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CONTINUOUS CASTING

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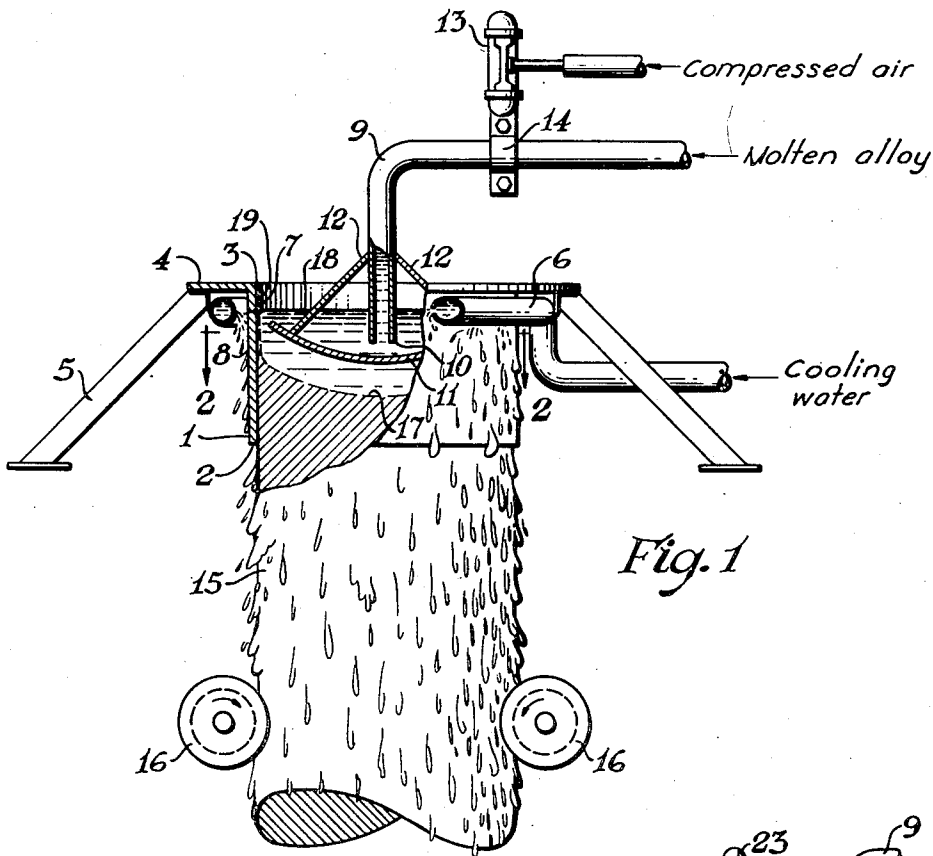


Fig. 1

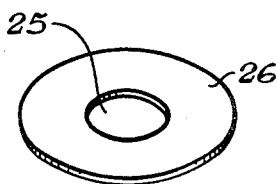


Fig. 4

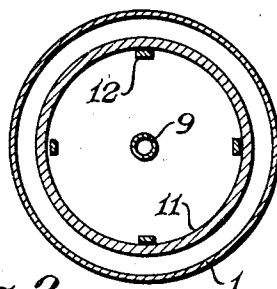


Fig. 2

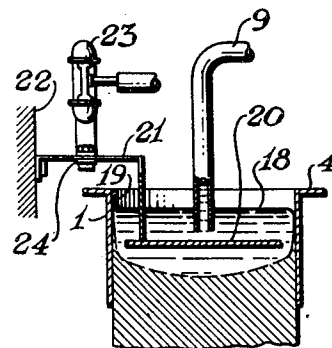


Fig. 3

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## CONTINUOUS CASTING

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1 Claim. (Cl. 22—57.2)

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The invention relates to an improved apparatus for the continuous casting of metal and is particularly advantageous in forming ingots of magnesium-base alloy.

One of the well-known processes for the continuous casting of ingots involves introducing molten metal continuously into one end of a permanent mold to form a liquid metal pool in the upper end, cooling the metal to cause it to solidify in the mold, and withdrawing the solid metal so formed continuously from the other end of the mold. The process, however, has the disadvantage that the surface of the ingot is not generally smooth. Instead, it is usually indented by folds or creases formed apparently as a result of irregularities in the manner in which the liquid metal at the edge of the upper surface of the pool moves toward and solidifies against the mold wall. The movement of metal in the upper surface toward the mold wall and the way in which the metal lies against the mold is affected by the oxidic film normally covering the exposed metal surface and by the reduction in temperature and resulting decrease in fluidity of the metal as it approaches the mold wall. Particles of solidifying metal may also form in the liquid metal near the surface of the pool adjacent to the mold and interfere with the metal lying smoothly against the mold wall. However the folds and creases may be formed, such blemished surface of the ingot must be removed as by machining to make the ingot useful for many purposes, as for example, extrusion. Not only does this considerably increase the cost of the ingot but it also wastes a significant percentage of the metal as the entire surface of the ingot generally must be machined off to the depth of the deepest indentation.

The continuous casting in this manner of magnesium-base alloy, which is quite readily reacted upon by the ambient atmosphere when the metal is molten forming a tough oxidic skin, gives rise to creasing and folding of the metal adjacent to the mold wall to a very severe extent. In addition, segregation or stratification of alloying constituent usually occurs, being greatest at the external cast metal surface and extending to a depth of one-half of an inch or more into the ingot. Such segregation gives rise to hot short cracks when such ingots are used for making extrusions. This problem is further magnified in the case of magnesium-base alloys containing from 3 to 10 per cent of aluminum as the major alloying element, since the somewhat unusual manner of solidification of these alloys renders sub-surface segregation or stratification to be almost inevitable. Such segregation is further ag-

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gravated by the creases, laps, and folds produced in the surface of the ingot because the points of the beginning of the segregation are deepened to the depth of the creases, laps, and folds.

It is an object of the invention to provide an apparatus for the continuous casting of metals and particularly of magnesium-base alloys in a mold, as briefly described above, which prevents surface indentations due to creasing, lapping, or folding of oxidic skins adjacent to the mold wall and reduces the depth of stratification of the metal adjacent to the mold.

Other objects and advantages will appear as the description of the invention proceeds.

These objects are obtained in a continuous casting process and apparatus of the invention in which excessive indentation of the cast metal surface due to creasing, folding or lapping of the metal is obviated and depth of segregation adjacent to the mold wall is reduced by subjecting the molten portion of the metal within the mold to an undulatory motion of relatively low amplitude and frequency, so as to create undulations in the upper surface of molten metal while the mold remains in a substantially fixed position. The actual frequency and amplitude of undulations do not appear to be critical as effective results are obtained over a relatively wide range of magnitude of these factors. The area of exposed molten metal surface appears to be a factor and determines to some extent the amplitude and frequency required. In order to impart the undulatory motion to the molten metal so as to create the desired undulations, we oscillate a submerged, preferably horizontal paddle therein, the oscillations being largely in the vertical direction. Any suitable relatively thin object, whose dimensions as to length and width are maintained in a more or less horizontal plane, preferably under the pouring spout, and large enough to extend to near the mold wall, may be used as a paddle. One of the most advantageous forms of the submerged paddle, for cylindrical molds, is a circular horizontal disc or dish having a diameter somewhat less than that of the interior diameter of the mold and centrally disposed therein, just below the pouring spout, so that the flow of liquid metal into the mold is baffled and deflected laterally at the same time as the oscillatory motion is imparted to the molten body of metal to create a current surge in the liquid in the region of the junction of the mold wall and the metal surface and to create undulations therein. For rectangular or other shapes of molds, the baffle or paddle is given a peripheral shape preferably corresponding to that of the horizontal cross section of

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the mold, allowing a clearance of about  $1\frac{1}{2}$  inch or more between the edge of the baffle and the mold wall, the submergence being  $\frac{1}{2}$  inch to  $1\frac{1}{2}$  inch or more.

The invention may be further explained with reference to the accompanying drawing.

In the said drawing:

Fig. 1 illustrates in vertical partial section one form of apparatus embodying the principle of the invention.

Fig. 2 is a section on the line 2-2 of Fig. 1.

Fig. 3 is a fragmentary view of Fig. 1 showing a modification thereof.

Fig. 4 is a perspective view of an alternate form of baffle for producing undulations in the liquid metal surface.

In the several views like numerals designate like parts.

As shown in Figs. 1 and 2, a magnesium ingot is continuously formed in a hollow cylindrical thin wall mold 1 open at the bottom 2 and top 3 and attached to a flange 4 resting upon a suitable substantially rigid supporting means 5. Surrounding the mold near the upper end is a cooling fluid distributor 6 with openings 7 directed toward the exterior of the mold wall 8. Molten metal is introduced into the mold continuously through a pipe 9 from a source of molten metal (not shown). Below the lower open end 10 of the pipe 9 is a submerged baffle 11, which also functions as a deflector and is secured to the pipe by brackets 12. A pneumatic vibrator 13 is secured to the pipe 9 by a clamp 14 and serves to impart vibrations to the baffle 11 by motion imparted to the pipe 9. The solidified ingot 15 is guided by pinch rolls 16 as the ingot forms and descends below the mold, the rate of descent being controlled by regulating the speed of rotation of the pinch rolls to maintain an appropriate balance with the rate of introduction of molten metal to the mold.

In the modification of Fig. 3, the paddle or baffle 20 in the form of a flat disc is held in the molten metal beneath the pipe 9 by a bracket 21 secured to a support 22. Vibratory motion, mostly in the vertical plane, is imparted to the baffle by the vibrator 23 secured to the bracket 21 by the clamp 24.

The alternate form of baffle, shown in Fig. 4, may be secured to either the bracket 21 which is mounted independently of the pipe or the brackets 12 which are supported by the pipe. The opening 25 may be positioned so as to be directly below the pipe if desired. The diameter of the annular ring 26 is made preferably from about  $\frac{1}{2}$  to  $1\frac{1}{2}$  inch less than the internal diameter of the mold, and these dimensions may be followed with the other baffle shown in Figs. 1 and 3.

In operation of the apparatus and method, a cooling fluid is directed from pipe 6 against the mold so as to abstract heat from it and to cool the ingot below the mold wall, the boundary between the solidified metal at the top of the ingot and the molten metal being generally dish-shape, as shown at 17.

While the metal is thus continuously cast, the baffle or paddle is continuously vibrated, preferably in the vertical plane, so as to impart an undulatory motion to the unso'ldified or liquid metal in the mold creating a continuous series of undulations, like waves, in the liquid surface. With the modification of Fig. 1, this is accomplished by operating the pneumatic vibrator 13 so as to oscillate the pipe 9 and its attached baffle

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or paddle 11, preferably in the vertical direction. We have found that oscillating the baffle up and down with an amplitude of from about 0.05 to 0.2 of an inch or more and with a frequency of 5-50 cycles per second produced satisfactory results, although other frequencies and amplitudes may be employed. In the modification of Fig. 3, the baffle 20 is similarly oscillated by the vibrator 23, the oscillations being imparted to the baffle by the support 21 independently of the pipe. Other forms of baffles or paddles, such as shown in Fig. 4, may be used with either the modification of Fig. 1 or 3. If desired, the baffle may be perforated with a series of holes.

The undulations thus produced in the molten metal have the effect of continuously breaking the oxidic film which normally forms on the surface 18 of the molten metal. As a result, the film moves toward the inner surface 19 of the mold in more or less discontinuous pieces and does not form tenacious skins or folds to indent the surface of the ingot. Instead, the oxidic film, being broken into substantially discrete particles, causes the convexity of the meniscus to be greatly reduced so that the oxidic particles and metal lie smoothly against the mold wall as the casting proceeds without producing laps or folds, and there is a corresponding reduction in depth of segregation or stratification otherwise produced at the interface between the mold and the solidifying metal.

In the use of this method with magnesium-base alloys, that is, alloys in which the magnesium content amounts to 80 per cent or more of the weight of the alloy, ingots having rectangular and circular cross sections of various diameters of from about 6 to 16 inches have been cast continuously in unbroken lengths of several hundred feet with no significant indentation of the surface of the ingot due to creases, laps or folds in the wall of the casting, and the depth of segregation or stratification of the alloying constituents adjacent to the surface has been greatly reduced. In addition by means of the invention, these desirable results are achieved without adversely affecting the grain structure of the cast metal.

We claim:

In a metal casting apparatus, in combination with a mold adapted to contain a pool of molten metal, a delivery means positioned in said mold to feed metal to said pool and a baffle positioned in said mold to contact the pool therein, means for supporting said baffle in said mold, said means comprising an arm fixed to said baffle and mounted at a point removed from said baffle and means for periodically and momentarily applying a force to said arm at a point beyond said point of support to cause momentary displacement of said arm from its normal position.

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