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 [33] **Japan**
 [31] **42/81875, 42/81878 and 42/81879**

[56]

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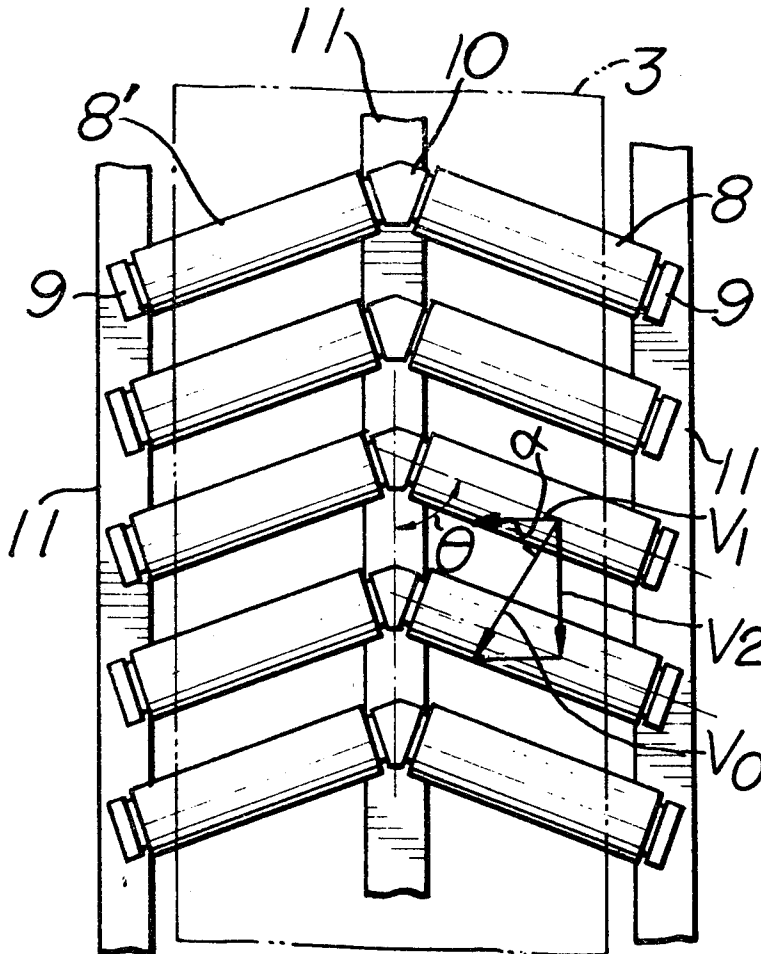
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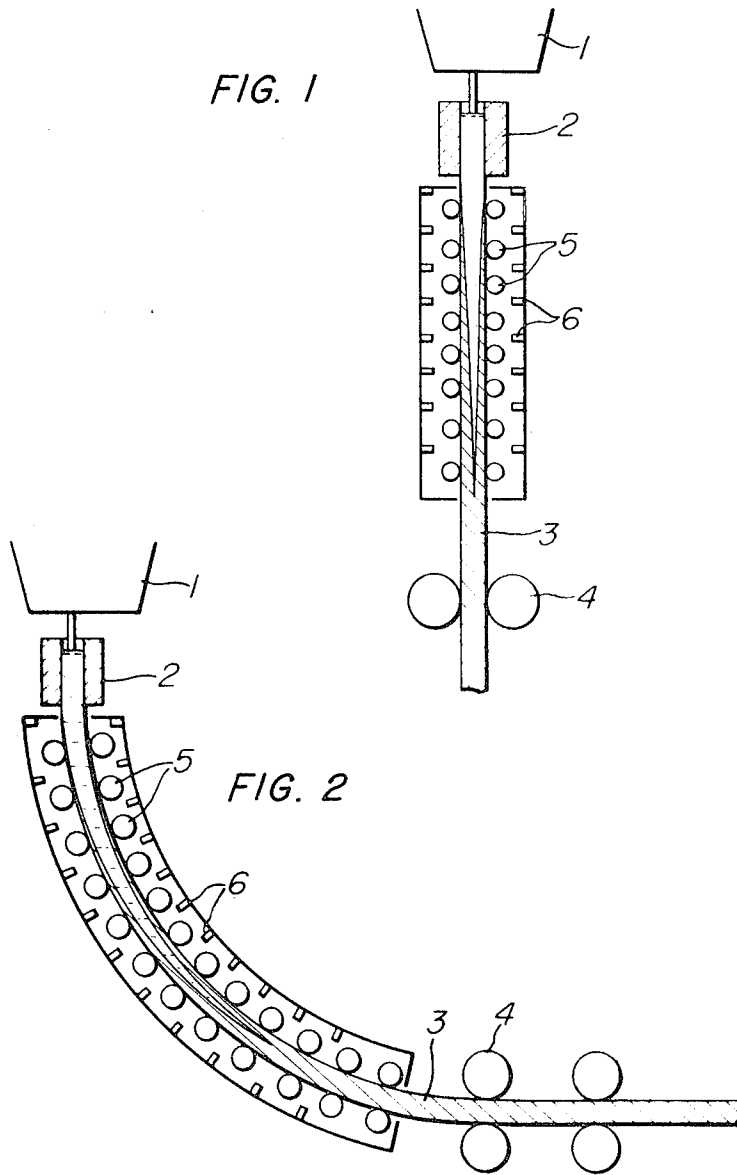
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[54] **CONTINUOUS CASTING APPARATUS HAVING A ROLLER ARRANGEMENT FOR DIMINISHING THE RESTRAINING FORCE AGAINST SHRINKAGE OF THE CAST METAL**
 13 Claims, 11 Drawing Figs.

[52] U.S. Cl. 164/282, 164/82
 [51] Int. Cl. B22d 11/12
 [50] Field of Search 164/82, 89, 273, 274, 282, 283; 193/37; 198/127, 167, 202

ABSTRACT: A continuous casting apparatus having means, in order to reduce a force created between the surfaces of a cast metal and each of guide rolls and acting in the direction to restrain a tendency of shrinking of the cast metal after it is discharged from a casting mould, for applying a force on the surface of the cast metal in the direction normal to the direction of travel of the cast metal and in the same direction as that in which the metal shrinks, whereby longitudinal splits can effectively be prevented.





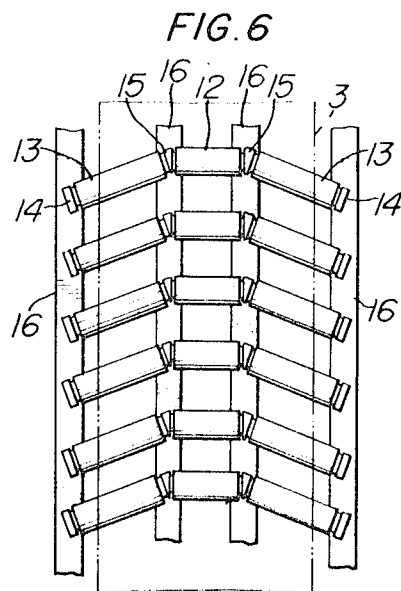
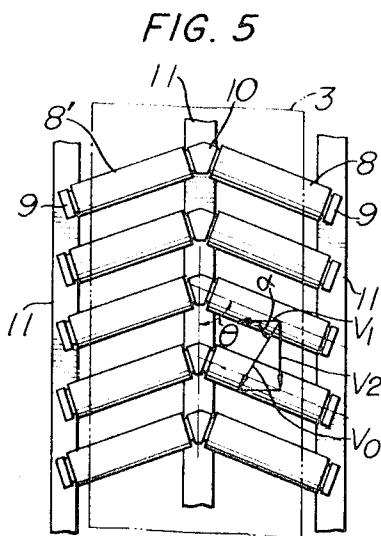
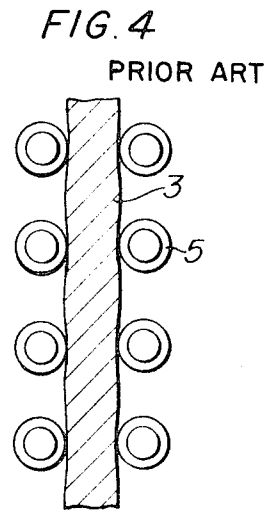
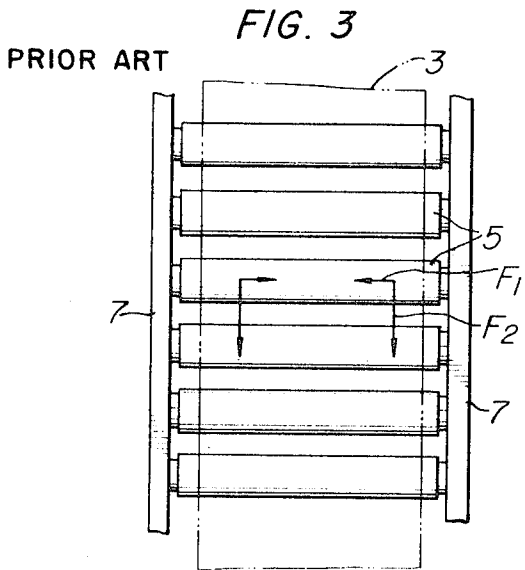
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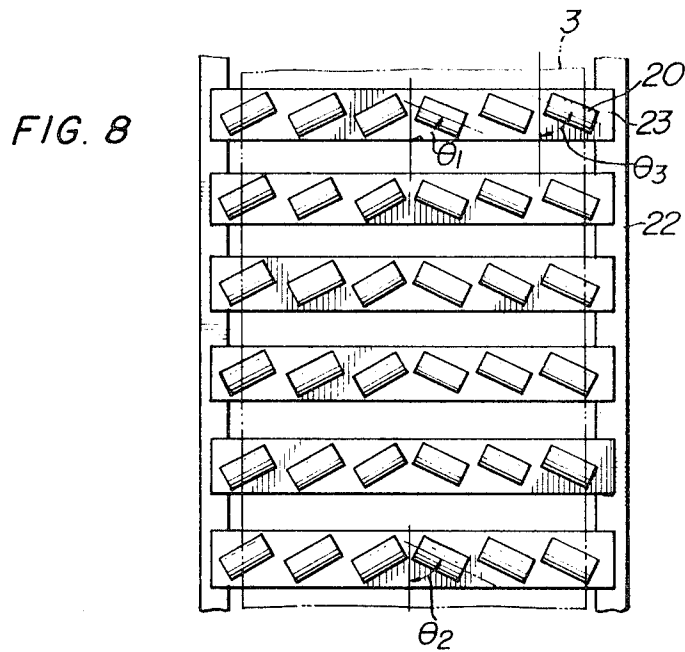
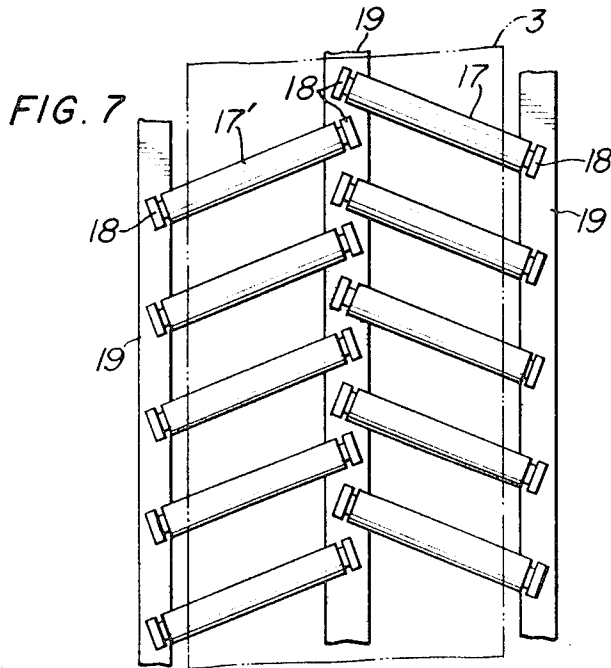
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FIG. 9

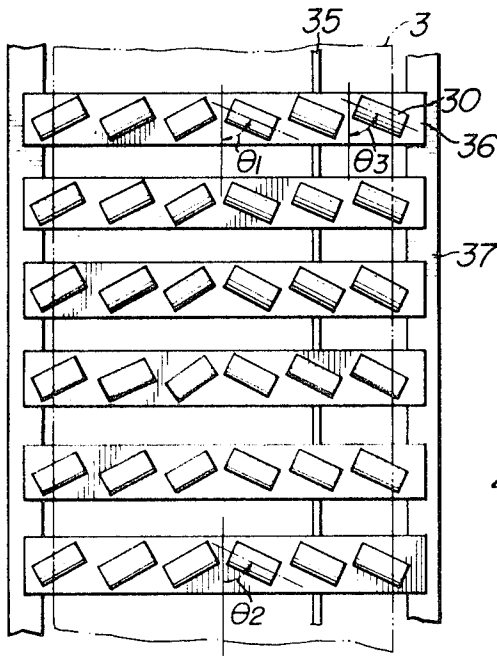


FIG. 10

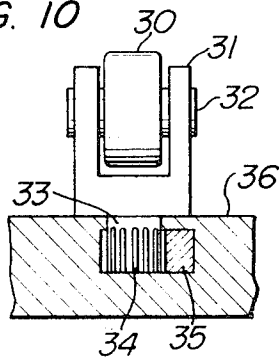
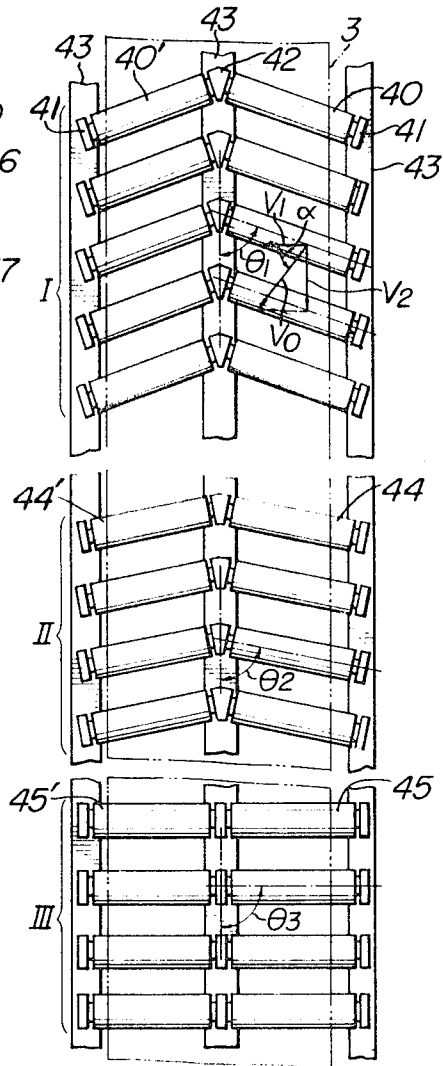


FIG. 11



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**CONTINUOUS CASTING APPARATUS HAVING A
ROLLER ARRANGEMENT FOR DIMINISHING THE
RESTRAINING FORCE AGAINST SHRINKAGE OF THE
CAST METAL**

The present invention relates to a continuous casting apparatus for a metal, and more particularly to a means for guiding a cast metal continuously drawn from a water-cooled casting mould to a secondary cooling zone.

It is well known that, in a continuous metal casting apparatus, a cast metal which has just been discharged from a water-cooled casting mould still has an unsolidified inner portion and then the cast metal is guided by guide rolls through a secondary cooling zone so that it is cooled by means of a water spray to solidify the inner part thereof. In this instance, it has been well recognized that the spacing between pairs of the guide rolls and the amount of spray water have a substantial effect on the quality of the cast metal. Therefore, it has been common practice to make the spacing or pitch of the pairs of guide rolls and the amount of cooling water adjustable. Particularly, it has already been well known to those skilled in the art that when a wide slab is being cast, while the guide rolls are subjected to a large ferro-static pressure, the roll pitch is set as small as possible in order to reduce the ferro-static pressure acting on the rolls and to prevent the cast metal from cracking by suppressing the tendency of the cast metal to become bulged under the influence of ferro-static pressure at the portion located between two adjacent rolls. However, even if such arrangement is employed, there still exists, when a wide slab is cast, the tendency that a longitudinal split occurs in the cast metal. Particularly, in a case where the width of the cast metal exceeds 1,200 mm., this tendency increases remarkably and hence the quality of the cast metal is markedly decreased. Therefore, we have tried to solve these problems not only by varying the roll pitch but also by suitably controlling the amount of spray at the cooling zone by an automatic spray controller, however, this arrangement was not satisfactory for casting an increasingly wider slab.

Recently, it has become necessary to produce increasingly wider slabs which are as wide as 1,600 mm. or more, however, the most critical barrier to the production of such a wide slab is that there is no reliable means for preventing said longitudinal split.

It is of course true that the longitudinal split of a cast metal occurs when suitable cooling is not performed and/or the roll pitch is excessively large, but the restraining force applied on the cast metal by the guide rolls is also considered to be one of the major causes of the longitudinal split. Namely, as the cast metal is cooled and progressively solidified, its surface temperature decreases and at the same time the cast metal shrinks, however, at the outer surface of the metal where the amount of shrinkage is greatest, there occurs a force tending to prevent the shrinking of the metal so that an internal tensile stress is created in the metal. If the stress exceeds the ultimate tensile strength of the solidified metal layer, longitudinal splits will occur in the metal.

The force which may tend to prevent the shrinking of the metal surface is the gross summary of a tensile force created due to the influence of the ferro-static pressure of the metal, restraining force due to the temperature difference between the inner and outer faces of the solidified layer and the restraining force applied by the guide rolls. Among these forces, those which have the greatest effect on a wide slab are the tensile force created at the longitudinal sides of the cast slab and the restraining force applied by the guide rolls. The tensile stress caused by these forces is found to increase in relation with an increase in the width of the slab. Although the tensile force at the longitudinal sides of the slab can be suppressed by decreasing the roll pitch, the restraining force applied by the guide rolls cannot be suppressed unless the coefficient of friction between the cast metal and the rolls could be reduced.

A conventional continuous casting apparatus of this type has, as disclosed in U.S. Pat. No. 2,284,503, guide rolls with rotational axes disposed normal to the direction of movement of the cast metal. The arrangement is seen in a continuous casting apparatus of the vertical type, curved type or any other type of apparatus. However, in such a known arrangement, since there exists a sliding contact between the cast metal and each of the guide rolls resulting in a large frictional coefficient and since each of the guide rolls engages the cast metal at a limited area extending transversely the direction of travel of the latter, the above-mentioned restraining force has a strong effect on the cast metal and promotes the occurrence of said longitudinal split. In the actual practice of manufacturing wide slabs, longitudinal splits occur with the result that the quality of the product is remarkably lowered. For this reason, it has been very difficult in the prior apparatus, to manufacture wide slabs over a certain width.

The present invention successfully provides, through investigating the causes of the longitudinal splits in a cast metal, a means which is very effective for preventing such longitudinal splits.

Thus, a principal object of the present invention is to provide a continuous casting apparatus which can prevent the above-described longitudinal splits and produce a high quality cast metal.

A further object of the present invention is to provide an arrangement of guide rolls which is very effective for preventing said longitudinal splits.

A still further object of the present invention is to arrange the guide rolls in a suitable and reasonable manner in relation to cast metals of various shapes.

A further object of the present invention is to provide an arrangement of the guide rolls, which can be speedily established and which can increase the flexibility of the operation of the apparatus whereby to reduce the standstill thereof in running.

The other objects of the present invention will become apparent from the following descriptions of the preferred embodiments with reference to the accompanying drawings.

According to one aspect of the present invention, there is provided a continuous casting apparatus having means, in order to reduce a force (restraining force applied by a guide roller) created between the surfaces of a cast metal and each of guide rolls and acting in the direction to restrain the tendency of shrinking of the cast metal after it is discharged from a casting mould, for applying a force on the surface of the cast metal in the direction normal to the direction of the travel of the cast metal in such a sense that the restraining force is reduced.

According to a further aspect of the present invention, as shown and described with respect to the preferred embodiments, there is provided an arrangement of guide rolls in which the rolls are angularly and adjustably mounted wherein sets of rolls disposed at the upstream portion with respect to the direction of travel of a cast metal are arranged in a different manner as compared with those at the down stream portion.

FIG. 1 is a diagrammatic side view showing a vertical type continuous casting apparatus;

FIG. 2 is a diagrammatic side view of a curved path type continuous casting apparatus;

FIG. 3 is a front view of a cast metal guide means of a conventional type and particularly shows the arrangement of guide rolls;

FIG. 4 is a side view of the means shown in FIG. 3;

FIGS. 5 to 8 are front elevational views of various embodiments of cast metal guide means made in accordance with the present invention;

FIG. 9 is a front elevational view of a further embodiment of cast metal guide means in accordance with the present invention, in which means guide rolls are angularly adjustably mounted;

FIG. 10 is a partly sectional view of angle adjusting means for a guide rolls; and

FIG. 11 is a front elevational view of a further embodiment of the cast metal guide means in accordance with the present invention in which guide rolls at upstream portion are disposed in a different way as compared with downstream portion guide rolls

First of all, a vertical type and a curved path type continuous casting apparatus which are the typical examples of conventional continuous casting apparatus will now be described with reference to FIGS. 1 and 2. Molten metal is continuously poured from a tundish 1 into a water-cooled casting mould 2 at a predetermined rate. The molten metal is partially solidified in the water-cooled casting mould 2 to form a thin solidified metal layer and is held and guided by means of guide rolls 5 provided in a secondary cooling zone during its subsequent travel along a path arranged in a vertical or in a curved way. During the travel the cast metal 3 is cooled and completely solidified toward the center portion thereof by means of cooling water spray discharged from nozzles 6, and thereafter continuously drawn by a pinch roll means or a straightener 4.

FIGS. 3 and 4 show cast metal guide means, particularly the arrangement of guide rolls employed in a conventional apparatus such as the one disclosed in the aforementioned United States patent. As is obvious from the drawings, each of the guide rolls 5 is disposed normal to the direction of travel of the cast metal 3. In the drawings, there is shown a structure in which only a few guide rolls are carried on a pair of support columns 7, however, it would be apparent that a plurality of such roll groups can be arranged in series. In this arrangement, the guide rolls 5 are subjected to a ferro-static pressure of molten metal and the cast metal has a tendency of bulging at portions between pairs of the guide rolls as shown in FIG. 4. In this condition, since the guide rolls 5 are rotationally driven and are engaged with the cast metal, a force F_2 is created in the direction of the advance of the metal. Further, as the cast metal is cooled during its downward movement, its surface shrinks so that a frictional force F_1 is created between the surfaces of the cast metal and each of the rolls in the direction normal to the direction of travel of the cast metal. Therefore, equivalent reaction forces act on the cast metal in the direction opposite to the forces F_1 and F_2 . The aforementioned reaction force opposite to the force F_1 is the cause of the longitudinal splits.

FIGS. 5 to 8 show various embodiments of the present invention in which each guide roll is so arranged that it serves to reduce the restraining force created between the surfaces of the cast metal and the guide rolls and acting against shrinking of the cast metal. In FIG. 5, guide rolls are arranged in two rows in side-by-side relation. Each of the guide rolls 8 and 8' is disposed with its axis inclined toward the outer and downward direction by an acute angle θ with respect to the direction of the travel of the cast metal. In other words, each roll is arranged so that its inner end located at the center part of the cast metal is disposed behind the outer end located at the side edge portion of the cast metal with respect to the direction of travel. Further, two adjacent guide rolls 8 and 8' are disposed in a symmetrical relationship about the centerline of the cast metal and are supported by three support columns 11 by means of bearings 9 and 10. Said angle θ should preferably be selected to satisfy the relation $\theta \leq \alpha$, where α is the angle between the transverse shrinking speed V_1 and the resultant speed V_0 of the descending speed V_2 of the cast metal and the speed V_1 , however, it may be practical to select it within the range $90^\circ > \theta > \alpha$.

FIG. 5 shows an arrangement comprising central short guide rolls 12 disposed normal to the direction of the travel of the cast metal and long guide rolls 13 disposed at the opposite sides of the short rolls, said rolls 13 being inclined so as to form an acute angle with respect to the direction of travel of the cast metal as in the case of the aforementioned example. In this instance, the rolls are carried by four support columns 16 by means of bearings 14 and 15.

FIG. 7 shows a further improved arrangement of guide rolls in which each of the rolls is supported with an inclined relation

as in the preceding examples, and at the same time, the rolls in the adjacent rows are disposed in staggered relation with each other. In this arrangement, two adjacent rolls 17 and 17' can be placed in slightly overlapped relation with each other at or adjacent to the center portion of the slab, so that the guide rolls can engage with the cast metal 3 without leaving any unengaged portion. Thus, the arrangement is effective to suitably convey the cast metal and obtain high quality products. In this instance, the guide rolls 17 and 17' are supported by three support columns 19 by means of bearings 18.

FIG. 8 shows an arrangement in which a plurality of short rolls 20 is arranged in the transverse direction of the cast metal 3, each of the rolls 20 being inclined with respect to the direction of the movement of the cast metal 3. Each guide roll 20 is mounted on a frame 23 secured to a pair of support columns 22, a plurality of identical roll groups can be arranged in the direction of the travel of the cast metal. According to this arrangement, the angle of inclination θ_1 , θ_2 and θ_3 of the guide rolls 20 can be selected as desired so that they may become suitable to operational conditions.

FIG. 9 shows a structure similar to that shown in FIG. 8 but the inclination angle of each of the short guide rolls 30 is independently adjustable. As shown in FIG. 10, each of the short guide rolls 30 is pivotally supported on a bearing 31 by means of a pin 32, the bearing 31 being in turn supported by a frame 36 secured to support columns 37. The bearing 31 has a downwardly directed shaft portion 33 provided at its lower end, the shaft portion 33 being provided around its periphery with gear teeth 34 to which a rack 36 engages. By externally actuating the rack 35, the angle of inclination of the guide roll 30 with respect to the direction of the travel of the cast metal 3 can be adjusted as desired. In the example illustrated in the drawing, the guide rolls which are aligned in the direction of the travel of the cast metal are simultaneously adjusted, however, it will be apparent to those skilled in the art that the guide rolls disposed in side-by-side relation can also be simultaneously adjusted.

According to the above described arrangement, the angles of inclination θ_1 , θ_2 and θ_3 can be adjusted as desired with respect to the dimensions of the castings and/or the location of each of the rolls, so that the most suitable adjustment of the guide rolls can readily be ensured with the result that flexibility of operation of the apparatus can be obtained and that products of improved quality can be obtained. Further, the arrangement is effective to reduce the standstill of the apparatus. FIG. 11 shows an arrangement in which the angle between the rotational axis of the guide roll and the direction of the travel of the cast metal is varied in accordance with the vertical position of the roll. The guide rolls are disposed in two rows arranged in side-by-side relation. In the upper group I, each of the guide rolls 40 and 40' is disposed with its rotational axis inclined at an acute angle θ_1 with respect to the direction of the movement of the cast metal 3. In other words, the roll is so disposed that the inner end thereof located at the center part of the cast metal is higher in the vertical position than the outer end thereof disposed at the side edge portion of the cast metal. Further, each pair of adjacent guide rolls 40 and 40' is symmetrical with another about the longitudinal center line of the cast metal. The guide rolls 40 and 40' are supported by three support columns 43 by means of bearings 41 and 42. The angle θ_1 is determined as explained in connection with FIG. 5. In the intermediate group II, each of the guide rolls 44 and 44' is inclined at an acute angle θ_2 which is larger than the angle θ_1 . The angle θ_2 is not a right angle but is closer to a right angle than the angle θ_1 with respect to the direction of the travel of the cast metal 3 ($\theta_2 > \theta_1$). The other arrangements and structures are the same as those in the preceding group I. In the lower group III, each of the guide rolls 45 and 45' is disposed with its rotational axis forming a right angle θ_3 with the direction of the cast metal 3 as in the conventional apparatus. The other arrangements and structures are the same as those in the preceding groups I and II.

According to the above-described arrangement, the inclination of each of the guide rolls is different in accordance with the restraining force thereof whether it is located at the upper part of the apparatus where the restraining force of the guide roll is large, or the lower part of the apparatus where the restraining force of the guide roll is small. Therefore, by this arrangement, a suitable and reasonable operation of the apparatus can be obtained and the quality of the products can be remarkably improved.

According to the present invention, in either one of the above-described embodiments, a transverse compression force can be applied on the surface of the cast metal simultaneously with its advance, so that the transverse restraining force against shrinking of the metal can be reduced or eliminated. Therefore, the present invention is effective to prevent longitudinal splits in the cast metal and thus the quality of the products can be substantially improved. Further, the present invention greatly contributes to the development of the continuous casting of wide slabs.

It is apparent that the present invention should not be limited to the arrangements as described in connection with the illustrated embodiment, but can be interpreted or modified in various ways within the scope of the appended claims.

I claim:

1. In a continuous apparatus including a storage for molten metal, a casting mould having a cooling means for said molten metal to be discharged from said casting mould, a second cooling means for said cast metal and a guide means for guiding said cast metal emerged from said casting mould; wherein the improvement is characterized by the fact that said guide means comprise a transverse plurality of guide rolls, each of said plurality of guide rolls being inclined with respect to the direction transverse to the direction of travel of said cast metal and each of said guide rolls is arranged so as to compress said cast metal towards the direction of the center line thereof, and reduce a force restraining against the shrinkage which occurs in said cast metal, being progressively cooled by said cooling means, so as to prevent the occurrence of a longitudinal split in said cast metal.

2. A continuous casting apparatus in accordance with claim 1, wherein said guide rolls are arranged in a plurality of groups disposed in side-by-side relationship, each of said guide rolls being inclined forming an acute angle with respect to the direction of travel of the cast metal with each of the inner ends thereof disposed behind the outer ends with respect to the direction of travel, whereby the restraining force against shrinking of the cast metal between the surface of said guide rolls and said cast metal is diminished.

3. A continuous casting apparatus in accordance with claim 1, wherein said guide rolls for guiding the cast metal are disposed in two rows arranged in side-by-side relation, each of said guide rolls being inclined at an acute angle with respect to the direction of the travel of the cast metal with each of the inner ends thereof disposed behind the outer ends with respect to the direction of the travel, each of two transversely adjacent rolls being disposed in a symmetrical relation with each other about the longitudinal centerline of the cast metal whereby the restraining force against shrinkage of the cast metal between the surface of said guide rolls and the cast metal is diminished.

4. A continuous coasting apparatus in accordance with claim 1, wherein said guide rolls comprise short guide rolls disposed at the central zone along the longitudinal axis of the cast metal in the direction normal to the direction of the travel of the cast metal, and long guide rolls disposed at each out-

ward side of each of the short roll, each of said long guide rolls being inclined forming an acute angle with respect to the direction of the travel of the cast metal.

5. A continuous casting apparatus in accordance with claim 1, wherein the guide rolls for guiding a cast metal are arranged in a plurality of rows disposed in side-by-side relation, each of said rolls being inclined forming an acute angle with respect to the direction of the travel of the cast metal with its inner end disposed behind the outer end with respect to its direction of travel, and the guide rolls in two adjacent rows being disposed in a staggered relation with each other.

6. A continuous casting apparatus in accordance with claim 1, wherein said guide rolls for guiding a cast metal are arranged in a plurality of rows disposed in side-by-side relation, each of said rolls being inclined forming an acute angle with its inner end disposed behind the outer end with respect to the direction of the travel of the cast metal, said guide rolls in two adjacent rows being disposed in a staggered relation with each other and their inside ends opposing each other at the central zone of the travel line.

7. A continuous casting apparatus in accordance with claim 1, wherein each of said guide rolls is so mounted that the angle between the direction of the travel of the cast metal and the axis of the roll can be adjusted as desired.

8. A continuous casting apparatus in accordance with claim 1, wherein said guide rolls comprise a plurality of short rolls which constitute a plurality of rows in both the longitudinal and transverse directions with respect to the travel line of the cast metal, said short rolls being mounted so that their inclination angle can be adjusted as desired.

9. A continuous casting apparatus in accordance with claim 1, wherein said guide rolls comprise plurality of short rolls which are arranged in a plurality of rows in both the longitudinal and transverse directions with respect to the travel line of the cast metal, said short rolls being journaled on a frame secured to support columns and being mounted so that their inclination angle can be adjusted as desired.

10. A continuous casting apparatus in accordance with claim 1, wherein said guide rolls comprise a plurality of short rolls which are arranged in a plurality of rows in both the longitudinal and transverse directions with respect to the travel line of the cast metal, each of said short rolls is rotatably journaled by bearing means at its bearing pin, said bearing being supported on the frame secured to support columns, said bearing being provided with a downwardly projecting shaft having gear teeth therearound to which a rack is adapted to engage so that the inclination angle of said short rolls can be adjusted as desired.

11. A continuous casting apparatus in accordance with claim 1, in which said guide rolls are mounted in such a manner that those disposed at the upstream portion of the travel line of the cast metal have a different inclination angle from those at the downstream portion thereof so as to effect a suitable restraining force in accordance with the varying extent of solidification in the cast metal.

12. A continuous casting apparatus in accordance with claim 1, in which said guide rolls are mounted in such a manner that the inclination angle thereof with respect to the travel line increases gradually toward a right angle from that located at the upstream portion of the travel line to that located at the downstream portion thereof.

13. A continuous casting apparatus in accordance with claim 1, wherein said guide rolls are arranged in a plurality of groups in which each of the said guide rolls in the same group has the same inclination angle.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,586,094 Dated June 22, 1971

Inventor(s) Kinju Machida

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the first Page, left hand column, line 8, December 22, 1962
and line 9
should read -- December 22, 1967. --

Signed and sealed this 14th day of December 1971.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents