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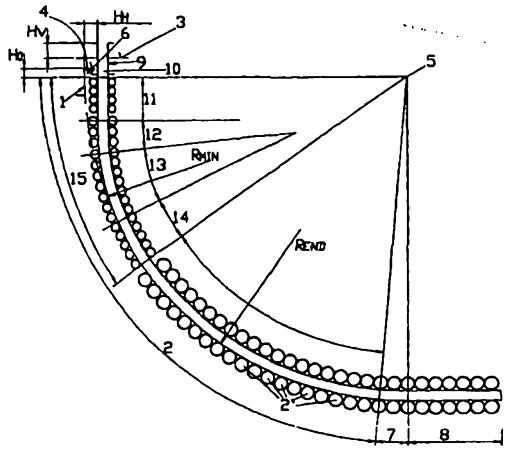
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(54) Title: METHOD FOR CONTINUOUSLY CASTING METAL AND A CONTINUOUS CASTING INSTALLATION PROVIDED THEREFOR

(54) Bezeichnung: VERFAHREN ZUM STRANGGIESSEN VON METALL SOWIE STRANGGIESSANLAGE HIERZU

(57) Abstract

The aim of the invention is to create an installation comprising a straight permanent mold (9) out of a continuous casting installation having a curved permanent mold (1), whereby as many components as possible of the continuous casting installation having the curved permanent mold (1) can be used for additional applications. To this end, the straight casting which exits the straight permanent mold (9) is, in at least one bending zone (12), curved along a transition curve to form the shape of a circular arc comprising a first radius (R_{min}). In addition, said casting is, in at least one successive straightening zone (14), curved along a transition curve to form the shape of a circular arc comprising a second radius (R_{end}) which is larger than the first radius (R_{min}). Said radius (R_{end}) preferably corresponds to the shape of the circular arc of an initial continuous casting installation having a curved permanent mold (1).



(57) Zusammenfassung

Um ausgehend von einer Stranggießanlage mit einer Bogenkokille (1) eine Anlage mit einer geraden Kokille (9) zu schaffen, wobei möglichst viele Komponenten der Stranggießanlage mit der Bogenkokille (1) weiter Verwendung finden können, wird wie folgt vorgegangen: der aus der geraden Kokille (9) austretende gerade Strang wird in mindestens einer Biegezone (12) entlang einer Übergangskurve in eine einen ersten Radius (R_{min}) aufweisende Kreisbogenform gebogen, in mindestens einer nachgeordneten Richtzone (14) entlang einer Übergangskurve in eine Kreisbogenform mit größerem zweiten Radius (R_{end}) als der erste Radius (R_{min}) gebogen, welcher Radius (R_{end}) vorzugsweise dem der Kreisbogenform einer ursprünglich vorhandenen Stranggießanlage mit Bogenkokille (1) entspricht.

Process for Continuously Casting Metal and Continuous Casting Apparatus Used Therefor

The invention relates to a process for continuously casting metal strands and, in particular, steel strands by casting the metal into a straight, vertically oriented mold and subsequently drawing off the straight strand formed in the mold, wherein the straight strand at first is bent in a bending zone along a transition curve into a circular arc shape having a radius, is guided along a circular arc guide having said radius, subsequently is straightened in a final straightening zone along a transition curve and, after this, is extracted via an approximately horizontal straight guide, as well as a continuous casting apparatus for carrying out said process and a process for converting a continuous casting apparatus including a curved mold into a continuous casting apparatus including a straight mold.

It is known, for instance, from AT-B - 373 518 and AT-B - 331 439 to use a straight mold in order to produce a metal strand by the continuous casting method, i.e., a mold whose cavity receiving the liquid metal is designed straight and oriented in a vertical sense. After emergence from the mold, the strand is guided over a guide comprising a roller system installed either in supporting segments or in throughgoing longitudinal carriers and cooled in a manner that the still thin strand skin is sufficiently supported against bulging caused by the ferrostatic pressure. In most cases, the strand below the mold initially is still guided by a straight guide extenting over a length so as to impart on the strand a sufficiently solid strand shell due to direct cooling below the mold such that the strand may subsequently be bent in a bending zone in a manner so as to be able to be further conveyed along a circular arc guide following the bending zone and having a predetermined radius. Upon the circular arc guide follows a final straightening zone, in which the strand is straightened again. In the straight state, the strand is extracted via an approximately horizontally oriented straight guide .

It is, furthermore, known, for instance, from AT-B - 249 896 to cast the strand already in a bent shape in a socalled curved mold in order to produce a metal strand by the continuous casting method, avoiding a bending zone. In such a curved mold, the cavity into which the liquid metal is cast is arc-shaped and, preferably, circular arc-shaped such that the strand emerging from the mold can be supported and conveyed by a circular arc guide immediately upon its emergence. In that case, it will do to provide a final straightening zone at the end of the circular arc guide, in which the strand is straightened again so as to be subsequently extractable from an approximately horizontal straight guide, as described above.

Continuous casting plants comprising curved molds have been built worldwide; yet, such plants involve metallurgical drawbacks, which are to be seen primarily in that impurities and

gas bubbles introduced by the casting jet and penetrating deeply into the strand core can no longer ascend to the meniscus as easily as in a straight mold. Besides, the flow ratios in a curved mold are less beneficial such that disturbances in the shell growth are quite likely to occur.

For the above reasons, attempts have been made to convert continuous casting apparatus including curved molds into continuous casting apparatus including straight molds. If, in doing so, the same strand guide is to be used as provided in the original curved mold continuous casting apparatus, one is forced to arrange a bending zone to precede the circular arc-shaped strand guide as well as a straight continuous casting mold in alignment above the same. However, this involves difficulties since the level of the straight mold will be far above the height of the originally provided curved mold. This is inacceptable, eventually requiring not only an enlargement of the casting hall, but also a redevelopment of the overall hall concept with the casting platform, intermediate vessels and ladle carrying tower as well as the ladle supplies etc. having to be adapted to that new level. As a result, the casting hall will have to be completely reorganized, which is accordingly expensive and, on the other hand, necessitates a long standstill of the casting operation.

Another option consists in replacing the circular arc guide with a circular arc guide adapted to the straight mold and consecutive bending zone. This is, however, also very cumbersome and expensive so that the metallurgical drawbacks of a curved mold will have to be put up with in most cases.

The invention has as its object to provide a continuous casting process as well as a continuous casting apparatus for carrying out said process, which enable casting of the strand using a straight mold and applying the most important components of a continuous casting apparatus including a curved mold such as, e.g., the circular arc guide, the casting platform, etc. Another aim of the invention consists in approximately keeping in a continuous casting apparatus including a straight mold, the structural height of a continuous casting apparatus including a curved mold at the same radius of the casting strand and the circular arc guide, respectively. Conversions required when changing from a curved mold to a straight mold are to be minimized in terms of both time and cost.

In a process for continuously casting a metal strand of the initially defined kind, this object is achieved in that the strand in at least one bending zone along a transition curve is bent into a circular arc shape having a first radius and in at least one consecutively arranged straightening zone along a transition curve is bent into a circular arc shape having a larger radius than the

curve at first is bent into a circular arc shape having a first radius and in at least one consecutively arranged first straightening zone along a transition curve is straightened into a circular arc shape having a larger radius than the radius of the strand after the first bending zone, the strand being straightened along a transition curve in a final straightening zone, and the strand being extracted via an approximately horizontal straight guide after having passed through the final straightening zone.

Preferably, the strand having a first radius between the first bending zone and the first consecutively arranged straightening zone is guided along a circular arc guide having said first radius, the straight strand emerging from the mold advantageously being guided between the mold and the first bending zone along a vertical straight guide.

If the radius of the circular arc guide is very large, the strand, after having been bent in the first straightening zone following the bending zone, in at least one further consecutively arranged straightening zone suitably is bent into a circular arc shape having a larger radius than the radius of the strand in front of the further consecutively arranged straightening zone.

According to a variant, in the event of large radii of the circular arc guide, at least one further shaping of the strand may be effected in a further bending zone and consecutively arranged straightening zone, following shaping in the first bending zone and consecutively arranged straightening zone.

A continuous casting apparatus for carrying out the process according to the invention, comprising a straight mold, a strand guide following upon said mold in the strand extraction direction and including a first bending zone, a circular arc guide and a final

straightening zone followed by an approximately horizontal straight guide is characterized in that at least one first straightening zone straightening the strand into a circular arc shape with a larger radius, as compared with the first bending zone, and being followed by a consecutively arranged circular arc guide is arranged to follow at least one first bending zone.

Advantageously, a circular arc guide is provided between the first bending zone and the first straightening zone, a vertical straight guide suitably being provided for the strand between the mold and the first bending zone.

According to a variant, at least one further bending zone followed by a straightening zone is arranged to follow the first bending zone and consecutively arranged straightening zone.

A preferred embodiment is characterized in that, according to AT-B - 331 439, the strand elongation course caused by the bending zone(s) and straightening zones, respectively, in at least one of the two transitional regions approximately has the shape of an obliquely distorted "S" including an inflectional tangent, wherein the slopes at the beginning and end of the elongation curve plotted above said region are zero, based on the X axis of a cartesian coordinate system whose original is each located in the beginning of the transition curve and whose X axis constitutes a tangent to the transition curve.

In that case, the inclination of the inflectional tangent suitably at most corresponds to a maximally admissible change of elongation of 0.0025%/mm during bending and 0.0030%/mm during straightening.

Preferably, the transition curve follows the differential equation of the change of curvature (y"')

$$y''' = \varphi'(x_j) \cdot \frac{1}{R_{E_0} X_E \int \varphi'(x_j) dx}$$

and $\varphi'(x_j)$ is the function of the change of elongation, which, over the extension of the bending or straightening zone, has a course initially rising from zero, then reaching the maximum of the change of elongation and then dropping back to zero, R_E is the radius of the circular arc at the end of the bending zone or beginning of the straightening zone, respectively, and X_E is the vertical projection of the bending zone or the horizontal projection of the straightening zone, respectively, and x_j represents a position coordinate within the coordinate system.

A process for converting a continuous casting apparatus including a curved mold, a circular arc guide following thereupon and a final straightening zone with a consecutively arranged, approximately horizontal straight guide, into a continuous casting apparatus including a straight vertically oriented mold is characterized in that

- the curved mold and a circular arc guide part following thereupon are removed,
- a straight mold is installed on a continuous casting apparatus site whose distance relative to the center of curvature of the circular arc guide is smaller than the radius of the original circular arc guide,
- a bending zone including a transition curve is installed in alignment with the straight mold, from which bending zone the strand having a first radius smaller than the radius of the circular arc guide emerges, and
- at least one straightening zone is installed to follow the bending zone, from which straightening zone the strand having a second radius larger than the first radius emerges, and merges into this circular arc guide in an aligned, i.e., tangentially equal matter.

Preferably the second radius (R_{end}) corresponds to the radius (R_{end}) of the original circular guide.

Suitably, a circular arc guide is installed between the bending zone and the first straightening zone.

According to a preferred variant, a straight guide registering with the mold is installed between the mold and the bending zone.

In order to do with not too excessive a bending of the strand, the straight mold advantageously is installed into the continuous casting apparatus on a level only slightly deviating from the level of the curved mold, preferably lying closely above said level, wherein the deviation from the level of the curved mold is a function of the height of the hall, the crane system installed, etc. A "small height deviation" usually serves to denote a deviation that enables the avoidance of a conversion of the hall structure in any event; as a rule, the height deviation in usually designed casting halls ranges between half a meter and one meter at the most.

In the event of large radii of the circular arc guide it has proved suitable to install a further straightening zone with a consecutive circular arc guide so as to follow the first straightening zone.

According to another variant, it is suitable in case of large radii of the circular arc guide, if at least one further bending zone with a consecutive straightening zone is installed so as to follow the first bending zone and consecutively arranged straightening zone.

In the following, the invention will be explained in more detail by way of an exemplary embodiment illustrated in the drawing, the Figure showing a schematic side view of a continuous casting apparatus including a straight mold and a curved mold.

A curved mold 1 with a consecutively arranged strand guide 2 is illustrated in the Figure by broken lines, wherein in the illustration, for reasons of simplicity, the strand guide 2 in the upper region - i.e., immediately below the curved mold 1 - is represented merely by a broken line indicating the external or lower

side of the strand. As usual, this strand guide 2 is formed by supporting and guiding rollers 2' following upon the mold and supporting the strand at small distances on both sides, i.e., on the external or lower side and also on the internal or upper side. The lower or external side of the strand, which is illustrated by a broken line, thus constitutes an envelope of all of these rollers.

The casting platform 3 is located approximately on the level of the upper edge of the curved mold 1. The internal space 4 of the curved mold 1, i.e., the continuous cavity 4 receiving the metal melt, which via a usual casting ladle not illustrated streams into a likewise not illustrated, yet conventionally designed tundish and from there into the curved mold 1 via a casting tube, is designed to be arc-shaped, i.e., circular arc-shaped. The circular arc guide 2 following upon the curved mold 1 has a radius R_{end}. The center 5 of this circular arc guide is located approximately on the level of the lower half of the curved mold 1 and hence below the meniscus 6 of the curved mold 1 by about the height H_0.

The circular arc guide 2, which does not extend over a total quarter circular arc, is followed by a straightening zone 7, in which the strand is straightened by means of supporting and bending rollers. The straightening zone 7 advantageously comprises a transition curve as in accordance with AT-B - 331 439 in order to ensure the careful straightening of the strand. Following the straightening zone 7 is provided an approximately horizontally oriented straight guide 8, which likewise comprises closely adjacent supporting and guiding rollers. The strand is conveyed outwards along this straight guide 8 and, after this, is separated into individual strand pieces or also rolled directly. The straight guide 8 also may deviate from the horizontal line; thus, deviations of 5° $\pm$ from the horizontal are readily feasible.

The Figure in full lines depicts a continuous casting apparatus in which the curved mold 1 is replaced with a straight mold 9. As is apparent from the Figure, this straight mold 9 is arranged to be offset relative to the curved mold 1 in the direction towards the center 5 of the circular arc guide 2 by a horizontal amount H_H.

In addition, this straight mold 9 is offset relative to the curved mold 1 by a slight amount also in terms of height, i.e., by the height H_V. The straight mold 9, i.e., a mold 9 defining a vertically oriented and linear cavity 10 into which the metal melt is cast, is followed by a vertically oriented straight guide 11. This serves to safeguard a purely vertically oriented section of the cast strand ensuring efficient purification, i.e., rising of impurities and gas bubbles washed into the liquid core of the strand by the casting jet.

The vertical straight guide 11 is followed by a bending zone 12 including a transition curve along which the strand is bent from a rectilinear into a circular arc shape. Suitably, this transition curve likewise is configured in accordance with AT-B - 331 439.

The circular arc shape has a radius R_{min} smaller than the radius R_{end} of the circular arc shape 2 provided for the curved mold 1. The bending zone 12 is followed by a circular arc guide 13 having a radius R_{min} and extending only over a smaller radius angle of about 20°. The circular arc guide 13 is followed by a straightening zone 14 in which the strand is slightly straightened exactly to the radius R_{end} of the circular arc guide 2 originally provided for the curved mold 1. R_{min} is to be selected as a function of the material to be cast, the casting speed and the casting thickness (strand thickness). When choosing R_{min} it is to be borne in mind that the strand skin will not be exposed to excessive loads (excessive changes of elongation) during first-time bending.

The nearer the straight mold 9 is shifted to the center of curvature 5, the more readily is it feasible for the straight mold 9 - despite a relatively long straight guide 11 - to keep a level 3 of the curved mold 1, yet at a decrease of R_{min}, particularly if a long vertical straight guide 11 is desired.

In this manner, it is feasible to get the strand from a straight mold 9 into the circular arc guide 2 of the curved mold 1without having to lift the straight mold 9 to a large extent. It is, thus, feasible by way of but a small conversion - only the first part 15 of the circular arc guide 2 departing from the curved mold 1 and extending as far as to the end of the newly provided straightening zone 14 need be removed - to take advantage of all of the metallurgical benefits offered by a straight mold. The tundish and the ladle carrying tower may be readily used further, optionally upon slight lifting. The casting hall itself is not affected at all.

It is apparent from the Figure that slight shortening of the vertical straight guide 11 which follows upon the straight mold 9 would suffice in order for the mold 9 to be located exactly on the level of the curved mold 1.

It is essential to the invention that the strand emerging from the straight mold 9 at first is bent to a radius R_{min} smaller than the radius R_{end} of the circular arc guide 2 of the curved mold 1 and only after this is bent to that radius R_{min}. Bending of the linear strand to the radius R_{end} also may be effected in several steps, for instance by the consecutive arrangement of several straightening zones 14, but also by bending of the straight strand in a first bending zone 12 to a radius R_{min} smaller than the radius R_{end} of the circular arc guide, subsequent straightening to a slightly larger radius than R_{min} exhibited by the strand when leaving the first bending zone, which procedure also may be repeated several times until the radius R_{end} of the circular arc guide of the curved mold has been reached. Such variants including multi-stage straightening

and/or multi-stage bending-straightening advantageously are to be applied if the straight mold 9 is to be located exactly on the level 3 of the removed curved mold 1.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for continuously casting metal strands by casting the metal into a straight, vertically oriented mold and subsequently drawing off the straight strand formed in the mold, wherein the straight strand in at least one first bending zone is bent along a transition curve into a circular arc shape having a first radius (R_{min}) and in at least one consecutively arranged first straightening zone the strand is straightened along a transition curve into a circular arc shape having a larger radius than the radius (R_{min}) of the strand after the first bending zone, the strand being straightened along a transition curve in a final straightening zone and the strand being extracted via an approximately horizontal straight guide after having passed through the final straightening zone.

2. The process according to claim 1, characterized in that the radius of the strand formed in the first straightening zone corresponds to a radius (R_{end}) of a circular arc guide in front of the final straightening zone.

3. The process according to claim 1 or 2, characterized in that the strand having a first radius (R_{min}) between the first bending zone and the first consecutively arranged straightening zone is guided along a circular arc guide having said first radius (R_{min}).

4. The process according to any one of claims 1 to 3, characterized in that the straight strand emerging from the mold is guided between the mold and the first bending zone along a vertical straight guide.

5. The process according to any one of claims 1 to 4, characterized in that the strand, after having been shaped in the first straightening zone, which follows the bending zone, in at least one further consecutively arranged straightening zone is shaped into a circular arc shape having a larger radius than the radius (R_{min}) of the strand in front of the further consecutively arranged straightening zone.

6. The process according to any one of claims 1 to 5, characterized in that at least one further shaping of the strand is effected in a further bending zone and consecutively arranged straightening zone, following shaping in the first bending zone and the consecutively arranged said first straightening zone.

7. The process according to any one of claims 1 to 6, characterized in that the metal strand is a steel strand.

8. A continuous casting apparatus for carrying out the process according to any one of claims 1 to 7, comprising a straight mold, a strand guide following upon said mold in the strand extraction direction and including at least one first bending zone, a circular arc guide and a final straightening zone followed by an approximately horizontal straight guide, characterized in that at least one first straightening zone straightening the strand into a circular arc shape with a larger radius, as compared with the first bending zone, and being followed by a consecutively arranged circular arc guide is arranged to follow at least one first bending zone.

9. The continuous casting apparatus according to claim 8, characterized in that a circular arc guide is

provided between the first bending zone and the first straightening zone.

10. The continuous casting apparatus according to claim 8 or 9, characterized in that a vertical straight guide is provided for the strand between the mold and the first bending zone.

11. The continuous casting apparatus according to any one of claims 8 to 10, characterized in that at least one further bending zone followed by a straightening zone is arranged to follow the first bending zone and consecutively arranged straightening zone.

12. The continuous casting apparatus according to any one of claims 8 to 11, characterized in that the strand elongation course caused by the bending zone(s) and straightening zones, respectively, in at least one of the two transitional regions approximately has the shape of an obliquely distorted "S" including an inflectional tangent, wherein the slopes at the beginning and end of the elongation curve plotted above said region are zero, based on the X axis of a cartesian coordinate system whose origin is each located at the beginning of the transition curve and whose X axis constitutes a tangent to the transition curve.

13. The continuous casting apparatus according to claim 12, characterized in that the inclination of the inflectional tangent at most corresponds to a maximally admissible change of elongation of 0.0025%/mm during being and 0.0030%/mm during straightening.

14. The continuous casting apparatus according to claim 12 or 13, characterized in that the transition curve

follows the differential equation of the change of curvature (y''')

$$y''' = \varphi'(x_j) \cdot \frac{1}{R_{\varepsilon_e} X_\varepsilon \int \varphi'(x_j) dx}$$

and $\varphi'(x_j)$ is the function of the change of elongation, which, over the extension of the bending and straightening zones, has a course initially rising from zero, then reaching the maximum of the change of elongation and then dropping back to zero, R_E is the radius of the circular arc at the end of the bending zone or beginning of the straightening zone, respectively, and X_E is the vertical projection of the bending zone or the horizontal projection of the straightening zone, respectively, and x_j represents a position coordinate within the coordinate system.

15. A process for converting a continuous casting apparatus including a curved mold, a circular arc guide following thereupon and a final straightening zone with a consecutively arranged, approximately horizontal straight guide, into a continuous casting apparatus including a straight vertically oriented mold, wherein

- the curved mold and a circular arc guide part following thereupon are removed,
- a straight mold is installed on a continuous casting apparatus site whose distance relative to the center of curvature of the circular arc guide is smaller than the radius (R_{end}) of the original circular arc guide,
- a bending zone including a transition curve is installed in alignment with the straight mold, from which bending zone the strand having a first radius (R_{min})

smaller than the radius (R_{end}) of the circular arc guide emerges, and

- at least one straightening zone is installed to follow the bending zone, from which straightening zone the strand having a second radius (R_{end}) larger than the first radius (R_{min}) emerges, and merges into this circular arc guide in an aligned, i.e., tangentially equal manner.

16. The process according to claim 15, wherein the second radius (R_{end}) corresponds to the radius (R_{end}) of the original circular arc guide.

17. The process according to claim 15 or 16, characterized in that a circular arc guide is installed between the bending zone and the first straightening zone.

18. The process according to any one of claims 15 to 17, characterized in that a straight guide registering with the mold is installed between the mold and the bending zone.

19. The process according to any one of claims 15 to 18, characterized in that the straight mold is installed in the continuous casting apparatus on a level only slightly deviating from the level of the curved mold.

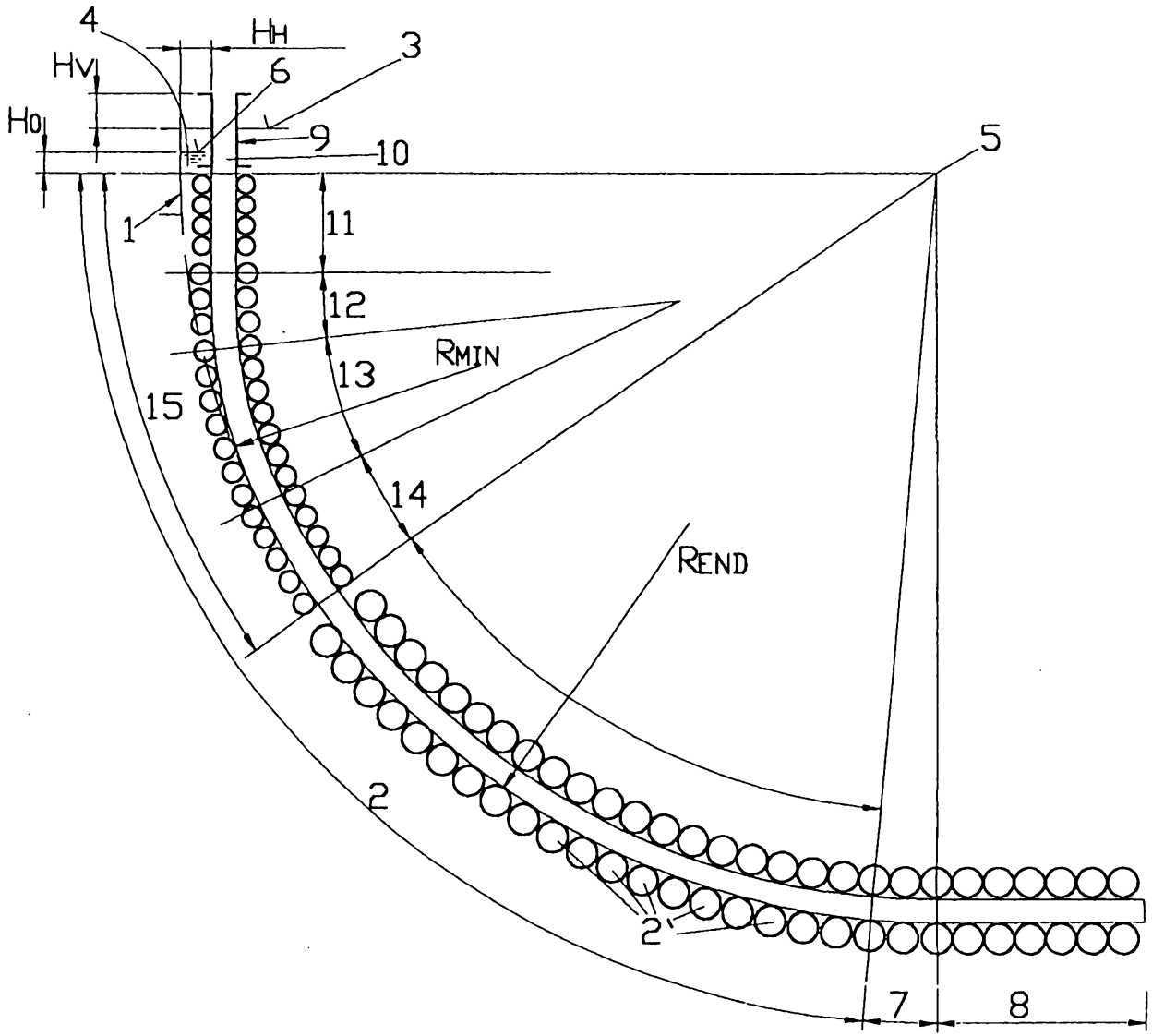
20. The process according to claim 19, wherein the straight mold is installed in the continuous casting apparatus on a level lying closely above the level of the curved mold.

21. The process according to any one of claims 13 to 16, characterized in that a further straightening zone with a consecutive circular arc guide is installed so as to follow the first straightening zone.

22. The process according to any one of claims 13 to 17, characterized in that at least one further bending zone with a consecutive straightening zone is installed so as to follow the first bending zone and consecutively arranged straightening zone.

23. A process for continuously casting metal substantially as herein described with reference to the accompanying figure.

Dated this 5th day of August 2003
VOEST-ALPINE INDUSTRIEANLAGENBAU GmbH
and SOLLAC-FOS
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