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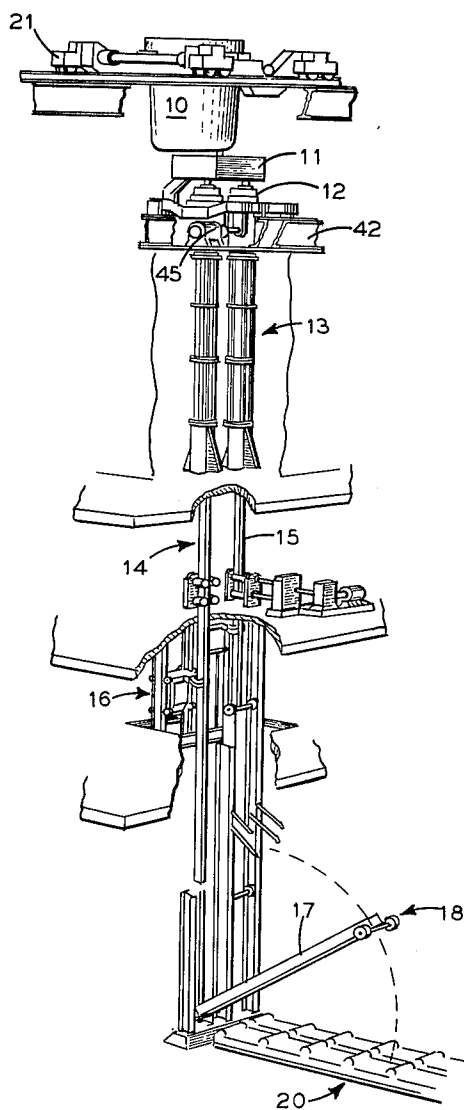
3,200,456

CONTINUOUS CASTING METHOD AND APPARATUS

Filed Sept. 12, 1961

2 Sheets-Sheet 1

FIG. 1



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FIG. 2

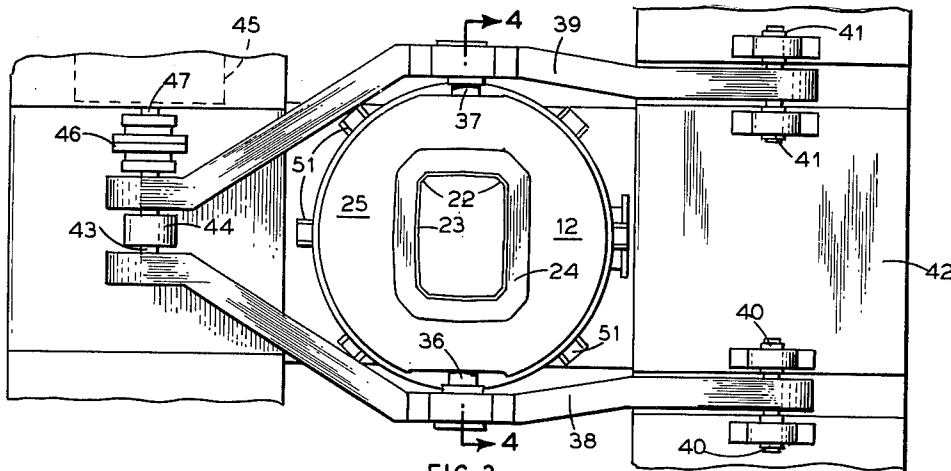


FIG. 3

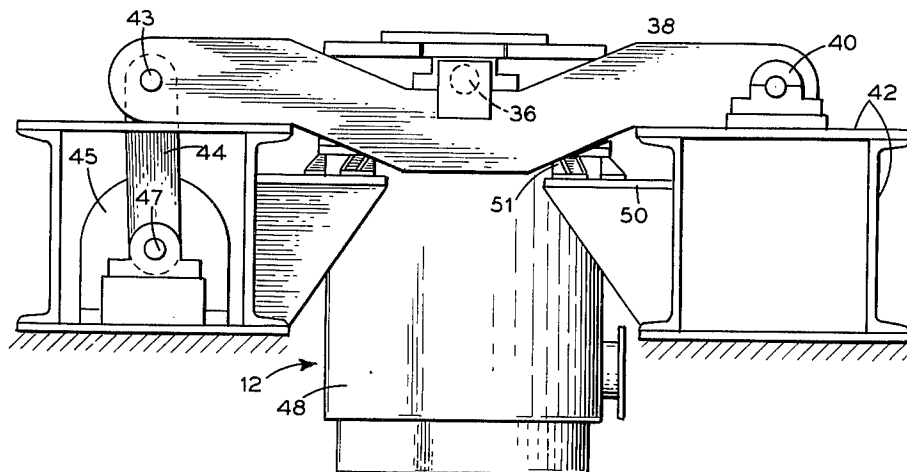
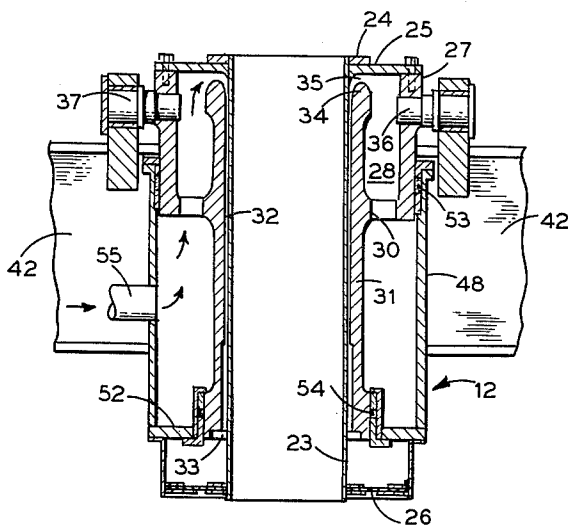


FIG. 4



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CONTINUOUS CASTING METHOD
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3 Claims. (Cl. 22—200.1)

The present invention relates to the continuous casting of metals and more particularly to improvements in the methods of an apparatus for the continuous casting of high melting temperature metals and alloys.

The continuous casting of metals is well established in the copper and aluminum field, but has not achieved as much success in the casting of high melting temperature metals, such as the ferrous alloys. While it is possible to continuously cast some particular ferrous alloys in certain sizes and shapes under commercially acceptable conditions, steel casting systems have been plagued by quality problems in the cast product. Such quality problems can take many forms such as internal porosity, pipe and cracks, or external defects including wrinkles, cracks and blow holes, or sometimes combination of external and internal defects. Some of the defects created in producing a casting can be corrected during subsequent working of the metal, as, for example, when internal voids may be healed during rolling or forging. Such healing can only occur when air is excluded from the voids during the healing or welding of the metal. However surface defects may be largely avoided by proper coordination of operating procedures during the continuous casting operation.

A continuous casting procedure is taught by U.S. Patent 2,682,691, wherein the mold is stationary and the casting withdrawal is intermittent, where the term includes "stop and run" of the casting withdrawal mechanism, as well as "fast and slow" withdrawal. Such a system teaches the operation of the withdrawal system so that the molten metal level within the mold varies through an amplitude of $\frac{1}{2}$ to 7 inches and a frequency of 2 to 10 cycles per minute. The advantage of this procedure is found in an increased heat transfer rate between the mold wall and the metal being cast due to the heat storage effect of the mold wall, as distinguished from other casting procedures where the molten metal level, in space, is maintained substantially uniform.

In the present invention, the "intermittent" withdrawal of the casting from a mold, preferably a continuous withdrawal at alternately fast and slow rates, is combined with vertical reciprocation of the mold so as to attain a high rate of casting production while at the same time obtaining a high quality product. While the reciprocation of the mold is of low amplitude and high frequency, the changing rate of the ingot withdrawal from the mold results in a relatively low frequency, high amplitude of molten metal level change within the mold. For example, it has been found that a mold reciprocation of 120 cycles per minute through an amplitude of $\frac{3}{16}$ to $\frac{3}{8}$ inch cooperates satisfactorily with a molten metal level change of 2 to 5 times per minute, under these conditions a high quality ingot can be produced from many steel alloys while maintaining a high production rate.

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 a preferred embodiment of the invention.

Of the drawings:

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FIG. 1 is a schematic elevation of a two string continuous casting unit incorporating the present invention;

FIG. 2 is a plan view of one of the continuous casting molds and its reciprocating mechanism, with the ladle and tundish removed for clarity;

FIG. 3 is an elevation of the mold and its reciprocating mechanism as shown in FIG. 2; and

FIG. 4 is a section taken on line 4—4 of FIG. 2.

As shown in FIGURE 1, the continuous casting unit is of the two string type and includes a common pouring apparatus such as a ladle 10 and tundish 11 for the delivery of molten metal to each of the continuous casting molds 12. With two casting strings, the casting arrangement is duplicated and a description of one is a description of both casting units. The molten metal is solidified, at least in part, within a mold 12 and is passed downwardly therefrom through an after-cooling section 13. Leaving the section 13 the casting is passed through a set of withdrawal rolls 14 which regulate the rate of movement of the ingot 15 from the mold. The cast ingot 15 is completely solidified in passing through the section 13 and in leaving the withdrawal rolls 14 will be cut to length for ease of handling by an oxygen lance 16 or the like. As shown in FIGURE 1, the cut lengths of casting or ingots 17 are removed by a handling mechanism 18 which lowers the ingot to a conveyor 20 for transportation to storage or points of further processing.

The ladle 10 is of the bottom pour type and is charged with molten metal from the furnaces (not shown), transported to the pouring location by an overhead crane (not shown) or other similar device, and mounted on a rail supported car 21 for exact positioning relative to the tundish 11. When the ladle is properly positioned molten metal is discharged therefrom through a bottom nozzle, at a rate controlled by a nozzle control rod for the delivery of the molten metal to the tundish.

In the illustrated embodiment of the invention, the tundish 11 is provided with two outlets for the controlled discharge of molten metal to the open upper end of each of a pair of continuous casting molds 12. The tundish is constructed and arranged for bottom pouring and for a maximum elimination of slag before the molten metal streams are delivered to the casting molds.

Each of the continuous casting molds 12 is mounted in an upright position to receive the molten metal at its upper ends and to permit the withdrawal of an embryo casting from its lower ends. As hereinafter described, each of the molds 12 is arranged for reciprocation along the vertical axis thereof to improve the quality of the cast product.

The embryo casting or ingot reaching the lower end of each mold will have a frozen skin of sufficient thickness to confine the molten metal core therein. In leaving the discharge end of the mold the ingot passes through the after-cooling section 13, wherein the ingot 15 is not only cooled by streams of water projected against the walls of the ingot, but the walls of the ingot are also supported by a roller support mechanism intended to avoid swelling of the casting. Such an after cooling and support section for continuous casting is shown in U.S. Patent 2,770,021.

Upon leaving the after-cooling section 13 the ingot will be completely solidified throughout its cross-section although the surface temperature thereof may be of the order of 1500° to 1800° F. The separate withdrawal mechanisms each engage the surface of each of the ingots, with the mechanism driven at a selected average speed so as to control the rate of movement of the ingot from the corresponding mold.

In the embodiment shown, the ingot leaving each of the withdrawal rolls is cut to preferred lengths by means of an oxygen torch. Since each ingot is moving through-

out the casting operation it is necessary for each torch to move with the respective casting 15 while cutting the ingot to the desired length. The cut length of ingot 17 from each string is engaged by a handling mechanism 18, which is pivoted, so as to transport the cut length of ingot 17 from a vertical receiving position to a horizontal discharging position. The ingot 17 is then removed from the casting unit by the roller conveyor 20.

According to the present invention each of the molds of the continuous casting unit is reciprocated in the direction of the longitudinal axis of the mold 12, for example, a rate of the order of 120 cycles per minute through an amplitude of from $\frac{3}{16}$ to $\frac{3}{8}$ of an inch does very well. The reciprocated mold is combined with a preferred mode of operating the withdrawal mechanism 14 so that the mold continuously moves relative to the ingot produced therein. In the present invention the withdrawal mechanism is operated in a cycle of fast and slow withdrawal rates, where the high speed portion of the cycle withdraws the casting at a greater rate than the delivery rate of molten metal to the mold, so that the molten metal level in the mold will be lowered. During the remainder of the withdrawal cycle the ingot is withdrawn at a slower rate than the rate of molten metal delivery to the mold, and the molten metal level within the mold will be rising.

With the fast and slow withdrawal cycle described, the molten metal level within the mold will vary between selected upper and lower limits where the distance between such levels may be of the order of $\frac{1}{2}$ " to 7". The two speeds of the withdrawal mechanism may be such as to produce a changing molten metal level within the mold of 2 to 7 times each minute. The fast and slow cycle of casting withdrawal and a control system therefore is disclosed in U.S. Patent 2,682,691. As described in said patent the withdrawal cycle may be of the "stop and go" type where the casting comes to rest for a short period of time in each of the withdrawal cycles. Preferably, however, the withdrawal mechanism is operated continuously, but at alternate fast and slow rates, so that the average rate per cycle of withdrawal of the casting from the mold 12 is approximately the same as the average rate of molten metal delivery to the mold.

The mechanism for reciprocating a mold 12 is shown in FIGURES 2 to 4. As shown in FIGURE 2, this particular continuous casting mold 12 is of generally rectangular horizontal internal cross-section where the internal configuration of the continuous casting mold is constructed with beveled corners 22, and with each of the sides of the mold bowed outwardly between the beveled corners. The illustrated constructure of the mold is intended to compensate for shrinkage of the cast metal and to avoid corner cracking in the cast ingot. As shown, the mold is roughly 8" by 11" in internal cross-section dimensions.

The constructional arrangement of the mold 12 and its supporting and enclosing housing is illustrated in FIGURE 4. As shown, the mold consists of an inner liner 23 which may be 20" to 45" in length and constructed with a thin wall, for example, .300 inch thick, and may be drawn as a one piece sleeve from phosphor deoxidized copper or of 85-15 red brass. The mold liner 23 is supported at its upper end by an attached flange 24 and an annular plate 25 with a flexible spacer or guide 26 at its lower end.

The annular wall 27 is formed as an integral part of a structure including an annular member 30 defining the perforated bottom of a cooling fluid distributing chamber 28, and an upright skirt 31 extending from an upper end spaced beneath the plate 25 to a lower end spaced above the lower end of the mold liner 23. The skirt 31 is constructed with its inner surface uniformly spaced from the outer peripheral surface of the liner 23 and cooperating therewith to define a cooling fluid flow passageway 32 for downward flow of fluid from the chamber 28 to an atmospheric discharge 33 at the lower end of the skirt.

The upper end 34 of the skirt 31 is rounded and cooperates with the lower surface to the plate 25 to define an anti-cavitational fluid inlet passage 35 to the passageway 32.

In the construction described, the mold liner 23 and the cooling fluid flow confining structure including parts 25, 27, 30 and 31 are mounted for reciprocation along the longitudinal axis of the liner 23. This is accomplished by vertical movements transmitted to pivot pins 36 and 37 mounted in the wall 27 on opposite sides of the mold (see FIGS. 2, 3 and 4), with the opposite ends of the pins 36 and 37 mounted for rotational movement in arms 38 and 39, respectively. The arms are mounted for pivotal movement about a fixed axis formed by bearings 40 and 41, respectively, where the bearings are supported on the structural member 42 of the continuous casting unit. The opposite end portion of the arms 38 and 39 are bent in a converging direction to embrace a common pivot shaft 43 which is provided with depending rod 44 positioned between the ends of the arms 38 and 39. The rod is reciprocated in a substantially vertical plane by an eccentric drive mechanism including a motorized speed reducer 45 connected through a coupling 46 and a shaft 47. In the arrangement described the rotation of the shaft 47 reciprocates the arms 38 and 39 so that the mold liner 23 and parts 25, 27, 30 and 31 move in a vertical direction at an amplitude and frequency determined by the configuration of the eccentric driving the rod 44 and the rotational spacing of the shaft 47.

The reciprocating movement of the mold liner is guided by a fixed housing 48 which is mounted on the structural member 42 by brackets 50 and ribs 51. As shown in FIG. 4, the upper portion of the housing 48 encircles the lower outer wall portion of the shield 27, while the lower end of the housing is provided with a horizontally disposed flange 52 having its inner periphery spaced closely adjacent the lower outer surface of the skirt 31. The upper end of the housing 48 and the inner end of flange 52 are each provided with a lubricated seal slip joint 53 and 54 engaging the reciprocating portion of the casting mold. With this arrangement the reciprocating mold portion is guided so as to maintain the axial movement of the mold liner. With the housing 48 stationary, the cooling fluid inlet pipe 55 is attached thereto and discharging into a plenum chamber 56 for upward movement through the openings 57 in the plate 30.

It will be understood that other forms of mechanisms can be utilized for controlled reciprocation of the continuous casting mold, providing the mechanism is separately driven and adjustable as to amplitude and frequency of the mold reciprocation.

In the operation of the continuous casting system described, the reciprocation of the mold combines with the "intermittent" withdrawal of the casting to produce a high quality ingot at a commercial production rate. It is believed the small rings or segments of the initially frozen metal are torn free from the mold wall during each cycle of mold reciprocation, thus preventing the growth of a weak shell of frozen metal which might adhere to the mold wall. Continued growth of such a shell would eventually result in a "hanger" which would tear away from the stronger shell of the casting during the withdrawal of the casting from the lower portion of the mold. Sometimes such hanger formations can cause a "run out" of molten metal below the low end of the mold, and frequently causes irregularities on the surface of the cast product. It is believed the torn segments of initially frozen metal stripped from the wall of the mold fall into the molten metal to reduce the superheat thereof and thereby permit a more regular and rapid solidification of the casting shell at a lower position in the mold. The intermittent withdrawal of the casting system is more fully described in U.S. Patent No. 2,682,691, where the controlled rise and fall of the molten metal level within the mold cavity, presents a colder mold surface to incom-

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ing metal than would be the case when the molten metal level within the mold is reasonably constant. Such a procedure aids in increasing the rate of heat removal from the metal and increases the permissible casting rate.

While in accordance with the provisions of the statutes we have illustrated and described herein the best form and mode of operation of the invention now known to us, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of our invention may sometimes be used to advantage without a corresponding use of other features.

The claims are:

1. In the continuous casting of metal wherein molten metal is delivered at a substantially continuous rate to an upright open ended fluid cooled mold and an embryo casting is withdrawn from the opposite end of said mold, the method of operation which comprises withdrawing the embryo casting from said mold in a pattern of changing withdrawal rates to vary the molten metal level in the mold between a range of selected upper and lower limits, and separately reciprocating the continuous casting mold in an axial direction.

2. In the continuous casting of metal wherein molten metal is delivered at a substantially continuous rate to an upright open ended fluid cooled mold and an embryo casting is withdrawn from the opposite end of said mold, the method of operation which comprises withdrawing the embryo casting from said mold in a low frequency pattern of changing withdrawal rates to vary the molten

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metal level in the mold between a range of selected upper and lower limits, and reciprocating the continuous casting mold in an axial direction at a frequency many times greater than that of the variation in molten metal level.

3. In the continuous casting of metal wherein molten metal is delivered at a substantially continuous rate to an upright open ended fluid cooled mold and an embryo casting is withdrawn from the opposite end of said mold, the method of operation which comprises withdrawing the embryo casting from said mold in a pattern of changing withdrawal rates to vary the molten metal level in the mold between a range of selected upper and lower limits, and reciprocating the continuous casting mold in an axial direction at a frequency greater than that of the variation in molten metal level within said mold, and at an amplitude less than the amplitude of the variation in molten metal level within said mold.

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