July 9, 1968 I. ROSSI 3,391,725

PROCESS AND APPARATUS FOR COOLING AND SUPPORTING A CONTINUOUS CASTING STRAND

Filed Jan. 13, 1966 2 Sheets-Sheet 1

FIG. 1

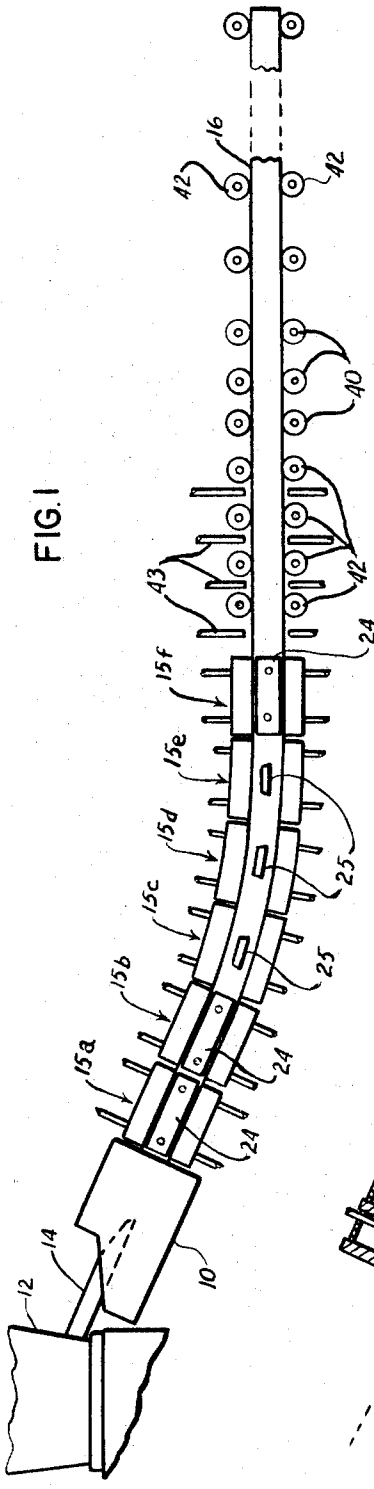
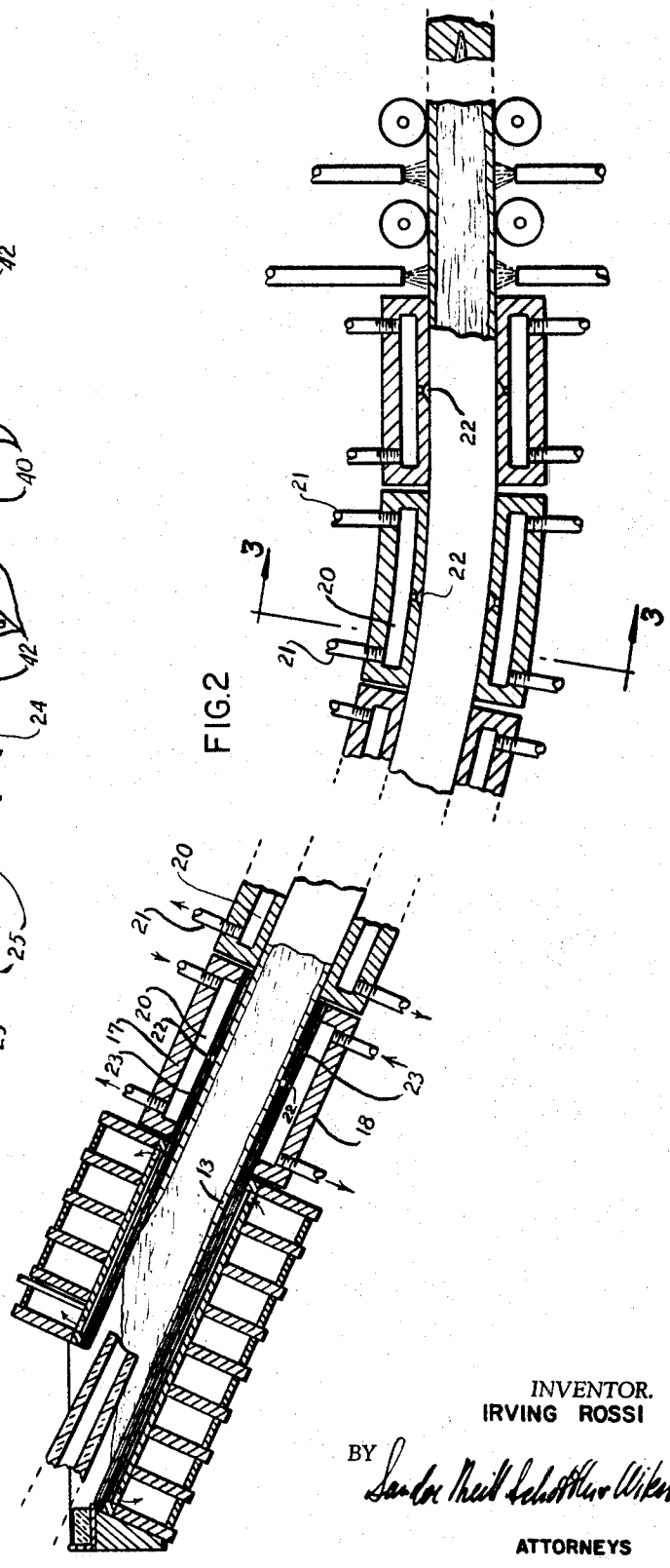


FIG. 2



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FIG.3

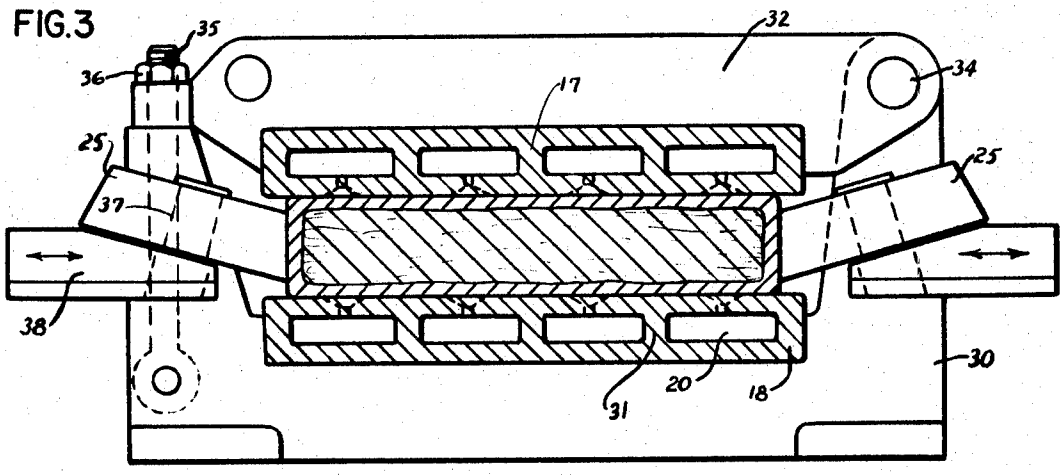
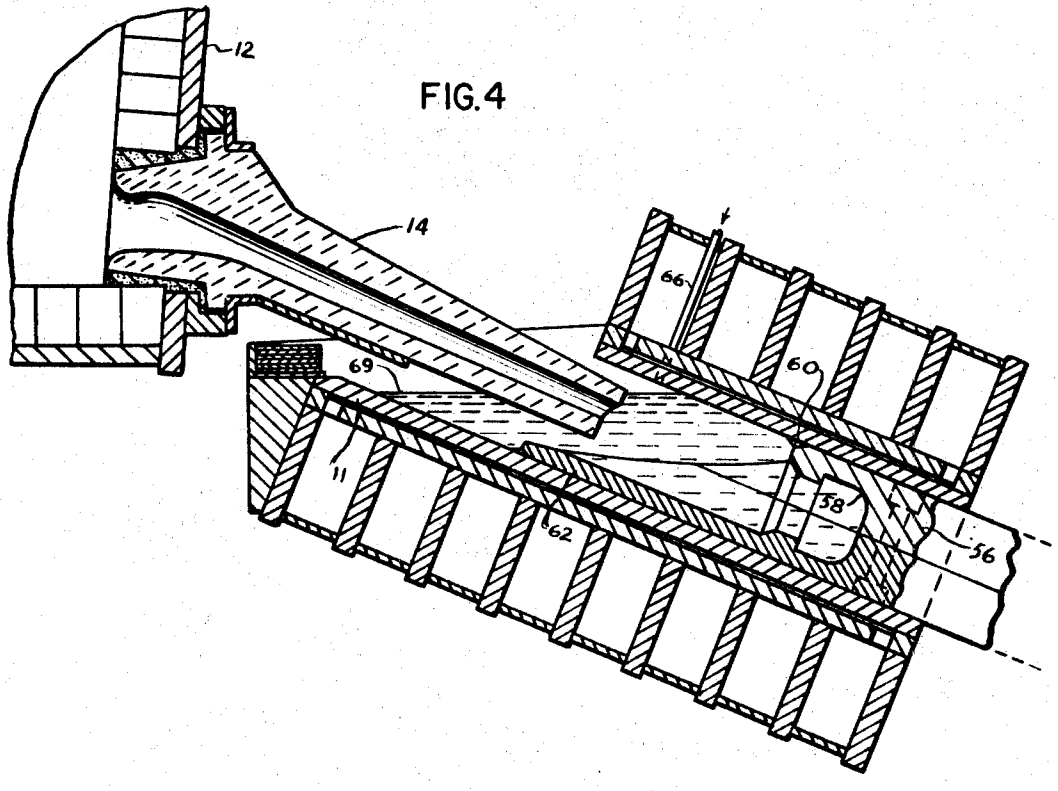


FIG.4



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PROCESS AND APPARATUS FOR COOLING AND SUPPORTING A CONTINUOUS CASTING STRAND

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11 Claims. (Cl. 164—89)

ABSTRACT OF THE DISCLOSURE

Method and apparatus for the continuous casting of steel wherein an open-ended mold is inclined from the horizontal sufficiently for molten metal to be poured into the open upper end thereof. From the lower end of the mold a strand of metal having a thin solidified peripheral skin passes through a passageway in which the strand is supported and which first bends the strand more to the horizontal and then straightens the strand while maintaining a temperature of the strand in the passageway such that the thickness of the solidified skin does not increase substantially. The major portion of the solidification of the strand therefore does not occur until after the strand emerges from the passageway in straight condition.

This invention relates to continuous casting of steel and pertains more particularly to methods and apparatus for the continuous casting of steel which makes it possible for the major portion of the solidification of the casting to take place while the solidifying strand is being transported in a substantially horizontal direction.

In the usual methods for the continuous casting of metals, the molten metal is poured into an open ended mold. The mold chills the periphery of the metal and solidifies the periphery to define a strand which is withdrawn continuously from the mold while molten metal is poured continuously into the mold at a rate adjusted to equal the withdrawal rate. After issuing from the mold, the strand is cooled as, for example, by water sprays directed on the strand to form a solidified strand. The cooling applied to the strand after it issues from the mold is known in the art as secondary cooling and is sufficient to complete the solidification of the strand.

In most continuous casting installations, the axis of the mold is vertical and the strand issues vertically downwardly therefrom. After the strand is completely solidified, pieces of the desired length are severed from the moving strand. Because it is necessary that the strand be completely solidified before cutting, casting speeds have been limited by vertical height considerations. That is, it has been necessary to limit casting speeds in order to permit complete solidification to take place within reasonable vertical dimensions between the mold and the cutting station. Otherwise, plant construction costs become excessive.

In the casting of steel, these problems have been of particular concern because of the high temperature of the molten steel, and the long time required to completely solidify the strand. For example, in typical installations for the continuous casting of steel, a distance of seventy feet between the mold and the cutting station is not uncommon, and even this distance requires restriction of the casting speed to less than that which is theoretically possible.

In order to reduce the vertical height requirements, it has been proposed to cast the strand in a vertically disposed mold, then to cool the emerging strand in a vertically disposed secondary cooling zone in which the casting is supported by rollers. The strand is then bent toward the horizontal by pairs of pressure rollers. In such

installations, the strand is bent through an arc of approximately 90° so that the bent strand becomes tangent to the horizontal. At the tangent point, the strand is rebent and straightened by pairs of pressure rollers, and it is then transported horizontally to a cutting station. This permits some reduction of machine height, but has not provided a satisfactory solution of the problem because a bending arc of relatively long radius is required. Even with a long radius, there is still difficulty in bending and rebending the solidified casting without cracking or otherwise damaging the casting.

It has also been proposed to cast the strand in a vertically disposed mold in which the axis of the mold passage is curved as disclosed in Schneckenburger Patent No. 2,947,075. In such a mold, the strand is cast in an arc and the emerging strand is cooled by water sprays in a secondary cooling zone immediately below the mold. Within the secondary cooling zone, the strand is supported by rollers to maintain the arc in which it is cast and, when tangent to the horizontal, the strand is straightened by pairs of pressure rollers for horizontal withdrawal and transport to a cutting station. This development also permitted some reduction of machine height, but again a relatively large arc of relatively long radius is required and, thus, a substantial vertical height is still required.

Although the constructions above described reduce the vertical height of the casting apparatus somewhat, casting speeds are limited. Moreover, the use of supporting rollers in a secondary cooling zone located immediately below the mold presents problems. Within this zone, and particularly near the mold, the peripheral skin of solidified metal is thin, and the hydrostatic head of molten metal causes bulging of the skin in the intervals between successive pairs of rollers. This action of successive bulging and compressing of the skin may cause rupture of the skin and consequent breakout of molten metal, and even under best conditions frequently results in surface cracks.

Throughout the development of continuous casting, it has been considered desirable to cast in a horizontally disposed mold. It has been recognized that this would not only permit maximum reduction of machine height, but would also provide the most desirable orientation of the cast strand from the viewpoint of secondary cooling, cutting and further processing. For example, with a horizontal strand, the distance between the mold and the cutting station loses significance, for in most plants, ample floor area can be easily provided. Therefore, with a horizontal strand, it is possible to cast at maximum speeds, and to adjust the distance from mold to cutting station as necessary.

Horizontal molds have been utilized heretofore for the continuous casting of aluminum in machines in which the molten aluminum is introduced into a horizontal mold through a refractory feed spout which extends through the end wall of the mold. When casting aluminum, the feed spout is not wet by the molten aluminum and it remains clean as casting proceeds. However, when casting steel, and in particular, where it is desired to use an oscillating mold, this type of horizontal mold with a refractory feed spout cannot be employed. It has been found that steel wets the spout and solidifies around the spout. The solidified steel tends to build up a false tube extending the length of the mold, resulting in a breakout of molten metal at the exit end of the mold.

It is an object of the present invention to provide a method for the continuous casting of steel in which, recognizing that it has not been possible to pour molten steel successfully into a horizontal mold, the mold, in which the molten metal is initially chilled to form a thin skin of solidified metal, is separated from the secondary cooling zone in which solidification is completed, by a

bending zone in which, by suitable control of temperatures, the direction of movement of the partially solidified strand may be changed without damage to the solidified skin. Thereby, utilizing a mold the axis of which is sufficiently inclined to the horizontal to permit pouring of molten metal into the open upper end thereof, it is possible to change the direction of the partially solidified strand to deliver it horizontally to a horizontally disposed secondary cooling zone. It will be understood, however, that it is not essential that the strand be delivered precisely horizontally, and that the advantages of the invention may be realized in installations in which for structural or other reasons, it may be desirable to deliver the strand in a direction which is somewhat inclined to the horizontal.

According to the present invention, molten steel at a temperature of approximately 3000° F. is poured continuously into the upper end of an open ended mold having a mold passage therethrough the axis of which is inclined to the horizontal. In accordance with prevailing practice, the mold lining is preferably made of a metal of high thermal conductivity, such as copper, and the mold is chilled by circulating coolant, such as cold water, therethrough.

The mold passage may be of any desired shape in transverse cross section, as for example, circular, square or rectangular.

In casting, the molten metal in the mold is chilled by withdrawal of heat through the mold walls to form a thin peripheral skin of solidified metal surrounding the molten metal within. The rate of withdrawal of heat is controlled with relation to the casting speed, by regulation of the rate of circulation of the mold coolant, or otherwise, so that the temperature of the exterior surface of the peripheral skin of solidified metal as it emerges from the mold does not exceed 2500° F. and is not less than 2000° F.

The emerging partially solidified strand is then conducted through a supporting passageway within which the strand is first bent and then straightened in order to change the direction of movement of the strand as it moves through the passageway so that it may be delivered in straightened condition to a substantially horizontal cooling zone for final cooling and solidification.

The said supporting passageway may be formed by a series of members which have surfaces which engage and support the strand, and which are arranged to provide a curved section of the passageway. As the strand enters the curved section, it is bent, and as it leaves the curved section, it is straightened. The said members have provision for circulation of coolant therein. Additionally, such members may have provision for direct application of a small quantity of coolant to the strand through the walls of the passageway in order to lubricate the passageway to facilitate the bending and straightening of the strand and the movement of the strand therethrough.

As the strand moves through the supporting passageway, it is important that the thin skin of solidified metal which is formed in the mold be maintained in order to prevent remelting by absorption of heat from the molten interior. On the other hand, in order to permit the strand to be bent and straightened without damage thereto, it is important that the thickness of the thin skin should not be increased substantially.

Therefore, while it is necessary to chill the strand as it moves through the supporting passageway to maintain the thin skin of solidified metal, it is desired to restrict the chilling within the supporting passageway to nearly the minimum required. For this purpose, the rate of heat withdrawal is controlled by regulation of the rate of circulation of coolant, or otherwise, to maintain the exterior surface of the skin as it emerges from the supporting passageway at a temperature not exceeding 2000° F. and not less than 1300° F.

As the strand emerges from the supporting passageway, it is conducted through a secondary cooling zone wherein it is chilled to complete the solidification thereof.

While the strand is being conducted through the secondary cooling zone, it is supported and maintained in its straightened condition until solidification is completed. For example, the strand may be supported from below on a series of closely spaced parallel rollers whose axes lie in a common plane. As the strand emerges from the supporting passageway it is received by said rollers, or other supporting structure, on which it may be transported to a cutting station while it is being chilled.

Preferably, the chilling in the secondary cooling zone is by direct application of coolant to the surfaces of the strand, as by water sprays directed against the surfaces.

The casting is withdrawn by driven pressure rollers, which advance the entire strand from the casting mold through the supporting passageway and through the secondary cooling zone.

Since the distance is very short from mold to the secondary cooling zone and the withdrawal forces very low, the withdrawal rollers may be positioned at the beginning of the secondary cooling, despite the fact that the strand skin is thin at this point.

A preferred embodiment of apparatus suitable for the practice of the invention is shown in the accompanying drawings, of which:

FIG. 1 is a side elevation of a continuous casting plant in accordance with the present invention;

FIG. 2 is a sectioned side elevation of a portion of the plant of FIG. 1 to enlarged scale;

FIG. 3 is a sectional view taken along lines **3—3** of FIG. 2; and

FIG. 4 is a sectional view of a mold showing the dummy head in place for start of casting.

In the figures, the the apparatus comprises an open ended mold **10** into which molten steel is poured continuously from a tundish **12** via a spout **14** entering the open upper end of the mold **10**. The mold is water cooled and the interior of the mold is lined with copper face plates **11** which are in engagement with the molten metal and permit rapid withdrawal of heat. As heat is withdrawn, the periphery of the molten metal solidifies to form a thin peripheral skin **13** defining a strand which is withdrawn continuously from the mold. If desired, the mold may be oscillated along the axis thereof as is well known in the continuous casting art. As the strand emerges from the mold, it enters and is conducted through a supporting passageway which is preferably composed of a plurality of section members **15***a*, **15***b*, **15***c*, **15***d*, **15***e* and **15***f*. The apparatus illustrated in the drawings is adapted for the casting of slabs **16**. Each section of the passageway comprises a top plate **17** and a bottom plate **18** which are mounted and held in spaced relationship by a suitable supporting structure. The plates are hollow and are water cooled by the circulation of cooling water through the hollow cavities **20** via the intake and outlet pipes **21**. Provision is also made for applying a small amount of the cooling water directly to the strand through the ports **22** which extend through the slab engaging face of the top and bottom plates. The ports communicate with the cavities of the plates and the pressure therein is regulated so as to discharge water through the ports **22**. The water so discharged serves to lubricate the passageway and facilitates the movement of the casting therethrough.

As will be noted, sections **15***a* and **15***b* of the passageway immediately below the mold are straight, sections **15***c*, **15***d* and **15***e* are curved and section **15***f* straight. As the strand moves from sections **15***a* and **15***b*, it is bent slightly to assume the curvature of section **15***c* and this curvature is maintained during the movement of the strand through sections **15***d* and **15***e* while the direction of movement of the strand is being changed from the direction in which it is initially formed in the mold to a horizontal or substantially horizontal direction. Then, as

the strand moves from section 15*e* into 15*f*, it is straightened so that it emerges from section 15*f* in straightened condition.

The first section 15*a* is preferably straight in order to ensure against the possibility of rupture of the thin skin of solidified material which is formed within the mold and to permit some stabilization of temperature conditions before the strand is bent. For this purpose, the face plates 23 of top and bottom plates of section 15*a* are copper plates. Preferably, however, the top and bottom plates of sections 15*b*, *c*, *d*, *e* and *f* are made of cast iron.

It will also be noted that section 15*b* is straight. As the strand is bent by section 15*c*, the strand will apply a reaction force against the side walls of the section immediately preceding section 15*c*. Although in some cases, section 15*a* could precede section 15*c*, the application of the reaction force against the soft copper plates of section 15*a* are desirably avoided. For this reason, section 15*b*, made of cast iron, is provided to take up the reaction forces of bending thereby to ensure that no reaction forces are applied to the soft copper face plates.

The radius of curvature of the passageway is preferably maintained sufficiently large so that as the strand is bent and then straightened, the elongation of the tensioned skin on the outside of the bend is no greater than 1–2½%. Thus, for example, for a 12-in. thick slab, the radius of curvature of the passageway would preferably be of the order of 33 feet.

As the strand moves through sections 15*a–f*, the circulation of coolant is carefully controlled to ensure that the solidified skin is maintained at a thickness sufficient to prevent rupture at the point of bending but to prevent excessive thickening of the skin thereafter during movement to the point of straightening such as to make straightening difficult or to cause surface cracking.

For this purpose, the chilling of the strand within the section members 15*a–f* is controlled so that the temperature of the strand as it emerges from the section 15*f* does not exceed 2000° F. and is not less than 1300° F.

In the sections 15*a*, 15*b* and 15*e*, the side walls of the strand may be engaged and supported by side plates 24 which are similar to the plates 17 and 18, being hollow and water cooled. In the curved sections 15*c*, 15*d* and 15*e*, however, it is preferable to support the side walls of the strand by means of a series of beveled rollers 25 mounted for rotation on axes which, if extended, would intersect the center of curvature of the curved sections of the passageway. As illustrated in the drawings, only a single pair of rollers is shown for each section 15*c*, 15*d* and 15*e*, it being understood that additional pairs of rollers may be utilized if desired.

The section members are preferably constructed to permit rapid access for repair and replacement as is shown in detail in FIG. 3. The bottom plate 18 is carried in a supporting frame 30 and is provided with internal chambers 20 for coolant flow. Webs or struts 31 provide the desired structural support. The upper plate 17 is carried in a frame 32 which is pivotally coupled to frame 30 by pivot 34 and is closed at the other end by bolt 35 and nut 36. The axles 37 of rollers 25 are carried in frame 38 slidably positioned within frame 30. The rollers are preferably water cooled in conventional manner. The conical shape and inclination of the axis of the rollers in the curved section members 15*c–e* ensures that the rollers engage the sides of the strand in supporting engagement without scraping the thin strand sides.

There are several contributing factors which make it possible to successively bend and straighten the strand without rupture or other damage thereto. First, the radius of curvature of the curved sections can be relatively long so that the strand is only slightly bent. Secondly, under the prescribed temperature conditions, the thin skin of solidified metal may be easily bent and straightened, while being supported within the supporting passageway. Finally, since the vertical distance between the level of the molten metal in the mold and the axis of the strand at the point where it emerges from the supporting passageway can be relatively small, the ferrostatic head within the strand can be greatly reduced below that which is common in other forms of continuous casting arrangements. For example, in the apparatus illustrated in the drawings, if the radius of curvature of the curved sections is approximately thirty-three feet, the distance between the level of the molten metal in the mold and the axis of the strand as it leaves section 15*e* need not exceed five feet. At that distance, the ferrostatic pressure is only of the order of 12 p.s.i. as compared with the pressures of 100 p.s.i. which are common in vertical continuous casting machines. The lower ferrostatic pressures can be more easily contained within the thin solidified wall and the strand can be bent and straightened with less danger of rupture.

As the strand emerges from the section 15*f*, it is received on a series of idler rollers 40 and driven rollers 42 which are arranged in a substantially horizontal plane and which support the strand while it is conducted through the secondary cooling zone. Within the secondary cooling zone, the strand is subjected to intense cooling by jets 43 or sprays of cooling water applied directly to the surfaces of the strand.

Initiation of the pouring of molten metal such as steel into an inclined mold requires certain precautions to avoid damage to the copper face plates of the mold shaft. This can be accomplished by the dummy bar head as is illustrated in FIG. 4.

In FIG. 4, there is shown a tundish 12 to which is coupled the pouring spout 14 to pour the molten steel into the mold 10. At the start of casting, a dummy bar is inserted which carries at the end thereof a dummy bar head 56. The dummy bar head is provided with a recess 58 within which molten metal flows and solidifies to secure the end of the strand to the dummy bar head to provide extraction force. The dummy bar head closely matches the dimensions of the strand and is usually sealed with an asbestos gasket 60 such as a gasket formed of asbestos cord wound in the V-shaped depression. Lower arm 62 of the dummy bar head is extended so as to extend beyond and under the exit end of the pouring nozzle 14. Thus, when a pour is started, the molten metal will impact upon the arm 62. Arm 62 will erode but will protect the face plate 11 of the mold against erosion by the hot molten steel. When the mold is completely filled as indicated by the level 69, the molten steel will form a cushion, preventing direct impacting of the steel stream upon the plate and the casting can proceed. In many cases, it is desirable to introduce a lubricant along the face plates which may be introduced through the pipe 66.

This invention may be variously modified and embodied within the scope of the subjoined claims.

What is claimed is:

1. In a method for the continuous casting of steel in which molten steel is poured into one end of an open-ended mold and a strand of the steel having a thin skin of solidified metal is withdrawn from the other end, the improvement comprising, bending and then straightening the strand after it leaves the mold while cooling the strand a controlled amount to maintain said skin of solidified metal without producing any substantial thickening of the skin during the bending and straightening; and thereafter cooling the straightened strand to completely solidify it.

2. The method of claim 1 in which the surface temperature of the strand is maintained at a temperature between about 2000° F. and 2500° F. during said bending and straightening.

3. The method of claim 1 in which the radius of the bending is such that said skin on the outside of said bend is elongated less than about 2½%.

4. The method of claim 1 in which the mold is inclined at an acute angle from the horizontal sufficient for the molten metal to be poured into its open end.

5. Apparatus for the continuous casting of steel, comprising an open ended mold having a mold passage extending therethrough, said mold being inclined at an acute angle from the horizontal sufficient for molten metal to be poured into its open end, means for chilling said mold to form metal therein into a strand having a thin skin of solidified metal, means providing a supporting passageway for said strand through which said strand moves from the mold to a secondary cooling zone, said passageway having a straight section at its entrance end, a straight section at its exit end, and an intermediate curved section therebetween within which said strand bent and then straightened, means for cooling said supporting passageway a controlled amount to maintain said thin skin of solidified metal without any substantial increase in the thickness of the skin as the strand moves through said passageway, and means for withdrawing said straightened strand from said passageway and transporting it to said secondary cooling zone for completion of the solidification of said strand.

6. Apparatus in accordance with claim 5 in which said means for withdrawing the strand from said passageway and transporting it to said secondary cooling zone comprises driven rollers on which said strand is supported, said rollers being at the downstream end of said passageway.

7. Apparatus in accordance with claim 5 including a dummy bar to be slideably received into the lower end of said mold passage for forming an end of said strand; said dummy bar having an arm projecting therefrom; and said arm, when said dummy bar is in said mold passage, projecting toward the upper end of said mold passage in position to receive the initial impact of molten metal when molten metal is first poured into said mold.

8. Apparatus for the continuous casting of steel, comprising: an open-ended mold having a mold passage extending therethrough; means for chilling said mold to form metal therein into a strand having a thin skin of solidified metal; means providing a supporting passageway for said strand through which said strand moves from the mold to a secondary cooling zone; said passageway comprising a plurality of section members including a straight section member at its entrance end, a straight section member at its exit end, and an intermediate curved section member therebetween within which said strand is bent and then straightened, each of said section members having an upper and a lower plate, each of said plates being water cooled for maintaining said thin skin of solidified metal as the strand moves through said passageway and being provided with means for introducing a water film between the plate and the respective skin wall of said strand, and means for transporting said straightened strand through said secondary cooling zone for completion of the solidification of said strand.

9. Apparatus in accordance with claim 8 in which said intermediate curved section has a radius of curvature of sufficient length with respect to the thickness of the strand passed therethrough so as to limit the elongation of the strand peripheral wall to not more than 2½%.

10. Apparatus in accordance with claim 8, in which said straight section members each have plates at opposite sides, the latter plates being water cooled and being provided with means for introducing a water film between the plate and the respective skin wall of said strand.

11. Apparatus in accordance with claim 8 in which said curved section member includes at least one roller at each side, the circumferential surfaces of the rollers defining the respective sides of the portion of said passageway through said section.

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