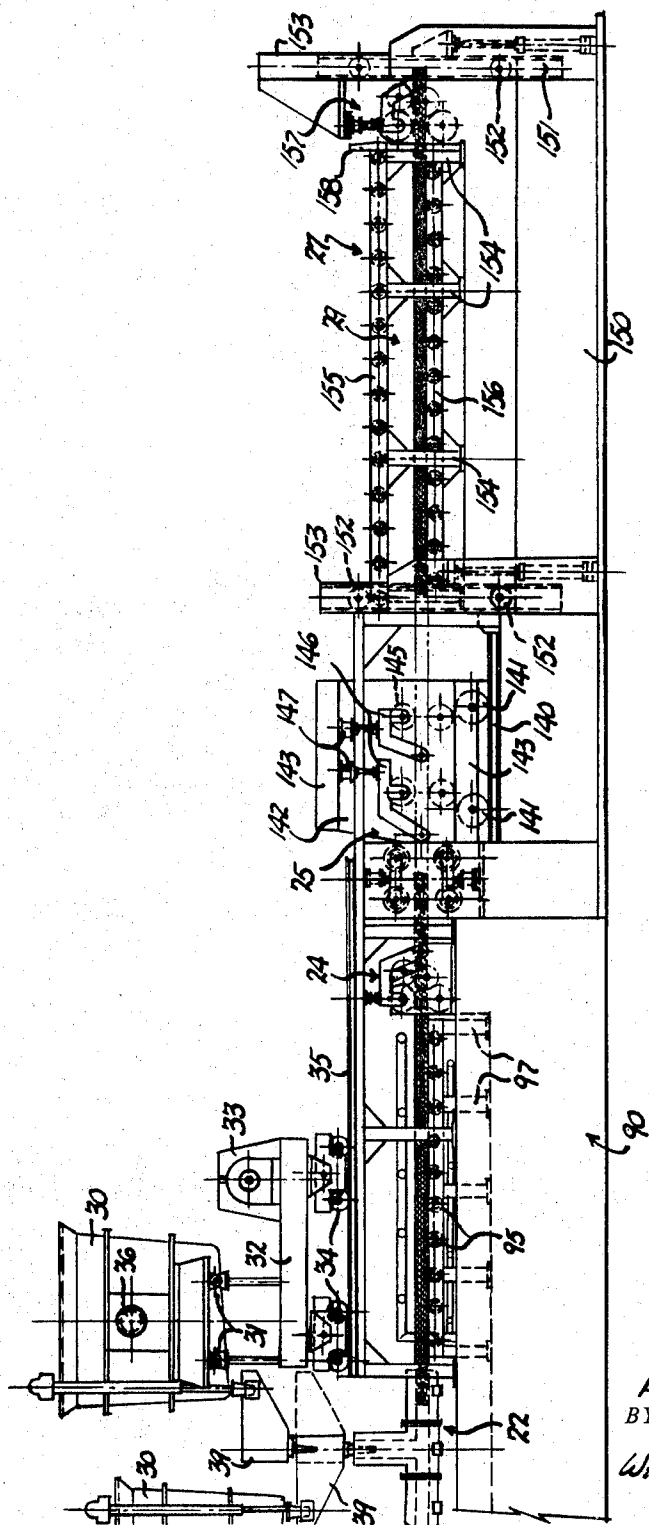


Fig. 14

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METHOD OF AND APPARATUS FOR CONTINUOUSLY CASTING STEEL

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Continuation of application Ser. No. 494,017, Oct. 8, 1965. This application Aug. 16, 1968, Ser. No. 768,206 Int. Cl. B22d 11/08, 11/12

U.S. Cl. 164—73

25 Claims

ABSTRACT OF THE DISCLOSURE

A method of and apparatus for continuously casting steel, forming a slab in a horizontal plane so that it need not be deflected after solidification of the slab has started. The casting takes place in a mold having an upright, refractory lined portion and preferably a pair of oppositely directed metallic, horizontal mold portions which are water cooled and through which the partially solidified slab issues. If desired, one of the horizontal mold portions can be eliminated. The complete molds is reciprocated longitudinally, the horizontally displaced slab leaving the mold being flushed with the coolant to complete solidification. The completely solidified slab passes through a traction device and the reciprocation of the mold, together with the continuously running traction device, strips the slab from the horizontal mold portion. The disclosure also proposes slitter rolls and a shearing or burning assembly to form the slab into billets or blooms. A starter bar arrangement and an elevator-type runner assembly are provided for storing and inserting the starter bar without interference with the product issuing from the traction assembly.

This application is a continuation of my application Ser. No. 494,017, filed Oct. 8, 1965 and now abandoned.

The present invention relates to a method of and apparatus for continuously casting steel. More particularly, the invention provides a novel method of truly continuously casting a slab of steel in a horizontal plane without deflecting the slab after it has started to solidify, and to an apparatus for so casting steel.

In the art of steel making, continuous casting apparatus and techniques have received much recent publicity, and several such installations have been and are currently being built. The advantages are too numerous and too well known to be described here. However, the present technology is such that there are several disadvantages, both operationally and financially, to the now standard vertical continuous casting installations. The most striking difficulty in the vertical casting apparatus is the extreme over-all height of the complete system which necessarily pours, casts and then completely solidifies the molten metal in a single vertical plane. This over-all height not only adds to the cost of the installation but results in the intermittent operation of the installation, since the finished slab or article must be removed from the vertical plane before additional casting can be carried out.

Recently, there has been proposed the utilization of a curved mold in which the initial casting and solidification occurs in a vertical plane, the partially solidified slab or other casting then being deflected toward the horizontal. By this technique, the over-all height has been substantially reduced but difficulties have been encountered in making a sound casting which is free of those internal defects caused by deflecting the partially solidified material.

Further, it is necessary to reciprocate the mold in any continuous casting operation, thereby subjecting the

metal, during solidification, to alternate tensile and compression forces. In this way, the compressive forces (e.g. when a vertical mold moves downwardly) prevents any ruptures in the shell or skin, while the tensile forces (e.g. the upward motion of the vertical mold) aids in stripping the casting from the mold. When a curved mold is utilized, the effectiveness of such reciprocating action is materially lessened.

The present invention now proposes a new and novel method of and apparatus for the continuous casting of steel and wherein the above described difficulties are eliminated. The proposal of the present invention is premised upon a true horizontal, continuous casting technique, preferably utilizing a mold of inverted T-shaped configuration. This mold includes a central upright portion which is refractory lined and into which the molten metal is initially introduced directly from a ladle or re-tort, or, if such is utilized, from a de-gassing apparatus.

Communicating with this upright central portion are a pair of oppositely directed horizontal mold portions, preferably formed of copper or similar heat conductive metal and water cooled to extract the maximum amount of heat from the metal passing therethrough. These horizontal mold portions form the bottom legs of the inverted T-shaped configuration and partially solidified metal issues from each of these molds simultaneously.

The complete mold is reciprocated longitudinally, i.e. in the plane of movement of the partially solidified metal, at a speed which is carefully correlated with the withdrawal rate of metal from the heat extracting mold portions. The metal leaving the mold is supported on horizontally disposed rollers and is flushed with a coolant until such time as the metal is completely solidified. The completely solidified metal then passes between a pair of pinch rolls or similar traction device which serves to pull the metal from the mold legs. This traction means, positioned exteriorly of the mold, in combination with the reciprocation of the mold, subjects the metal in the mold to alternate compression and tensile forces. These forces completely counterbalance one another, so that the mold reciprocation subjects metal in one of the mold legs to compression while metal in the other mold leg is being subjected to tension. Thus, all of the advantages of surface defect healing and mold stripping are obtained in a completely "overlapped" correlation.

While operating in this manner, it is possible to form a slab of metal of appreciable size at each of the horizontal legs of the T-shaped mold. Of course, an L-shaped mold may be utilized, if desired, such an L-shaped mold having only one horizontal leg.

After the slab has been formed and completely solidified, the slab preferably is passed through sets of adjustable slitter rolls in order to slit the slab and make billets or blooms of predetermined size and configuration, depending upon the slitter roll arrangement and adjustment. Beyond the slitter rolls, a shearing or burning assembly is located to cut the blooms or billets to the desired length.

By virtue of the horizontal issuance of the slab from the lower legs of the T-shaped mold, a simplified starter bar, or "dummy bar," can be utilized, this bar simply being inserted into the open extreme end of each mold leg by means of the pinch rolls prior to the introduction of molten metal into the vertical leg of the mold.

The pinch rolls then are utilized to pull the starter bar from the mold and the continuous casting operation is initiated. A preferred starter bar arrangement and a novel elevator-type roller assembly is provided by the present invention for facilitating the storage and feeding of the starter bar while, at the same time, providing for the handling of the end product after cutting to length.

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It is, therefore, an important object of the present invention to provide a new and improved method of and apparatus for the continuous casting of steel in a mold having a vertical leg into which molten steel is introduced and a horizontal leg from which the steel issues in an at least partially solidified form.

Another important object of this invention is the provision of a continuous casting apparatus and method utilizing a T-shaped mold having an upper upright leg for receiving molten steel and two oppositely directed chilled legs from which partially solidified steel issues in a horizontal plane, the complete mold being reciprocated horizontally.

It is a further important object of this invention to provide a continuous casting method and apparatus wherein molten steel is introduced from a ladle or similar retort directly into an upstanding portion of a horizontally reciprocating mold for issuance from a cooled horizontal leg of the mold in a partially solidified form for passage over a horizontal supporting table upon which the partially solidified steel is flushed with coolant, the steel being subsequently slit and sized into blooms or billets of desired configuration and length.

Still another object of this invention is the provision of a continuous casting apparatus for steel or the like wherein partially solidified steel issues from a water-chilled horizontal mold for subsequent passage through a traction device, and a starter bar is horizontally inserted into the mold by means of the same traction device, to initiate the casting process.

Still another important object of this invention is the provision of a mold for a continuous casting process, the mold being of inverted T-shape configuration and having oppositely directed water-cooled lower portion, each such portion communicating with a central riser portion into which molten metal is introduced by an overhead retort or the like, the mold being horizontally reciprocable.

Other objects of this invention will appear in the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

On the drawings:

FIGURE 1 is a side elevational view of a continuous casting apparatus of the present invention capable of carrying out the method of the present invention;

FIGURE 2 is a fragmentary plan view, on a reduced scale, of the apparatus of FIGURE 1;

FIGURE 3 is an enlarged sectional view taken along the plane 3—3 of FIGURE 1;

FIGURE 4 is an enlarged side elevational view of the mold portion of the apparatus;

FIGURE 5 is a view similar to FIGURE 4, but illustrating in greater detail the heating and cooling means therefor;

FIGURE 6 is a view similar to FIGURE 5, but in section;

FIGURE 7 is an enlarged plan view similar to FIGURE 2 but illustrating in greater detail the supporting rolls and the driving mechanisms therefor;

FIGURE 8 is a sectional view taken along the plane 8—8 of FIGURE 1;

FIGURE 9 is a side elevational view of that portion of the apparatus illustrated in FIGURE 8;

FIGURE 10 is a sectional view taken along the plane 10—10 of FIGURE 1;

FIGURE 11 is a side elevational view of the apparatus shown on FIGURE 10;

FIGURE 12 is a view similar to FIGURE 10 but illustrating that portion of the apparatus in adjusted operating position;

FIGURE 13 is a side elevational view of the apparatus when adjusted as shown in FIGURE 12; and

FIGURE 14 is a side elevational view similar to FIG-

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URE 1 but illustrating the apparatus in an adjusted operating position.

Before explaining the present invention in detail, it is to be understood that the invention is not limited to its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

As shown on the drawings:

In FIGURE 1 reference numeral 20 indicates generally an apparatus of the present invention capable of carrying out the method of the present invention, and comprising several component assemblies including a hot metal supply assembly, indicated generally at 21; a reciprocating mold assembly indicated generally at 22; a cooling and supporting assembly shown generally at 23; a traction assembly indicated generally at 24; a slitter assembly indicated generally at 25; a cutoff assembly indicated generally at 26; and a vertically movable starter bar and removal assembly indicated generally at 27.

Each of these several components will be hereinafter more fully described, but generally it will be observed from FIGURE 1 that the hot metal supply assembly supplies molten steel to the reciprocating mold assembly 22 from which the steel issues as an at least partially solidified metal slab 28. Actually, this slab 28 consists of a solidified peripheral skin surrounding a still-molten center, which slab is completely solidified by being flushed with coolant while the slab is supported upon the assembly 23. The traction device 24 pulls the slab 28 from the mold 22 at a substantially constant rate, the traction device contacting the slab only after the slab has been substantially completely solidified. The slitter assembly 25 subdivides the still hot but completely solidified slab into desired shapes and sizes, e.g. bars, strips or the like, and the assembly 26 functions to cut these pieces to a desired length which are then retained in the assembly 27 for removal to appropriate further processing apparatus.

The assembly 27 also serves to insert a starter bar, or "dummy bar" 29 into the mold assembly 22 to initiate the molding process after the apparatus has been shut down for any reason.

The components of this over-all apparatus will now be described in detail, as follows:

THE HOT METAL SUPPLY ASSEMBLY 21

The hot metal supply assembly 21 consists of a molten metal ladle or other receptacle 30.

While any type of bottom-pour ladle can be utilized, it is preferred that the ladle be of the type illustrated and described in my copending application for U.S. Letters Patent, Ser. No. 383,356, filed July 17, 1964, this type of ladle having a specific pouring nozzle for the nonturbulent, controlled, low velocity flow of molten metal independently of the head of molten metal in the ladle 30.

The ladle 30 is mounted, as by pins and brackets indicated generally at 31, on a ladle car 32 which is self-propelled by a driving means 33 for travel on wheels 34 on tracks 35. These tracks 35 are disposed generally above the mold assembly 22 and accommodate the movement of the ladle longitudinally with respect to the mold to positions at which the ladle can be readily removed by engagement of its trunnions 36 by an overhead crane (not shown).

In FIGURE 2 of the drawings, the ladles 30 are not shown but it will be seen that two opposed sets of tracks 35 are provided, each set being capable of supporting a ladle 30. By utilization of a pair of ladles 30, there will be no interruption in the supply of molten metal to the mold assembly 22.

To facilitate the introduction of molten metal into the mold 22 (in a manner to be hereinafter more fully de-

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scribed) a funnel or metal introduction vessel 37 is provided, this funnel having a central lower pouring nozzle or plurality of nozzles 38 and upwardly and outwardly flaring funnel projections 39 underlying the outlet openings from the ladles 30. Thus, molten metal can be introduced into the mold assembly 22 from either or both of the ladles 30. Thus, the emptying of one ladle 30 does not require stopping of the molding operation, as in conventional continuous casting operations, since the second ladle 30 is already positioned to continue the introduction of molten metal into the mold 22. Further, as will be hereinafter described in greater detail, the mold 22 in and of itself provides a reservoir of molten metal to further promote the continuity of the casting operation.

THE MOLD ASSEMBLY 22

As best illustrated in FIGURES 3 through 6, the mold assembly 22 of the present invention is generally of the configuration of an inverted T, the mold consisting of a central upstanding or vertical leg 40 and a pair of lower, transversely projecting and oppositely directed legs 41, as best shown in the sectional view of FIGURE 6. The upstanding vertical mold leg 40 comprises an outer sheet metal assembly 43 which is welded or otherwise unitized to form the outer skin of this mold portion. This assembly 43 (FIGURE 6) includes a central bottom wall portion 44 and laterally out-turned flanges 45 which terminate in laterally outwardly directed openings circumscribed by out-turned attachment flanges 46. This outer sheet metal cover or skin encloses an interior refractory lining 47 which, in turn, surrounds a vertically extending hollow chamber or reservoir space 48 communicating at its lower ends with laterally directed, relatively short extensions 49.

It will be noted from FIGURE 6 that embedded in this refractory lining 47 are electrical heating coils 50 which are attached to a suitable source of electricity to (1) maintain the molten steel in a molten state despite the inevitable heat loss through the refractory lining 47 and the surrounding assembly 53 and, (2) to prevent segregation of the components of the molten metal by induction stirring.

It will be noted from FIGURES 3 and 6 that each of the horizontal mold passages 60 open fully onto the refractory lined reservoir passages 49.

Also, it will be noted that the transverse passages 49 open fully onto the reservoir space 48, these two passages merging at a central lower location, indicated generally at 51, this location 51 being elevated or "crowned" to a certain extent to aid in promoting the smooth flow of the metal from the vertical reservoir 48 into the lateral extensions 49.

Secured to the flanges 46 of the lateral extensions 45 are further horizontal extensions or chill molds, indicated generally at 53, respectively, these chill molds being formed of a heat conductive metal, preferably copper, and having spaced outer walls 54, inner walls 55, and end walls 56 to circumscribe an interior heat exchange space 57 adapted to receive a heat exchange fluid, e.g. water. The inner walls 55 of the chill molds 53 circumscribe a generally rectangular space 60 which communicates fully with the lateral reservoir extensions 49. The outer walls 54 are provided with transversely projecting flanges 58 by means of which the extensions or chill molds 53 can be secured to the flanges 46 of the sheet metal cover 43 by suitable means, as by nuts and bolts traversing registering flange apertures.

Interposed between the extensions 49 and the chill molds 53 are peripheral permeable oil diffuser rings 62. Specifically, these rings are positioned in recesses 63 formed at the extreme outer ends of the refractory passages 49 and by complementary recesses 64 formed in the inner end walls 56 of the chill molds 53. An additional outer open space 65 is provided in surrounding relation to the diffuser rings 62, this space communicating through a conduit 66 with a source of a suitable

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lubricant under pressure. The diffuser rings 62 are porous powdered iron compacts and serve the dual functions of (1) providing a gasket between the refractory liner 47 and the metallic extensions 53, and (2) introducing lubricant fluid onto the surface of the molten metal just prior to the entry of the molten metal into the passages 60 of the chill molds.

The horizontal mold portions 53 are provided with heat exchange fluid, such as water, through an inlet line 68 and an outlet 69, as best shown in FIGURE 5 of the drawings.

As shown in FIGURE 3 of the drawings, it can be seen that the slab 70 issuing from the opening 71 in the chilled portions 53 of the mold has generally the configuration of the opening 71, but that the center 72 of the slab 70 is still molten. Thus, the slab can best be defined as consisting of a peripheral skin 73 formed by the chilling effect of the heat exchange fluid introduced into the chamber 57, which skin surrounds the still molten center 72.

As best shown in FIGURES 3 and 4 of the drawings, the mold is supported for oscillatory motion. More specifically, a mold supporting frame is provided, this frame consisting of a plurality of vertical or upright posts 74 joined by transverse braces 74a, the posts and braces supporting inwardly directed double flanged rails 75 which are open at their confronting faces to receive therein support wheels 76, respectively, these wheels being mounted upon a transverse shaft 77.

As shown in FIGURE 4, a plurality of sets of wheels 76 are provided so that the mold 22 is supported in a stable position for rolling movement along the rails 75.

The wheels 76 and the axles 77 are secured to the mold by means of angle brackets 78. The brackets 78 are joined by longitudinal reinforcing stringers 80 joined by transverse channels 81 and an additional center bracket 82 is provided from which a depending pivot pin 83 projects to receive at its lower end a crank 84 driven by a motor 85. Upon actuation of the motor 85, the crank 84 will reciprocate the entire mold assembly 22 in a uniform harmonic motion to either side of the centerline 86.

THE COOLING AND SUPPORTING ASSEMBLY 23

As best illustrated in FIGURES 1 and 2, the slab 70, issuing from the mold 22 (FIGURE 3), is supported and moved longitudinally away from the mold by the supporting assembly 23. At the same time, the hot slab, having its center still molten, is flushed with coolant, such as water, to chill the slab to such an extent that the molten center is solidified.

As shown in FIGURE 1, the vertical supports 74 project upwardly from a lower support 90 which preferably is in the form of a tank containing a body of coolant liquid, such as water, at a substantially constant level 91. The elevated rails 35 for the vessel carriages 32 also are carried by the support 90.

Submerged in the body of coolant beneath the level 91 is a pump 92 which supplies coolant to conduits 93 in which nozzles 94 are interposed to spray coolant onto the upper and lower exposed surfaces of the slab 70 to aid in chilling the molten center 72 thereof. The liquid thus sprayed onto the slab 70 will gravity drain back into the tank 90.

The slab 70 is supported during such cooling on a plurality of support rolls 95 (FIGURES 1, 2 and 7) these rolls 95 being journaled in longitudinal support beams 96 supported from the base 90 on vertical posts 97. Each roll is driven by its own electric motor 98, and the upper periphery of each roll is horizontally aligned to provide an over-all horizontal support for the still hot slab from the mold assembly 22 to the traction assembly 24.

THE TRACTION ASSEMBLY

As best shown in FIGURES 1 and 14, the traction assembly 24 receives the solidified slab 70 from the support rolls 95. The function, of course, of this traction device is to exert a substantially constant tensile force upon the slab to pull the slab longitudinally from the fold assembly 22.

As best shown in detail in FIGURES 8 and 9, the traction device comprises a pair of vertical end plates 100 projecting upwardly from fittings 101 secured to the base 90 heretofore described. The end plates 100 journal a lower traction roll 102. An upper traction roll 103 is carried in a journal slide 104 mounted for vertical movement in a correspondingly shaped vertical slot 105 at the upper extremities of the end plates 100, the open upper end of this slot 105 being covered by an angular cover plate 106. The slide bracket 104 is carried by a generally U-shaped arm 107 having a first depending leg pivoted to the bracket 104, as at 108, and having a second depending arm 109 pivoted to the side plate 100, as at 110.

The arm 107 is constantly urged in a downward direction by means of a fluid pressure cylinder 111 secured to the arm 107 in general vertical alignment with the pivot 108, and secured at its upper end in fixed position to the support superstructure carrying the rails 35, as by a fitting 112.

The traction rolls 102, 103 are driven by meshing gears 113, 114, the gear 114 being driven by a suitable drive means, as by an electric motor 115, at a substantially constant speed. The gear 114 meshes directly with a drive gear 116 secured to the lower roll 102, while the upper gear 113 meshes with a second gear 117. The orientation of the gears 113, 117 and of the arm 107 is such that meshing contact will be maintained between the gears 113 and 117, despite slight vertical adjustments of the roll 103.

As noted above, the traction device 24 operates to exert a substantially constant tensile force upon the slab 70 issuing from the mold 22. The correlation of the speed of the traction assembly 24 and the speed of oscillation of the mold assembly 22 will be hereinafter described in greater detail.

THE SLITTER ASSEMBLY

As shown in the over-all view of FIGURE 1, and as specifically illustrated in FIGURES 10 through 13, the slitter assembly 25 serves to slit the billet into cross sectional shapes and configurations which might be desired as end products from the casting operation.

From FIGURE 1 it will be seen that the slitter assembly is located immediately behind the traction assembly 24. From FIGURE 10 it will be seen that this slitter assembly comprises two sets of shafts 120, each set comprising two shafts and the sets being vertically spaced to receive therebetween the cast slab 70.

The two shafts of each pair are joined by a longitudinally extending pivot link 121 and a vertically disposed hydraulic cylinder 122 acts on each link, there being four cylinders in all. Mounted on the shafts 120 are cylindrical rollers 123 of substantially equal axial extent and interposed between these rollers 123 are cylindrical spacers 124, the diameter of the spacers 124 being substantially less than the diameter of the rollers 123.

The rollers 123 of the upper and lower shafts 120 are each adapted to project radially into radial alignment with the spacers of the other shafts, respectively. Thus, it will be seen that upon actuation of the cylinders 122 from their retracted positions of FIGURES 10, 11 to their extended positions of FIGURES 12, 13, the upper rollers 123 are moved downwardly into contact with the still hot billet 70 and the cooperating rollers 123 of the upper shafts 120, and 123 of the lower shafts 120, serve to confine spaced portions of the slab therebetween so that the slab is subdivided into smaller bars, blooms or the like.

Referring to FIGURE 12 of the drawings, it will be seen that the first bar is provided by confining a portion of the billet between the periphery 125 of an upper roll 123 and the side surfaces 126 of a pair of adjacent lower rolls 123 and the periphery 127 of a spacer 124 on the lower shaft 120. Of course, the volume of the slab and the volume of the subdivided bars 130 remains the same, and thus it will be seen that the rolls 123 actually are moved by the cylinders 122 to such an extent that the peripheries of the rolls merely come into horizontal alignment. Thus, there is no actual interdigitation of the rolls 123 of the upper shafts 120 with the rolls 123 of the lower shafts 120.

Further, it will be noted that the shafts 120 are not driven. Rather, the slab is moved between the freely rotatable rolls by the driving force exerted thereon by the traction assembly 24.

The cutoff assembly 26 is illustrated in FIGURE 1 of the drawings. While this assembly is not illustrated in detail, it will be appreciated that the assembly comprises generally a reciprocating carriage mounted on lower support rails 140 and movable therealong by means of flanged wheels 141. The reciprocating carriage comprises a pair of side plates 142 joined by top and bottom plates 143, the side plates 142 journalling lower, longitudinally spaced support rolls 144. A pair of upper gripping rolls 145 is carried for vertical displacement relative to the side plates 142, in the same manner as the traction rolls 103 (of FIGURES 8 and 9) are carried, these rolls 145 being carried by pivot arms 146, actuated, respectively, by vertically disposed fluid pressure cylinders 147.

The reciprocating carriage of the cutoff assembly 26 carries a shear or burning assembly (not shown) by means of which the earlier formed rods or bars 130 can be sheared or burned to the desired length. The carriage reciprocates, so that actuation of the cylinders 147 to displace the gripper rolls 145 downwardly into engagement with the bars or rods will cause the complete carriage to move with the bars or rods as they are moved toward the right (as viewed in FIGURE 1) by the traction device 24.

Next, the finished cut-to-length bars or rods are introduced into the vertically movable starter bar and removal assembly, indicated generally at 27.

THE STARTER BAR AND REMOVAL ASSEMBLY

The assembly 27 comprises a lower vertically movable frame 150 having secured thereto at either longitudinal extremity a plurality of upstanding vertical guide members 151 bearing guide rollers 152, respectively, which engage guide channels 153, thus guiding the frame 150 for vertical displacement.

Carried by this frame 150 for vertical displacement therewith are a plurality of upstanding posts which are longitudinally spaced and which include the posts 154 maintaining in spaced parallel relation a pair of vertically spaced roller conveyor tables 155 and 156. These tables are spaced so that when the frame 150 is in its lowered position of FIGURE 1, the upper surface of the rollers of the table 155 are aligned with the bars or rods 130 issuing from the cutoff or burn-off mechanism 26, and the lower table 156 is disposed therebeneath in an inactive position.

When the frame 150 is elevated to its position of FIGURE 14, the lower roller table 156 is aligned with the bars or rods.

Also, from FIGURES 1 and 14 it will be seen that the frame 150 carries with it for reciprocation a second traction device 157 substantially identical with the traction device 24 heretofore described. Disposed upon the rollers of the table 156 is the dummy bar or starter bar 29 having its rear end normally disposed in the traction device 157 and having its forward end extending to the forward extremity of the table 156.

As shown in FIGURE 1, a vertical stop 158 is provided against which a cut-to-length bar or rod abuts to retain the bars or rods on the upper table 155. The bars or rods are then removed from this table by any suitable means, such as a crane or the like.

9 OPERATION

While the operation of the apparatus of the present invention may be comprehended from a study of the foregoing description, it is believed that the operation of this apparatus and the method itself should be explained, as hereinafter set forth.

Assuming that the apparatus is to be initially started with the mold assembly 22 empty, but with a ladle 30 in position illustrated in FIGURE 1 of the drawings, the first step is to insert the starter bar 29 into the mold cavity 60. It will be appreciated that two starter bars must be simultaneously inserted into the mold, such insertion occurring into each of the mold openings 71. Since the two bars 29 are identical, only one such bar and its insertion need be disclosed in detail.

The starter bar and removal assembly 27 is actuated to elevate the vertically movable frame 150 to its position of FIGURE 14, so that the starter bar 29 is longitudinally aligned with the cavity 60. Next, the traction device 157 is actuated to displace the starter bar toward the left, i.e. toward the mold assembly 22. The starter bar can be further actuated, if desired, by utilization of the reciprocal carriage 143. Of course, the slitter assembly 25 is actuated to its position illustrated in FIGURE 14, the slitter being elevated by means of the actuating cylinder 122 from contact with the starter bar. Finally, the starter bar is inserted into the mold by means of the traction assembly 24.

The starter bar, as best illustrated in FIGURE 4 of the drawings, is provided at its leading end, i.e. that end inserted into the mold space 60, with a reentrant recess 160, into which is transversely threaded a dumbbell pin 161 having an enlarged end 162 which projects into the mold space 60. Next, molten metal is introduced into the mold assembly 22 from the ladle 30 through the vessel 37. This molten metal enters the hollow chamber or reservoir space 48 and flows therefrom into the mold space 60. This molten metal in the mold space 60 is solidified by the coolant circulating through the passages 57, and this molten metal solidifies about the enlarged end 162 of the dumbbell insert 161. Since the insert is retained in the opening 160 of the starter bar, the bar and the metal are thus united. Next, the bar is withdrawn by the traction assembly 24 as more molten metal is introduced into the mold, until such time as the inner extremity of the starter bar passes the traction assembly 24, at which time the traction assembly then will engage the continuously cast ingot itself.

As the starter bar passes through the slitter assembly 25, the slitters remain withdrawn but the reciprocable carriage 143 and the cutoff assembly 26, including the carriage, is utilized to sever the starter bar from the ingot which is being cast. This can be very readily accomplished by use of the burner assembly or other severing device incorporated in the severing assembly 26. After severance, the starter bar travels onto the roller assembly 156, and the frame 150 is lowered by means of the actuating cylinder so that the bar receiving table assembly 155 is positioned as illustrated in FIGURE 1 to receive subsequently cast, slit and cut-to-length shapes.

Thus, it will be appreciated that the mechanism of the present invention provides for the insertion of the starter bars into the oppositely directed mold spaces 60 and the subsequent withdrawal of the starter bars to initiate the casting operation.

Considering now in more detail the casting operation itself, it will be seen that the utilization of the two ladles 30 and of the pouring vessel 37 makes possible the continuous casting of molten metal in a manner heretofore not possible. When one of the ladles 30 is empty, it is merely removed longitudinally along the rails 35 and removed by a crane to a teeming location, at which the ladle is refilled, while pouring from the other ladle is initiated. Further, the use of the vessel 37 spanning the

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two ladles makes possible the transition from one ladle to the other without any wasted time.

Additionally, the utilization of the nozzles 38 of the vessels 37 inserted into the reservoir space 40 of the mold 22 insures the steady pouring of molten metal without interruption and without splashing.

The vertically extending chamber or space 40 provides a head of liquid metal to flow smoothly and continuously downwardly therefrom through the cooled mold passages 60. The induction coils 50 serve the dual functions of heating the molten metal in the chamber 40 to maintain it molten and also in the lower laterally disposed chambers 49, while at the same time providing for induction stirring of the molten metal to prevent any possible segregation. This stirring of the molten metals is quite an important feature of the present invention inasmuch as segregation and separation of the steel components when in the molten condition has posed a problem in earlier continuous casting operations.

The hydrostatic or molten metal head in the center chamber 40 of the mold also aids in preventing surface defects since it prevents rimming at the water-cooled mold. This rimming is further prevented by the fact that the steel enters the mold from the quiet bottom of the reservoir provided by the upstanding mold cavity 40.

The diffuser rings 62 provide for the spreading of lubricant onto the surface of the molten metal at the point where the lubricant is specifically required, i.e. immediately before formation of the solidified skin on the molten metal as the molten metal passes through the chilled mold space 60. Such lubricants are well known in the prior art and the provision of the lubricant aids in preventing tearing of the cast ingot surface because of adherence between the chilled metal surface and the chill-mold walls.

Of course, as the molten metal passes through the chill-mold passages 60, the surface of the molten metal is chilled to an extent such that the skin is formed thereon, the thickness of this skin increasing as the metal progressively travels through the chamber 60.

The mold is oscillated by means of the motor 85 and the crank 84 at a predetermined amplitude and at a predetermined frequency. The speed of oscillation of the mold is carefully correlated with the speed of withdrawal of the ingot by the traction assembly 24. More specifically, the speed of withdrawal is such that the ingot travels transversely outwardly at a speed slightly less than the speed at which the mold is oscillated.

When the mold is traveling in the direction of withdrawal, this differential in speed tends to compress the metal in the chamber 60. Conversely, when the mold is traveling in the opposite direction during its reversal, the traction device tends to pull the ingot from the mold at a greater speed. This, of course, strips the partially solidified ingot from the chamber 60, while the earlier described compression effect tends to compress the partially chilled skin. It has been found that the subsection of the material in the chamber 60 to these alternate compression and tension effects cures any surface defects at the partially chilled periphery of the ingot while, at the same time, a constant over-all withdrawal rate is maintained.

The partially solidified ingot, exteriorly of the mold chamber 60, is supported upon the roller assembly while coolant liquid, such as water, is forced by the pump 62 through the conduits 93 to be sprayed over all exposed exterior surfaces of the ingot, thereby insuring complete solidification of the ingot before it attains the position of the traction device 24.

The operation of the traction device and the slitter device have already been described in detail, and there appears to be no reason to go into further detail at this time.

Similarly, the cutoff assembly 26 can utilize any desirable cutoff mechanism, and the assembly 27 is provided for the purpose of disposing of the cut shapes while, at

the same time, accommodating insertion of the dummy bars in the manner heretofore described in detail.

SUMMARY

From the foregoing, it will be seen that the present invention provides a large number of practical advantages over the previously utilized continuous casting apparatus and methods.

For example, the utilization of the reciprocating T-shaped mold, together with the specific pouring assembly 21 utilizing the two receptacles or ladles 30, provides for the continuous casting in a truly continuous fashion. Further, as a practical matter, the extensive lading facilities heretofore described, the elaborate tundish structures of the prior art, and the extremely troublesome tundish nozzle structures are all eliminated.

A second, general, over-all advantage of the arrangement of the present invention resides in the fact that the enormously high, complicated building arrangements heretofore necessary for vertical casting are completely eliminated. The utilization of the horizontal casting operation of this invention also avoids the necessity of elevating the molten steel to the extremely high pouring platforms necessary for vertical casting operations.

Further, the inherent limitations on size of cast product, length of cast product, and the necessity of transferring from a vertical as-cast position to a horizontal removal position are also eliminated by the present arrangement.

The heretofore utilized vertical continuous casting installations have necessarily provided relatively small casting molds which are arranged in a series of "strands" from which the final product issues as a relatively small bar. The present invention provides a solid ingot of appreciable size which can be subdivided, if desired, or which can be obtained as an integral ingot for subsequent processing. In any event, the tonnage output of steel is greatly increased.

An additional advantage flowing from the production of the ingots is the fact that there is less exposed surface of the steel and resultant oxidation during cooling is greatly reduced. Similarly, thinner shapes can be provided and, upon subdivision as by the proposed splitter, an almost infinite variety of shapes can be obtained from the still warm ingot.

Another related advantage which might not be immediately apparent is the fact that full mold contact is maintained by the combined effects of the head of molten metal in the upper portion 40 of the mold (maintaining, in effect, a hydrostatic head in the mold passage 60) and the fact that the sheer weight and mass of the ingot will resist compression during the outward oscillation of the mold, thereby outwardly distending the solidified skin against the walls of the chill mold. Additionally, the mass of the ingot aids in retaining the ingot in a fixed position as the mold is oscillated inwardly for stripping.

Numerous other advantages are obtained. For example, the horizontal reciprocation of the mold conforms to the natural level of the molten metal, any excess metal pushed toward one set of pinch rolls during oscillation merely flows toward the other pinch rolls, and there is no fluctuation in the molten metal level. Of course, the compression stroke within one chamber 60, is the tension stroke (or stripping stroke) in the other chamber 60, so there is no waste of motion or oscillation effort.

All in all, it is submitted that the present invention provides a new and novel method and apparatus for continuously casting steel.

I claim:

1. A method of continuously casting metal comprising the steps of introducing molten metal into a vertical holding chamber, flowing metal from said chamber in an unobstructed fashion horizontally in opposite directions through a thermally conductive chamber, respectively, each such conductive chamber completely peripherally confining the metal, cooling the metal as it flows through

said conductive chambers to form at least a peripheral skin thereon, further cooling the metal exteriorly of said chambers to substantially solidify the metal, horizontally withdrawing the metal from each one of said conductive chambers in opposite directions, and horizontally jointly reciprocating said chambers, so that the partially solidified metal is stripped from first one conductive chamber and then the other.

2. A method as defined in claim 1, including the additional step of injecting a lubricant at the location of the conductive chamber to facilitate the stripping thereof.

3. A method as defined in claim 1, including the additional step of heating the molten metal prior to its entry into said conductive chamber to prevent premature solidification of the metal.

4. A method as defined in claim 1, wherein the step of horizontally withdrawing occurs at a substantially constant speed.

5. A method as defined in claim 4, wherein the speed of horizontal withdrawal is less than the maximum speed attained by the chambers upon reciprocation.

6. An apparatus for continuously casting metal comprising a mold structure having a central vertical holding chamber and a pair of lower thermally conductive chambers each opening in an unobstructed fashion onto the holding chamber and projecting horizontally therefrom in opposite directions, means for introducing molten metal into said holding chamber for flow horizontally in opposite directions through said conductive chambers, means for cooling the conductive chambers to chill metal flowing therethrough to form at least a peripheral skin on the metal, means for further cooling the metal exteriorly of the chambers to substantially solidify the metal, means for horizontally withdrawing the metal from each one of said conductive chambers in opposite directions, and means for horizontally jointly reciprocating said chamber, so that the partially solidified metal is stripped from first one conductive chamber and then the other.

7. An apparatus as defined in claim 6, including in addition means for injecting a lubricant at the location of the conductive chamber to facilitate stripping thereof.

8. An apparatus as defined in claim 6, including in addition means for heating the molten metal prior to its entry into said conductive chamber to prevent premature solidification of the metal.

9. A method of continuously casting molten metal into a shape having improved surface characteristics comprising the steps of (1) introducing molten metal into a hollow mold having an upper vertical refractory-lined reservoir portion and a lower horizontal chilled leg portion, the reservoir portion and the leg portion having continuous interior passages in full communication with each other, (2) continuously flowing molten metal from said reservoir portion into and through said chilled leg portion in an unimpeded stream (a) so that the walls of the continuous interior passages are continuously wiped by the flow of the molten metal therethrough, and (b) so that substantially all of the metal introduced into the hollow mold is maintained in a dynamic state both in said reservoir portion and in said chilled leg portion, (3) chilling the metal as it flows through the chilled leg portion to solidify at least a complete peripheral skin on the metal prior to its issuance from said leg portion, and (4) stripping the at least partially solidified metal from said horizontal chilled leg portion of said mold.

10. A method as defined in claim 9, wherein the step (4) includes the steps of oscillating the hollow mold horizontally and withdrawing the partially solidified metal from the leg portion of the mold.

11. A method as defined in claim 10, wherein the oscillating step involves varying the speed of horizontal movement of the mold and the step of withdrawing is carried out at a substantially constant speed less than the maximum speed of the mold.

12. A method as defined in claim 10, including the

additional step of injecting a lubricant at the location of the conductive chamber to facilitate the stripping thereof.

13. A method as defined in claim 10, including the additional step of heating the molten metal prior to its entry into said conductive chamber to prevent premature solidification of the metal.

14. A method as defined in claim 10, and wherein the mold is provided with two oppositely directed horizontal chilled leg portions opening fully into said reservoir portion and through each of which molten metal flows from a common upper reservoir portion.

15. In a continuous casting apparatus for steel or the like, the improvements of a hollow mold having a vertical reservoir, a horizontal chilling mold passage and a joining passage interconnecting said reservoir and said mold passage, said reservoir and said joining passage being refractory lined and said chilling mold passage being circumscribed by water cooled metallic surfaces, the chilling mold passage being of substantially constant cross-section corresponding to the cross-section of the cast shape to be formed and said joining passage having that end adjacent the chilling mold passage of substantially the same cross-section and opening onto the chilling mold passage in full and open communication therewith, the other end of the joining portion opening fully onto the vertical reservoir without restriction to accommodate the free flow of molten steel through the joining portion and into the horizontal passage, the flow of molten steel from the vertical reservoir into the horizontal chilling passage being accommodated about a surface which is continuously wiped by the flow of molten steel therealong, and the overall flow path of molten steel from the vertical reservoir through the joining portion and into the chilling mold passage being substantially unimpeded and without dead spots, so that the molten steel flows freely therethrough in a constant dynamic state with the water cooled heat conductive surface of the chilling mold passage solidifying at least a complete peripheral skin on the metal passing therethrough, traction means engaging the at least partially solidified metal exteriorly of said mold to pull said metal from said mold leg, and means for horizontally oscillating said mold.

16. In a casting apparatus as defined in claim 15, the further improvements wherein two oppositely directed horizontal chilling mold passages are provided, each such chilling mold passage being interconnected with the reservoir through a separate joining passage which opens fully into said reservoir.

17. An apparatus as defined in claim 15, and wherein means are provided for injecting a lubricant at the location of the chilling mold passage to facilitate the stripping of molten metal therefrom.

18. An apparatus as defined in claim 15, and wherein means are provided for heating the molten metal prior to its entry into the chilling mold passage to prevent premature solidification of the metal.

19. In an apparatus for continuously casting metal, a mold including a vertical holding chamber and two opposite horizontal conductive chambers, each communicating with said holding chamber, each such chamber peripherally confining the metal flowing therethrough and each horizontal chamber being enclosed by a cooling jacket, each such conductive chamber defining a single interior space of substantially constant cross-section and opening fully onto the holding chamber so that the molten metal from said holding chamber flows freely in a dynamic state and without hang-up into and through said conductive chambers, means for introducing heat exchange fluid into said jacket to cool the metal as it flows through said conductive chambers, thereby forming at least a peripheral solidified skin thereon, means for withdrawing the metal from said conductive chambers, respectively, and means for horizontally reciprocating said mold.

20. In a continuous casting apparatus for steel or the like metals, means for simultaneously issuing two solidified metal slabs in opposite horizontal directions from a central molten pouring station comprising a mold of inverted T-shape and having a central vertical leg into which molten metal is introduced, said mold having two oppositely directed horizontal legs of heat conductive metal and receiving molten metal from said vertical leg, each of said horizontal legs and said vertical leg opening fully onto one another, means for cooling each of said horizontal legs to an extent such that the metal slab issuing therefrom is at least partially solidified, means for further cooling the metal slabs exteriorly of said mold to an extent such that said slabs are solidified but still hot, means engaging the solidified shapes exteriorly of said mold and tensioning the slabs to pull the same from said horizontal legs, respectively, at a substantially constant speed, means for horizontally reciprocating said mold to subject the metal in each horizontal leg to alternate compression and tensile forces, respectively, and means for slitting each of said still hot slabs into desired shapes and sizes.

21. An apparatus as defined in claim 15, and including means for further cooling the partially solidified metal to a fully solidified shape, means for slitting the solidified shape to form separate, discrete continuous lengths, and means for cutting said continuous lengths.

22. A method of continuously casting molten metal into a shape having improved surface characteristics comprising the steps of (1) introducing molten metal into a hollow mold having an upper vertical refractory-lined reservoir portion and a lower horizontal chilled leg portion, the reservoir portion and the leg portion having continuous interior passages communicating with and opening fully onto each other, (2) flowing molten metal from said reservoir portion into and through said chilled leg portion, (3) chilling the metal as it flows through the chilled leg portion to solidify at least a complete peripheral skin on the metal prior to its issuance from said leg portion, (4) stripping the at least partially solidified metal from said horizontal chilled leg portion of said mold, and (5) applying heat at the reservoir portion immediately adjacent the chilled leg portion in an amount sufficient (a) to prevent any premature solidification of the molten metal prior to its entry into the chilled leg portion and (b) to limit skin formation to that metal in said chilled leg portion.

23. The method of claim 9, including the further steps of completely solidifying said metal exteriorly of said mold and slitting said completely solidified metal into desired shapes and sizes.

24. The apparatus of claim 15, and including means for further cooling the partially solidified metal to a fully solidified slab, and means for cutting and slitting the slab to form separate, discrete lengths and sizes.

25. The method of claim 22, further comprising the steps of completely solidifying the metal shape exteriorly of said mold and slitting the completely solidified metal shape into desired shapes and sizes.

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