United States Patent

Bykov et al.

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[45] **Sept. 5, 1972**

[54] **SECONDARY COOLING SYSTEM FOR CONTINUOUS CASTING PLANTS**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 37,404, May 11, 1970, abandoned, Continuation of Ser. No. 619,816, March 1, 1967, abandoned.

[52] **U.S. Cl.** **164/283,** 164/82

[51] **Int. Cl.** **B22d 11/12**

[58] **Field of Search** 164/82, 282, 283

[56] **References Cited**

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[57] **ABSTRACT**

In a secondary cooling system for continuous casting plants longitudinally extending bars are used for contacting the ingot to cool same, to prevent bulges from occuring due to the ferrostatic pressure, and to guide the ingot along a predetermined path. These longitudinal bars are cooled with a coolant, and in the instant invention these bars have replaceable planks, which planks have the coolant passages in them and the working surface of the plank is contoured so as to have a different square area ingot contacting surface at any point along the longitudinal axis of the bar. The ingot contacting surface decreases in the direction of ingot travel which necessarily decreases the rate of cooling of the ingot.

7 Claims, 7 Drawing Figures

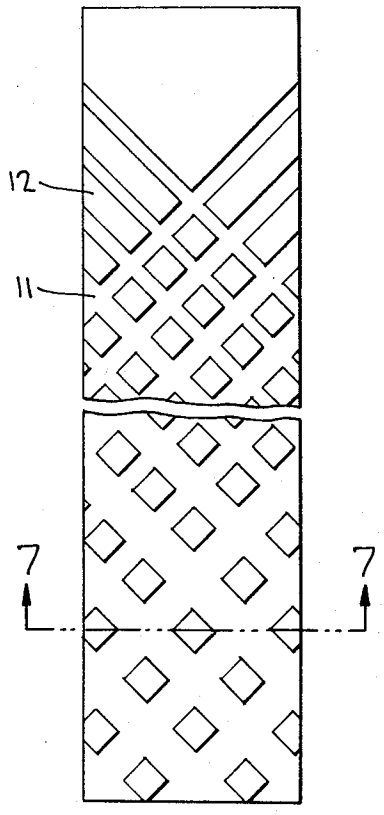


FIG. 1

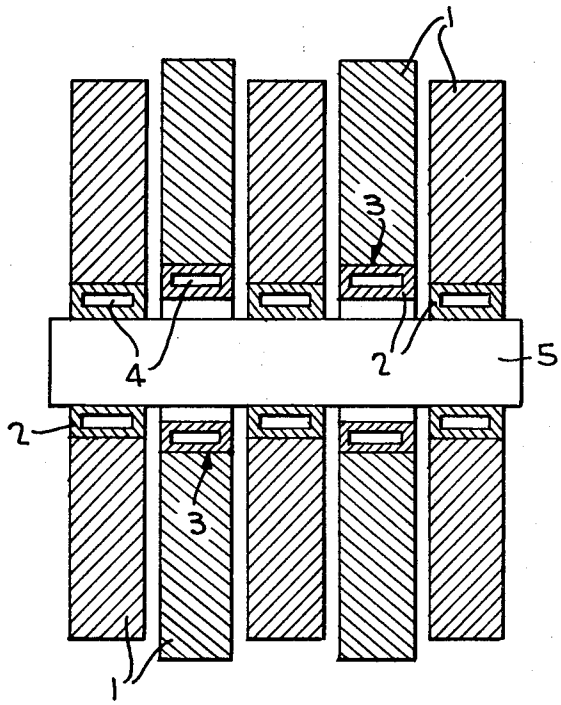


FIG. 2

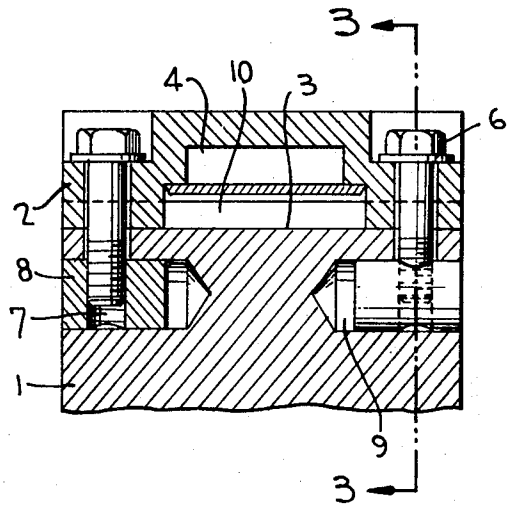
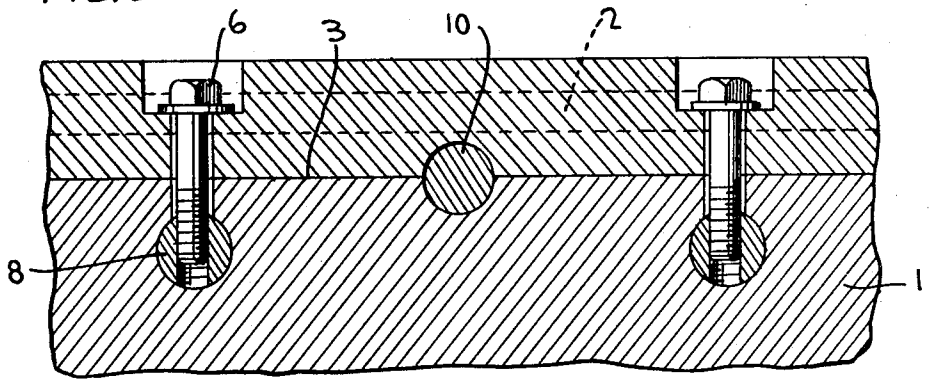


FIG. 3



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FIG. 4

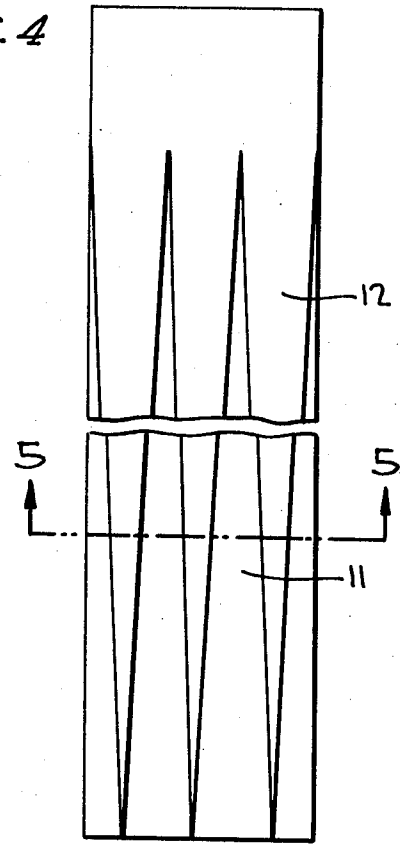


FIG. 6

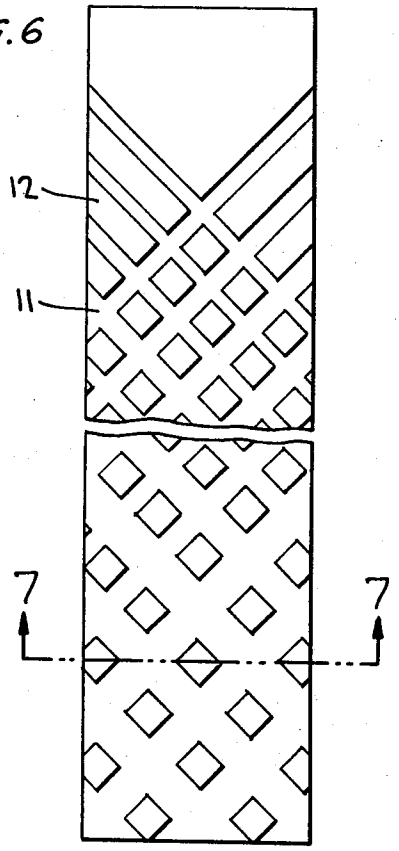


FIG. 5

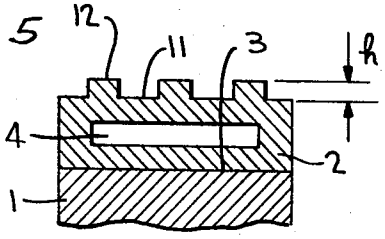
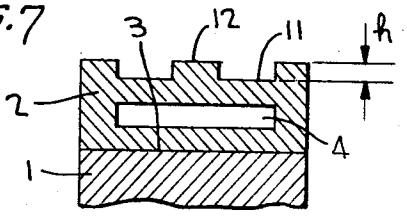


FIG. 7



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SECONDARY COOLING SYSTEM FOR CONTINUOUS CASTING PLANTS

The instant invention is a continuation-in-part of U.S. Ser. No. 37,404, filed May 11, 1970, now abandoned which in turn is a streamlined continuation of U.S. Ser. No. 619,816, filed Mar. 1, 1967, now abandoned.

BACKGROUND OF THE INVENTION

The instant invention relates to secondary cooling systems made up of bars, and in particular secondary cooling systems for use in continuous casting systems.

The bars usually utilized in systems for secondary cooling of continuously cast ingots are normally of one piece, and the bars are provided with channels through which a cooling liquid is circulated. This cooling liquid is normally introduced into the bars, and the working surface of the bars (the surface which contacts the ingot) has holes in it so that the cooling liquid passes through the holes and directly onto the ingot for direct cooling. Exemplary of this type of bar secondary cooling systems is U.S. Pat. No. 2,895,190.

The main disadvantages of the above-mentioned type of bar secondary cooling system is the difficulties of their manufacture; the absence of thermal protection of the bars; and the expensive replacement costs. It is clear from such secondary cooling systems that when it is desired to replace a part of the system such as when the ingot contacting surface of one of the bars becomes worn, it is necessary to replace the complete bar. Furthermore, the rate of cooling in such a system is relatively constant throughout the longitudinal length of each bar.

The instant invention provides a secondary cooling system which permits only a portion of the bar to be replaced when it is desired to replace the contacting surface of the bar, and furthermore the instant invention provides a contacting surface which provides a varying rate of cooling. Moreover, the instant invention furthermore provides for the thermal protection of the bars themselves. These advantages are achieved by the provision of detachable metal planks on each bar, which planks have cooling channels therein to allow the circulation of cooling liquid. Furthermore, these planks have a contoured working surface which allows a variation in the amount of contact cooling of the ingot along the longitudinal length of the plank.

Other objects and advantages of the instant invention will become more fully apparent from a consideration of the following detailed description and accompanying drawings, in which:

FIG. 1 is a cross-sectional view along the ingot path of the secondary cooling bars in accordance with the present invention;

FIG. 2 is an enlarged cross-section showing how the detachable planks are mounted onto the bar;

FIG. 3 is a section taken along line III—III in FIG. 2;

FIG. 4 is a plan view of the plank working surface showing a first embodiment thereof;

FIG. 5 i a section taken along line V—V in FIG. 4;

FIG. 6 is a plan view of the plank working surface showing a second embodiment thereof; and

FIG. 7 is a section taken along line VII—VII in FIG. 6.

DESCRIPTION OF PREFERRED EMBODIMENTS

Looking at FIG. 1 it will be seen that a plurality of bars 1 have, on their surfaces 3, attached thereto a series of planks 2. These planks are detachably attached to surfaces 3, and the bars and planks make up the secondary cooling zone of a continuous casting plant.

Channels 4 are provided in the detachable planks 2 for allowing a cooling liquid to circulate therethrough. This insures sufficient contact cooling of an ingot 5 without the need of sprayers or other means which would directly impinge a cooling liquid onto the surface of the solidifying ingot 5.

The interposing of detachable planks 2 between the bars 1 and the ingot 5 provides for the thermal protection of the bars, and simplifies their construction. It is therefore not necessary to provide channels or other cooling passages in the bars, because these are provided for in the detachable planks.

The plurality of bars and detachable planks are so positioned in the secondary cooling zone as to provide sufficient support for the outer skin of the solidifying ingot 5 to prevent bulging resulting from ferrostatic pressure.

Turning now to FIG. 2, it will be seen that the detachable planks 2 preferably are detachably connected to the bars 1 by means of bolts 6. These bolts 6 are screwed into threaded openings 7 in cylinders 8, which cylinders are located in cylindrical bores 9 made in the body of the bar 1. As the planks 2 expand, relative to the bars 1, under the effect of the conducted heat from the ingot 5, and also due to the different coefficients of thermal expansion, slippage takes place between the detachable planks 2 and bars 1. This slippage is accommodated by the oversized holes through which bolts 6 pass. A dowel 10, as seen in FIGS. 2 and 3, is provided in the central portion of bars 1 to relatively fix the position of the planks 2 to the bars 1, and to take up any major longitudinal shearing force.

Turning now to the first embodiment of the contouring on the working surface of plank 2, as graphically seen in FIGS. 4 and 5, it will be seen that the square area of the ingot contacting surface or working surface 12 of the planks 2 decreases from the top to the bottom of FIG. 4, which represents the direction of ingot travel. Consequently, as the ingot moves along the ingot path, the square are of the ingot contacting surface 12 of planks 2 decreases, thereby decreasing the rate of ingot cooling. This embodiment is preferably used with bars which see relative movement with respect to the ingot. One example of such bars would be bars which are fixed in the secondary cooling zone, and the ingot, by virtue of its traversing the ingot path, would then move relative to these fixed bars, and as the ingot moved further from the exit of the mold, through the secondary cooling zone, its outer surface would be contacted by further decreasing working surfaces 12 of planks 2.

FIG. 5 shows a cross-section of the plank of FIG. 4, and in this cross-section it will be seen that the raised working surfaces or ingot contacting surfaces 12 are in the form of a plateau, separated by a recess 11. The distance h between the working surface 12 and the recess 11 can range from about 3 to 10 mm. It will furthermore be seen that channel 4, which carries the coolant, is approximately centrally located in the plank 2.

The second embodiment of the plank contour is graphically seen in FIGS. 6 and 7. Preferably, this embodiment is utilized when there is no relative movement between the ingot and the plank, viz., when there are at least two groups of bars on each side of the ingot path, and while one group of bars is contacting and guiding the ingot, the other group of bars is moving in a direction opposite to the ingot direction. This type of bars may be called "walking bars", and it will be seen that when the working surface **12** of the planks are in contact with the ingot there is no relative movement, but rather the working surface remains fixed relative to the ingot. While one of the two groups of bars is in contact with the ingot, as mentioned above, the other group of bars is moving in a direction opposite to that in which the ingot is travelling, and in this way "walks" the ingot through the secondary cooling zone. In this fashion the ingot is guided, and in a sense drawn through the secondary cooling zone. It will be seen from FIG. **6** that the working surfaces **12** of the plank decrease in density number from the top of the figure towards the bottom. Because only the working surface **12** of the plank contacts the ingot, this means that the rate of cooling of the ingot will be less at the bottom (as viewed in FIG. **6**) of the plank as opposed to the top of the plank. The distance between the working surface **12** and recess **11** in this embodiment, as in the embodiment of FIGS. **4** and **5**, is also from about 3 to 10 mm.

It is well known that as the ingot traverses the secondary cooling zone, the crust of the ingot becomes thicker, and hence the heat which is transferred through this crust decreases so that less and less heat is conducted from the ingot. Consequently, a smaller area of contact surface is required between the secondary cooling zone and the ingot when the crust is thicker, because there is less heat to conduct away. By adjusting the length of the secondary cooling zone and the speed of withdrawal of the ingot, along with the particular contour on the working surface of the planks, the proper heat withdrawal from the ingot can be obtained so as to prevent overheating or overcooling of the ingot.

The thickness of the crust of the solidifying ingot is assumed to grow in accordance with the "square root" law, i.e.,

$$X_1 = k\sqrt{t_1}$$

$$X_2 = k\sqrt{t_2}$$

where X_1 is the thickness of the ingot crust at the beginning of the bars of the secondary cooling zone in centimeters; X_2 is the thickness of the ingot crust at the end of the bars in the secondary cooling zone in centimeters; t is the time counted from the beginning of the solidification in minutes; and k is a solidification constant, for example for carbon steel cast into slabs $k =$ 2.6 to 2.8 cm/min.

When the thickness of the ingot crust at the entrance and the exit of the bar system in the secondary cooling zone is known, it is easy to determine the area of the working surface of the planks in contact with the ingot by using the following relation:

$$X_1/X_2 = S_2/S_1$$

where S_1 is the area of contact between the plank working surface, and the ingot at the beginning of the bars of the secondary cooling zone; and S_2 is the area of contact between the plank working surface and the ingot at the end of the bars of the secondary cooling zone.

All of the intermediate values of the contact area between the working surface of the plans and the ingot, i.e., from the entrance of a secondary cooling zone to the exit thereof, may be assumed, with sufficient accuracy, to vary in direct proportion to its linear length from the beginning and the exit of the secondary cooling system.

In a specific example of a continuous casting plant for casting steel, in which two groups of walking bars were utilized on each side of the ingot path, an ingot having a dimension of 150 × 600 mm. was cooled. This particular system of walking bars had five bars on either side of the ingot, and as seen in FIG. **1** one group is made up of two bars which are seen out of contact with ingot **5**, and the other group, seen in contact with ingot **5**, is made up of three bars each. The length of the bars is 4 meters, and the width is 100 mm. The bars are made of cast iron, the plank is made of structural carbon steel, and the distance from the working surface **12** of the plank to the channel **4** is 12 mm. The depth of the channel **4** is 10 mm., and the cooling liquid is water under pressure of three atmospheres. The types of steel being continuously cast were the effervescing and killed carbon steels, along with alloyed and transformer steels. In this particular working example, both groups of bars "walked", and therefore were stationary with respect to the ingot when they were in contact with the ingot, and consequently the contouring on the working surface of the plank took the form as seen in FIGS. **6** and **7**, with h equalling 5 mm. At the beginning the planks had a 100 percent working surface in contact with the ingot, and at the end of the plank the working surface was approximately 50 percent of the total area of the plank which was in contact with the ingot. The area of contact between the beginning and the end of the plank decreased from 100 percent to 50 percent in direct proportion to length.

It was found that the proposed design of this particular type of secondary cooling zone bars for continuous casting plants improved the conditions and the controllability of the cooling of the crystallizing ingot, and furthermore markedly improved the quality of the ingot. While the present invention is described with reference to preferred embodiments thereof, it is evident that modifications may be made which do not depart from the spirit and scope of the invention as defined by the appended claims. It is possible in walking bars to have one of the groups of bars fixed, and to utilize the plank contour embodiment of FIGS. **4** and **5** on those bars, and to have the other group of bars "walking", viz., in sporadic contact with the ingot but when in contact there being no relative movement between the walking bar and the ingot. This second group of bars would then have a plank design as seen in FIGS. **6** and **7**. It is also possible to have more than two groups of bars on any one side of the ingot path. Moreover, it is possible to detachably connect the planks to the bars in other than the particular embodiment seen in FIGS. **2** and **3**, for example the bolts **6** may screw directly into the bars **1**, clamps rather than bolts may be used, etc.

What we claim is:

1. In a continuous casting plant having a plurality of bars in a secondary cooling zone, which bars extend substantially longitudinal to an ingot and are adapted to cool the ingot and guide same along an ingot path, the improvement consisting in that each bar has a plank detachably connected to it such that the plank is interposed between each said bar and said ingot path; passage means are provided in said planks for the circulation of a coolant introduced and removed respectively by inlet and outlet means; and that face of each plank which is adapted to contact the square area of ingot is contoured so as to have a different ingot contacting surface at any point along the longitudinal axis of the bar.

2. In a continuous casting plant as claimed in claim 1 wherein said square area of ingot contacting surface decreases in the direction of ingot travel which proportionately decreases the rate of ingot cooling.

3. In a continuous casting plant as claimed in claim 2 wherein said ingot contacting surface is in the form of a series of raised portions with recesses therebetween when viewed in cross-section, said raised portions continuously decreasing in width in the direction of ingot travel.

4. In a continuous casting plant as claimed in claim 2 wherein said ingot contacting surface is in the form of a plurality of distinct raised areas with recesses therebetween when viewed in plan, the number of said distinct raised areas decreasing in the direction of ingot travel.

5. In a continuous casting plant as claimed in claim 2 wherein said ingot contacting surface, in cross-section, is made up of a number of raised plateaus separated by recesses, the distance between the bottom of the recess to the top of the plateau being from 3 – 10 mm.

6. In a continuous casting plant as claimed in claim 1 wherein the plurality of bars on each side of said ingot path are divided into at least two independent groups and at least one of said groups being mounted so that it may be moved relative to the ingot.

7. In a continuous casting plant as claimed in claim 6 wherein there are two groups of bars on each side of said ingot path and each group is capable of movement relative to the ingot, while the first group is contacting and guiding the ingot, the second group is out of contact with the ingot and moving in a direction opposite to the direction of ingot travel.

* * * * *