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Method and apparatus for high-speed continuous casting plants with a strand thickness reduction during solidification

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Invention Title:

METHOD AND APPARATUS FOR HIGH-SPEED CONTINUOUS CASTING PLANTS WITH A STRAND THICKNESS REDUCTION DURING SOLIDIFICATION

The following statement is a full description of this invention, including the best method of performing it known to me/us:

ABSTRACT OF THE DISCLOSURE

A method and an apparatus for continuous casting plants for producing strands whose cross-section is reduced during solidification. The continuous casting method for producing strands, wherein the cross-section of the strands is reduced during the solidification, includes casting into a mold, particularly an oscillating mold, and reducing the strand cross-section linearly over a minimum length of the strand guiding unit immediately underneath the mold, i.e., casting and rolling, and subsequently carrying out a further strand cross-section reduction through the remaining strand guiding unit, i.e., soft reduction, up to maximum reduction immediately in front of the final solidification or sump tip.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and an apparatus for continuous casting plants for producing strands whose cross-section is reduced during solidification.

2. Description of the Related Art

It is known in the art that strands are manufactured in such high-speed plants generally with a solidification thickness of between 18 and 450mm and casting speeds of up to at most 15m/min., for example, in plants for casting slabs, blooms and billets with quadratic or round profiles, wherein a reduction of the strand cross-section is preferably carried out during the solidification after the strand emerges from the mold.

This technology of casting and rolling of thin slabs or round billets is known from German patents 44 03 048, 44 03 049 and 41 39 242; in the case of thin slabs, this technology is used daily in production plants.

For example, a thin slab having a thickness of, for example, 65mm is reduced to 40mm in segment 0 which is arranged directly underneath the mold. This strand thickness reduction of 25mm or 38.5% may be a disadvantage with respect to the quality of certain steels which are sensitive to internal ruptures. Thus, the internal deformation of the strand, due to the strand thickness reduction or also called casting and rolling, may trigger internal ruptures because the critical deformation of the material is exceeded at the inner strand shell liquid/solid, but also at the outer strand shell.

The above example is based on a circular arc segment 0 which has a length of 2m and which does not introduce bending work or bending deformation into the strand shell. In this case, the deformation speed of the strand shell during casting and during solidification, which represents a measure for the strand deformation, is 1.25mm/s at a casting speed of 6m/min. When the casting speed is increased to, for example, 10m/min., this value of the deformation speed increases to 2.08mm/s and becomes very critical. Such internal deformations caused by casting and rolling are not only critical for deep drawing steel qualities which are relatively insensitive to internal deformations, but primarily for sensitive steels, such as microalloyed APX -80 qualities.

In addition, in vertical bending units in which usually bending of the strand occurs in the segment underneath the mold simultaneously with the deformation caused by casting and rolling, the bending deformation introduced into the strand is significantly increased, so that the danger of exceeding the critical deformation and, thus, the formation of cracks is even further increased.

SUMMARY OF THE INVENTION

Therefore, in view of the findings and relationships described above, it is the primary object of the present invention to provide technical method measures and simple apparatus features for predetermining the deformation density of the strand cross-section reduction in such a way that the critical deformation of the strand is not exceeded while taking into consideration the casting speed and also the steel quality.

In accordance with the present invention, the continuous casting method for producing strands, wherein the cross-section of the strands is reduced during the solidification, the method includes casting liquid metal in a mold, preferably an oscillating mold, and reducing the strand cross-section linearly over a minimum length of the strand guiding means immediately underneath the mold, carrying out a further strand cross-section reduction through the remaining length strand guiding means, or a portion thereof, for effecting soft reduction, up to solidus point of the metal sump tip, wherein the total reduction of the strand cross-section is at most 60%.

The continuous casting plant according to the present invention for carrying out the above-described method includes the following elements:

an oscillating mold for casting liquid metal;

a strand guide means having a first segment which linearly reduces the strand in its cross-section by at most 40% over a length of at least 1m;

the strand guide means also having one or more further segments for soft reducing the strand in its cross-section up to the solidus point or sump tip of the metal;

wherein the total reduction of the strand cross-section in said first segment and said further segments is up to 60%.

The features of the present invention are applicable to all sizes cast in a strand and also for all types of continuous casting plants.

The following unexpected solution according to the present invention for achieving the above-described objects will be explained in more detail in connection with a thin slab, wherein the invention is particularly discussed with respect to casting of thin slabs having a thickness of between 60 and 120mm after solidification, i.e., the thickness of the slab in the edge areas is, for example, a minimum of 70mm and a maximum of 160mm at the mold exit. In accordance with the prior art, the reduction of the strand thickness, which usually takes place between the upper and the lower side of a strand guiding means, is today under test conditions at most 60%, i.e., a slab having a thickness of 50mm is reduced to about 20mm over a roll gap length of about 200mm, and is under production conditions at most 38.5%, i.e., the strand is reduced from 65 to 40mm over the length of the segment 0 which is about 2m, wherein segment 0 is arranged underneath the mold. In both cases, the maximum casting speed is 6m/min.

The invention will be described on the basis of an example of a thin slab having a thickness of 100mm at the mold exit and a solidification thickness of 80mm. The invention proposes a type of distribution and the realization of the slab thickness reduction during the solidification of the thin slab in the strand guiding stand for, for example, casting speeds of 6 and 10m/min.

In tables 1 and 1.1, the essential process and apparatus data of the invention are compared to those of the prior art. Table 1 shows the data for casting speeds of 6m/min and table 1.1 shows the data for casting speeds of 10m/min.

In both tables, the total reduction of the thickness of the strand of 20mm during the solidification is varied in its distribution between the segment 0 and the remaining strand guiding means, i.e., the segments 1 through at most 13. In the tables, the prior art is illustrated by a total reduction of the strand thickness of 20mm carried out solely in segment 0 (compare items 19 through 22 in column 1). This clearly shows that the reduction speed of the strand is increased in the segment 0 which has a length of 3m from 0.67 to 1.11mm/s, triggered by the strand thickness reduction or the casting and rolling process and, thus, functionally the strand shell deformation, wherein the casting speed increases from 6m/min to 10m/min.

Items 19-22 and 23-28, columns 2, 3 and 4 and items 29-34 represent the solution according to the present invention which results in a significant lowering of the deformation density of the strand shell by a redistribution of the total thickness reduction of 20mm between the segment 0 and the segments 1-n, also called soft reduction. This redistribution will be explained in detail with the aid of the following examples:

- 15mm in segment 0 and 5mm in the segments 1 to n, items 19-28, column 2;

- 10mm in segment 0 and 10mm in segments 1 to n, items 19-28, column 3;

- 5mm in segment 0 and 15mm in segments 1 to n, items 19-28, column 4;

- 20mm in segments 0 to n, items 29-34.

In this manner, the reduction speed, and, thus the functional deformation density of the strand shell with a 20mm total thickness reduction and 10m/min casting speed can be reduced from:

- 1.11mm/s, 20mm in segment 0, according to the prior art, item 21, column 1, to

- 0.114mm/s, 20mm in segments 0 to 13, item 33.

However, as a result of displacing a portion of the thickness reduction from segment 0 into the segments 1-13 or 1-2, depending on the casting speed, the work to be introduced into the stand increases with increasing strand shell thickness. Therefore, the present invention takes into account that an optimum distribution of the total thickness reduction in the total strand guiding means between the segment 0 and the segment n, which reaches immediately behind the final solidification, also includes the strand shell thickness. This is achieved in an advantageous manner by a square root function over the solidification time either in the areas of the segments 1-n, soft reduction or in the areas of the segments 0-n, soft reduction.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of the disclosure. For a better understanding of the invention, its operating advantages, specific objects attained by its use, reference should be had to the drawing and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

Figs. 1-7 are diagrams comparing the continuous casting of strands according to the prior art to the continuous casting of strands in accordance with a preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 of the drawing schematically shows in partial illustrations 1a and 1b the situation of a strand having a thickness in the mold of 100mm and a solidification thickness of 80mm, with a casting speed of 10m/min. and a total strand thickness reduction of 20mm. The upper profiles only in segment 0 represents casting and rolling according to the prior art. The other profiles, only changing by approximately 10mm in segment 0, and 10mm in segments 1-13, i.e., soft reduction represent the preferred embodiment of the invention. Moreover, the diagram shows the strand in the machine with its steel phases, such as:

- the overheating phase (1), the pure molten steel phase or also called penetration zone with its lowest liquidus point 1.1;

- the two-phase area melt/crystal (2) with its lowest solidus point, the sump tip 2.1 after 30m of strand guidance composed of a mold having a length of about 1.2m, a segment 0 having a length of 3m and the segments 1-13 having a total length of 26m; and

- solid phase or strand shell (3).

The pure molten steel phase or also penetration zone is located in the area of segment 0 in which is carried out a strand thickness reduction or the casting and rolling of 2 x 10mm or 20mm and no further reduction in the following segments 1-13, in accordance with the prior art as shown in sides 1a and 1b of Fig. 1, or, in accordance with the preferred embodiment, shown on sides 1a and 1b, a reduction of 2 x 5mm or 10mm per side, i.e., casting and rolling, and an additional 10mm in the following segments 1-13, i.e., soft reduction. The reduction of the strand thickness in segment 0, which is constructed, for example, as a tong-segment with two clamping devices, for example, hydraulic cylinders 14, at the segment exit, it is carried out linearly over a length of 3m; the reduction in the area of the segments 1-13 can take place partially in each segment, or also linearly over all segments as well as non-linearly, i.e., following the example of a square root. As can be seen, reduction of 10mm at sides 1a and 1b of the strand can be linearly distributed in segments 1-13, i.e., soft reduction.

When comparing the preferred embodiment of the present invention with the prior art, the reduction speed in mm/s of the strand shell which represents a measure for the strand shell deformation can be significantly reduced, as illustrated by the following values:

- prior art, sides 1a and 1b:

a) segment 0, total reduction of 20mm, casting and rolling, reduction speed 1.11mm/s;

b) segments 1-13, reduction 0mm, no soft reduction, reduction speed 0.

- Preferred embodiment of invention, sides 1a and 1b:

a) segment 0, total reduction of approximately 10mm, casting and rolling, reduction speed 0.56mm/s;

b) segments 1-13, total reduction approximately 10mm, soft reduction, reduction speed 0.064mm/s.

The distribution of the strand thickness reductions can now be selected between the segment 0 and the following segments 1-13 in an optimum manner with respect to the possible strand deformation while avoiding internal cracks and surface cracks and with respect to the minimum work to be introduced for strand thickness reduction which increases with the thickness of the strand shell.

This distribution effect on the reduction speed and, thus, on the load acting on the strand shell, is indicated in tables 1 and 1.1 and is shown in Figs. 2 and 3. Fig. 2 shows the reduction of the strand thickness in mm/m strand guidance for a total thickness reduction of 20mm in dependence on different reductions in the segment 0 and the corresponding complimentary thickness reduction in the segments 1-13 for the continuous casting speeds of 6 and 10m/min. In the case of a linear distribution of the total reduction of 20mm over all segments 0 to 8 or 13, the following values are adjusted with respect to thickness reduction RL-6 and RL-10 and reduction speed RS-6 and RS-10 of:

- 1.168mm/m strand guiding means RL-6 and 0.117mm/s RS-6 at 6m/min casting speed, or
- 0.685mm/m strand guiding means RL-10 and 0.114mm/s RS-10 at 10/min casting speed.

These values have the lowest deformation density, however, they require a maximum amount of work and result in a soft reduction process over the entire strand guiding means. The claimed invention takes into consideration the gap between the extreme of the total reduction of 20mm in segment 0 and the uniform reduction distributed over the strand guiding means in segment 0 to shortly behind the final solidification of the strand.

As is the case in Fig. 1, Fig. 4 schematically illustrates the situation of a strand having a thickness in the mold of 100mm and a solidification thickness of 80mm for the casting speeds VG of 6m/min, side 4a of Fig.4, and 10m/min, side 4b. In accordance with the preferred embodiment of the present invention, in the case of VG 6m/min, the strand thickness reduction of, for example, 10mm is carried out in segment 0 and the remaining reduction of 10mm is carried out in segments 1-8, corresponding to the shorter solidification distance. Thus, the lowest liquidus point 1.2 is already at about 1.8m and the sump tip 2.2 is at about 18.12m. Since the reduction of the strand thickness takes place at most over 18.12m, and simultaneously is to include the final solidification, the segments 1-8 are utilized for the reduction of the thickness. As is the case in Fig. 1, side 1b, side 4b of Fig. 4 shows the situation of the strand in the case of a casting speed of VG 10m/min.

The comparison of the casing situations according to the present invention shown on sides 4a and 4b of Fig. 4, results in the following values of the reduction speeds, and thus, loads acting on the strand shell:

6m/min, side 4a of Fig. 4 (example of the invention)

- segment 0, total reduction 10mm, reduction speed 0.33mm/s, casting and rolling;

- segments 1-8, reduction 10mm, reduction speed 0.071mm/s, soft reduction;

10m/min, side 4b of Fig. 4 (example of the invention)

- segment 0, total reduction of 10mm,

reduction speed 0.56mm/s, casting and rolling;

- segments 1-13, total reduction of 10mm, reduction speed 0.064mm/s, soft reduction.

This comparison demonstrates that the distribution of the thickness reduction is also a question of the casting speed and that, in accordance with the location of the sump tip, i.e., the casting speed, the thickness reduction and its distribution in the segments 1 to n 0 to n, must be adapted to an optimum casting situation with respect to the casting safety and the strand quality.

The drawing shows the effect of a distribution of the strand thickness reduction in segment 0 and in the segments 1-13 in accordance with the invention, illustrated in Fig. 5b, in the example of a vertical bending machine, as compared to the prior art shown in Fig. 5a, on the internal strand deformation caused by the bending deformation and the strand thickness reduction, in dependence on the strand guidance for the maximum casting speed of, for example 10m/min.

Fig. 5a representing the prior art shows the internal strand deformation in dependence on the strand guiding means 4, for example, for a maximum casting speed Vg-10 of 10m/min as compared to the limit deformation D-Gr. At the exit of the mold, the strand is subjected to a deformation caused by casting and rolling D-Gw in segment 0, as well as to a deformation caused by the bending process D-B. Both deformations are superimposed to the total deformation D-Ge which is greater than the limit deformation D-Gr and, thus, becomes critical. When the limit deformation is exceeded, this leads to internal cracks at the phase boundary solid/liquid, and, thus, to a diminished quality of the strand and to a lowering of the casting safety. The strand is subjected to another increase of the internal deformation D by the deformation D-R occurring during return bending in segment 4 from the inner circular arc into the horizontal which, however, cannot be critical because the number of return bending points is selected when "designing" the plant in such a way that the return bending process cannot trigger at maximum casting speed a critical internal deformation in the strand shell of the steel quality which is most sensitive to cracks.

Fig. 5b shows the technical features of the method according to the present invention in connection with a vertical bending plant, as schematically illustrated in Fig. 6. The internal deformation D of the strand shell 3 does not become critical at any moment of solidification, i.e., from the mold exit to the end of the stand 13. In accordance with the invention, this is ensured by the distribution of the total strand thickness reduction of 20mm to, for example, 10mm in segment 0 D-Gw and 10mm in the stands 1-13 D-sr. In addition, the bending process and the attendant deformation D-V has been transferred from segment 0 to segment 1 in order not to additionally increase the deformation density D-Gw in segment 0, which is caused by casting and rolling of, for example, 10mm and, while lowered, is still relatively high. The deformation D-SR produced in segments 1-13 and caused by soft reduction of a total of, for example, 10mm, is relatively small and does not result in a practical increase of the deformation D-R when return bending the strand in segment 4, i.e., D-Ge is approximately greater than/equal to D-R.

Fig. 6 shows a vertical bending unit in which the present invention can be used for casting slabs having a thickness of

100mm at the mold exit with a solidification thickness of 80mm and a maximum VG 10m/min. This plant has the technical method features described in connection with Figs. 1-5. In addition to a distributor V and a submerged pouring pipe Ta, the continuous casting plant includes:

- a vertical mold K having a length of about 1.0m, which is preferably constructed concavely in horizontal direction;
- a segment 0 having a length of 3m, which is equipped for casting and rolling or also for strand thickness reduction preferably as a tong-type segment and with two hydraulic cylinders 14 at its exit;
- segment 1 with 5 bending points 23;
- segments 2 and 3 with the inner circular arc having a radius of about 4m;
- segment 4 for return bending the strand from the inner circular arc through five return bending points 24 into the horizontal; and
- segments 5-13 in the horizontal portion of the machine.

This machine configuration with a maximum casting speed of 10m/min and a maximum capacity of about 3 million tons per year constitutes an extremely advantageous solution for use of the invention in which a minimum deformation density of the strand occurs during its solidification.

In order to be able to advantageously realize the type of strand thickness reduction according to the present invention in the above-described segments 1-13, the segments should be constructed in principle as illustrated in Fig. 7. A segment should preferable be constructed of an odd number of 3, 5, 7 or 9 pairs of rollers 15, wherein each pair has a lower roller 16 and an upper roller 17. Each segment, in turn, is alternatingly composed of a driven pair of rollers 18, controlled with respect to position and force by a hydraulic system 19, and two non-driven pairs of rollers 21 which are connected to a hydraulic system 20 in the area of the upper rollers 17 and are provided with a machine element 22 which makes it possible to allow the pair of rollers of the upper path in casting direction to swing about an angle of, for example +/- 5 degrees in order to be able to guide the strand and ensure its shape in any casting situation with a given strand thickness reduction.

This configuration of the segments 1-13 results in an optimum strand guidance in any type of distribution of the strand thickness reduction, any casting situation, any type of steel quality, with respect to its sensitivity to internal cracks, i.e., the level of the critical deformation limit and with respect to the use of a minimum of hydraulic systems for each pair of rollers. Thus, 0.66 hydraulic systems are used for each pair of rollers. Also, the use of driven pairs of rollers of 0.33 units per pair of rollers represents a mechanical minimum with a maximum effect with respect to process technology and quality of the strand to be cast and its outer surface quality and its internal quality, i.e., for example, a minimum structural requirement and a minimum cumulation of tensile stresses in the strand shell between the driven pairs of rollers.

The present invention has been described in connection with a thin slab plant; however, the present invention can also be utilized with respect to the method and the apparatus in other continuous casting plants, such as:

- slab plants;
- bloom plants; and
- billets plants for square and round billets.

While specific embodiments of the invention have been shown and described in detail to illustrate the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

Table 1

Casting Speed 6m/min

			1	2	3	4	5
1	Strand thickness	mm	100				
2	Solidification Thickness	mm	80				
3	Metallurgical length of the mold	m	1				
4	Length of the segment 0	m	3				
5	Length of segments 1-13	m	26				
6	Length of the total strand guidance	m	30				
7	Solidification time	min	3,02				
8	Solidification time	s	181,2				
9	Casting speed	m/min	6,0				
10	Metallurgical length of the strand	m	18,12				
11	Solidification time, entering segment 0	min	0,167				
12	Solidification time, entering segment 0	s	10,0				
13	Strand shell thickness, entering segment 0	mm	9,4				
14	Travel time of strand in segment 0	min	0,5				
15	Travel time of strand in segment 0	s	30,0				
16	Solidification time, leaving segment 0	min	0,667				
17	Solidification time, leaving segment 0	s	40,02				
18	Strand shell thickness, leaving segment 0	mm	18,78				
19	Thickness reduction in segment 0	mm	20	15	10	5	0

20	Thickness reduction in segment 0	%	20	15	10	5	0
21	Reduction speed	mm/s	0,67	0,5	0,33	0,17	0
22	Reduction/meters of strand guidance	mm/m	6,67	5,0	3,33	1,67	0
23	Soft reduction in segment 1-n(8)	mm	0	5	10	15	20
24	Time for remaining solidification	min			2,353		
25	Time for remaining solidification	s			141,18		
26	Soft reduction speed	mm/s	0	0,035	0,071	0,106	0,14
27	Metallurgical length of the residual solidification	m			14,12		
28	Soft reduction/meters residual solidification	mm/m	0	0,35	0,71	1,062	1,42
29	Soft reduction, segment 0-n(8)	mm			20		
30	Time of solidification in segments 0-n	min			2,853		
31	Time of solidification in segments 0-n	s			171,18		
32	Metallurgical length, segments 0-n	m			17,12		
33	Soft reduction - speed, segments 0-n	mm/s			0,117		
34	Soft reduction/meters solidification, segments 0-n	mm/m			1,168		

Table 1.1

Casting Speed 10m/min

			1	2	3	4	5
1	Strand thickness	mm	100				
2	Solidification Thickness	mm	80				
3	Metallurgical length of the mold	m	1				
4	Length of the segment 0	m	3				
5	Length of segments 1-13	m	20				
6	Length of the total strand guidance	m	30				
7	Solidification time	min	3,02				
8	Solidification time	s	181,2				
9	Casting speed	m/min	10,0				
10	Metallurgical length of the strand	m	30,20				
11	Solidification time, entering segment 0	min	0,10				
12	Solidification time, entering segment 0	s	6,0				
13	Strand shell thickness, entering segment 0	mm	7,3				
14	Travel time of strand in segment 0	min	0,3				
15	Travel time of strand in segment 0	s	18,0				
16	Solidification time, leaving segment 0	min	0,4				
17	Solidification time, leaving segment 0	s	24,0				
18	Strand shell thickness, leaving segment 0	mm	14,55				
19	Thickness reduction in segment 0	mm	20	15	10	5	0

20	Thickness reduction in segment 0	%	20	15	10	5	0
21	Reduction speed	mm/s	1,11	0,83	0,56	0,28	0
22	Reduction/meters of strand guidance	mm/m	6,67	5,0	3,33	1,67	0
23	Soft reduction in segment 1-n(13)	mm	0	5	10	15	20
24	Time for remaining solidification	min			2,62		
25	Time for remaining solidification	s			157,2		
26	Soft reduction speed	mm/s	0	0,032	0,064	0,095	0,127
27	Metallurgical length of the residual solidification	m			26,2		
28	Soft reduction/meters residual solidification	mm/m	0	0,19	0,38	0,57	0,76
29	Soft reduction, segment 0-n(13)	mm			20,0		
30	Time of solidification in segments 0-n	min			2,92		
31	Time of solidification in segments 0-n	s			175,2		
32	Metallurgical length, segments 0-n	m			29,2		
33	Soft reduction - speed, segments 0-n	mm/s			0,114		
34	Soft reduction/meters solidification, segments 0-n	mm/m			0,685		

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of continuous casting strands, wherein a cross-section of the strands is reduced during solidification, the method including:

casting liquid metal in a mold and reducing the strand cross-section linearly over a minimum length of a strand guiding means immediately below the mold; and

carrying out a subsequent further strand cross-section reduction over the length of the strand guiding means, or a portion thereof, for effecting soft reduction up to the solidus point or sump tip of the metal,

wherein the total reduction of the strand cross-section is at most 60%.

2. The method according to claim 1, including oscillating the mold.

3. The method according to claim 1, including reducing a strand thickness of thin slabs with a solidification thickness of 120-50mm.

4. The method according to claim 1, including reducing a strand thickness with a rate of less than 1.25mm/s by dividing a total thickness reduction into the rolling and casting reduction immediately underneath the mold and the soft reduction in the remaining strand guiding means at a maximum casting speed.

5. The method according to claim 1, including casting with a maximum casting speed of 12m/min.

6. The method according to claim 1, including

reducing a strand thickness during soft reduction linearly over a solidification length.

7. The method according to claim 1, including reducing a strand thickness during soft reduction non-linearly and in accordance with a square root function over a solidification period.

8. The method according to claim 1, wherein a total thickness reduction is carried out linearly and steadily from a mold exit to at most directly following the solidus point or sump tip.

9. The method according to claim 1, including bending of the strand into an inner circular while carrying out soft reduction.

10. The method according to claim 1, including carrying out casting and rolling exclusively in a vertical strand guiding means without the lowest liquidus point leaving the strand guiding means at a maximum casting speed.

11. A continuous casting plant for producing strands and, reducing the cross-section of the strands during solidification, the continuous casting plant including:

an oscillating mold for casting liquid metal;

a strand guide means having a first segment in which the strand is linearly reduced in its cross-section by at most 40% over a length of at least 1m;

the strand guide means also having one or more further segments for soft reducing the strand in its cross-section up to the solidus point or sump tip of the metal;

wherein the total reduction of the strand cross-section in said first segment and said further segments is up to 60%.

12. The continuous casting plant according to claim 11, wherein, for reducing the strand thickness, said first segment includes at an exit thereof two clamping cylinders controlled with respect to position and force applied by the rollers.

13. The continuous casting plant according to claim 11, wherein the first segment is configured for reducing the strand thickness by at most 100mm.

14. The continuous casting plant according to claim 11, wherein the or each further segment of the remaining strand guiding means comprise position-controlled and force-controlled strand thickness adjustments.

15. The continuous casting plant according to claim 14, wherein each segment has an odd number of pairs of rollers, wherein the number of pairs of rollers is at least 3.

16. The continuous casting plant according to claim 15, wherein each third pair of rollers is a pair of driven rollers.

17. The continuous casting plant according to claim 15, wherein each pair of rollers includes an upper roller, wherein the upper rollers of non-driven pairs of rollers are provided with position-controlled and force-controlled clamping cylinders.

18. The continuous casting plant according to claim 15, wherein the pairs of rollers include upper rollers, each upper roller of a pair of non-driven rollers and a

cylinder therefor comprising a means for permitting swinging of the rollers by +/- 5 degrees in casting direction.

19. The continuous casting plant according to claim 11, wherein said first segment is arranged vertically and has a maximum length of 5m.

20. The continuous casting plant according to claim 19, wherein the segment following the first segment has at least one bending point for bending the strand from the vertical into a circular arc.

21. The continuous casting plant according to claim 20, wherein at least one of the further segments includes at least one return bending point for straightening the strand from the circular into the horizontal.

22. The continuous casting plant according to claim 21, wherein the horizontal portion of the strand guiding means has a length of at least 4m.

23. The continuous casting plant according to claim 11, wherein the mold has concave mold walls.

24. The continuous casting plant according to claim 11, further including a submerged pouring pipe for casting and casting powder.

25. The continuous casting plant according to claim 11, wherein wide sides of the mold are shaped concavely in horizontal direction, and wherein the concavity of the wide sides decreases toward a mold exit.

26. The continuous casting plant according to claim 11, wherein narrow sides of the mold are shaped concavely in horizontal direction.

27. A method of continuous casting strands substantially as hereinbefore described with reference to the accompanying figures.

28. A continuous casting plant substantially as hereinbefore described with reference to the accompanying figures.

Dated this 5th day of August 2002

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By their Patent Attorneys

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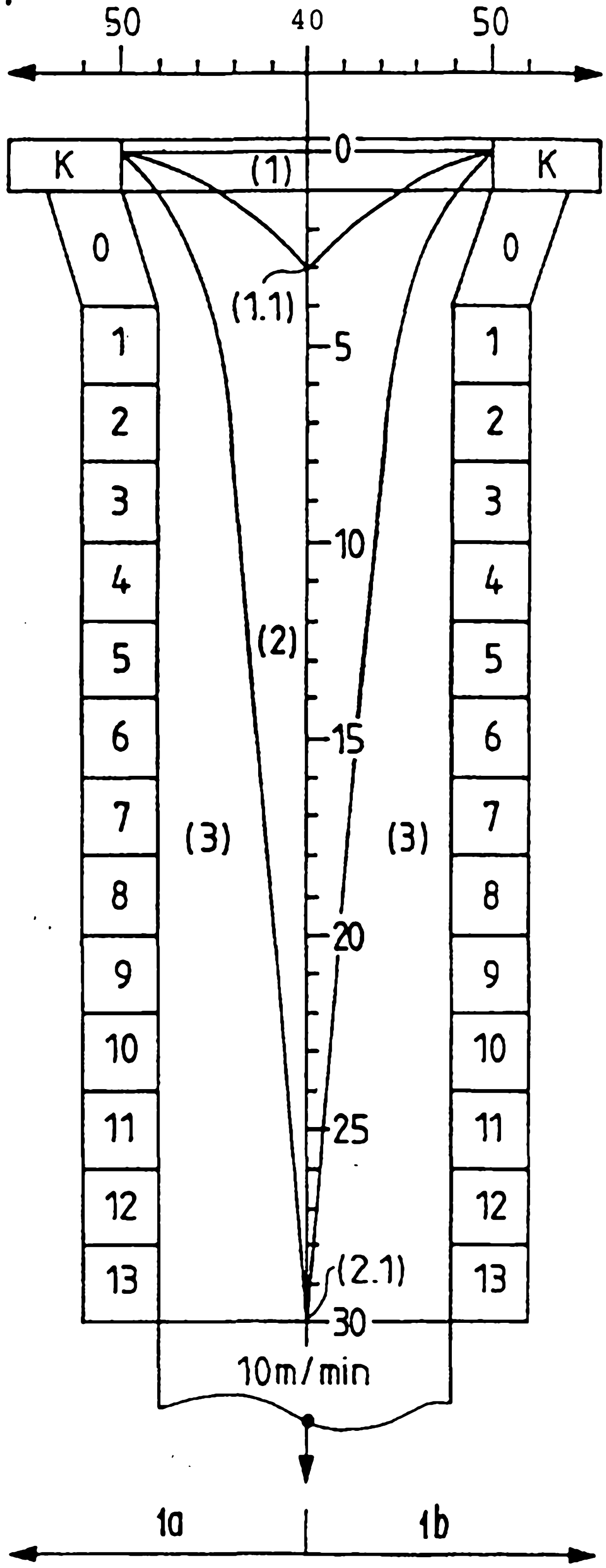
Trade Mark Attorneys of Australia

FIG.1


50
40
50
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(1)
0
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0
0
(1.1)
5
10
(2)
15
(3)
(3)
20
25
(2.1)
30
1
2
3
4
5
6
7
8
9
10
11
12
13
10m/min
1a
1b

FIG.2

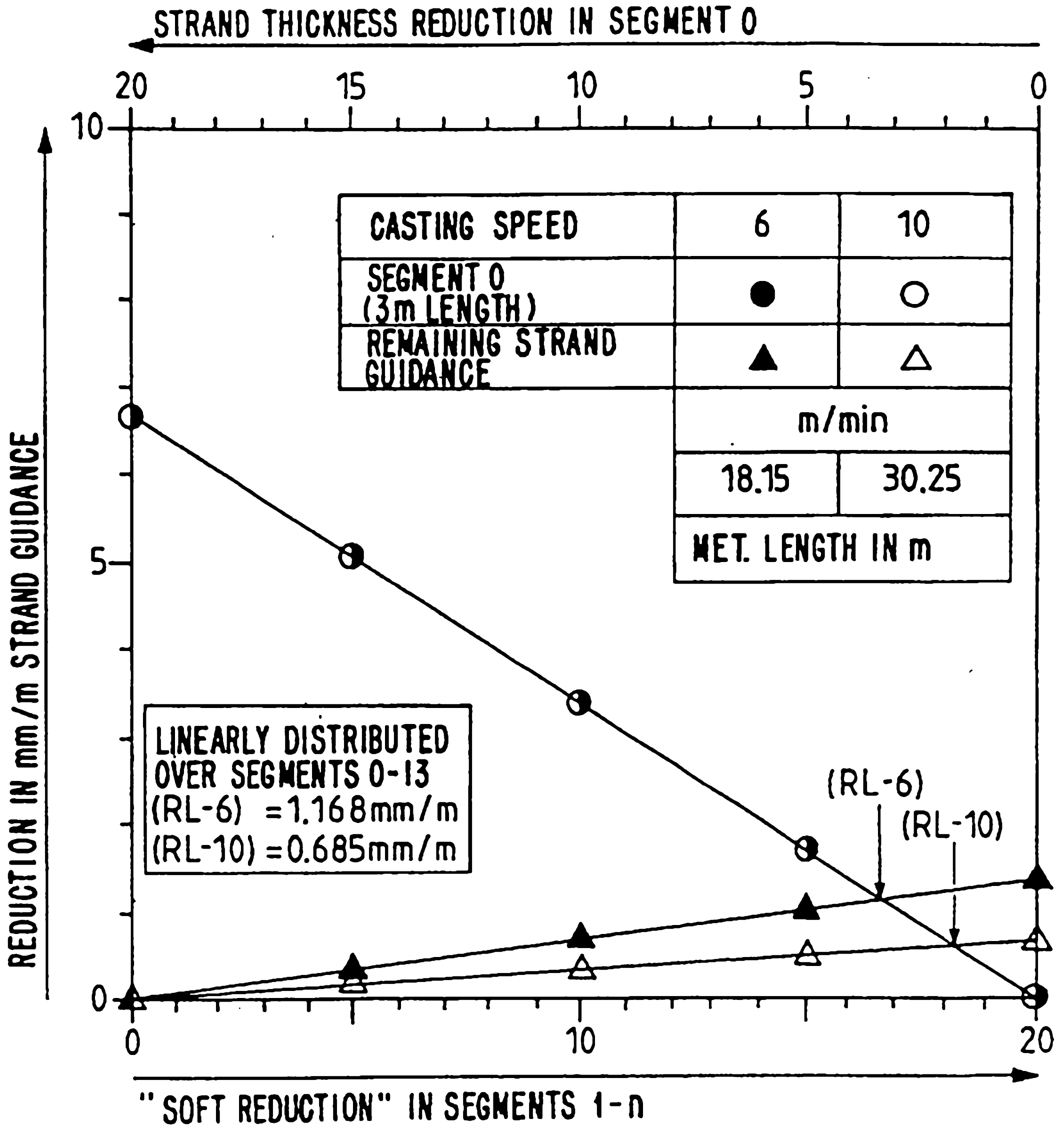

STRAND THICKNESS REDUCTION IN SEGMENT 0
20
15
10
5
0
10
5
0
REDUCTION IN mm/m STRAND GUIDANCE
CASTING SPEED
6
10
SEGMENT 0 (3m LENGTH)
REMAINING STRAND GUIDANCE
m/min
18.15
30.25
MET. LENGTH IN m
LINEARLY DISTRIBUTED OVER SEGMENTS 0-13
(RL-6) =1.168mm/m
(RL-10) =0.685mm/m
(RL-6)
(RL-10)
0
10
20
"SOFT REDUCTION" IN SEGMENTS 1-n

FIG.3

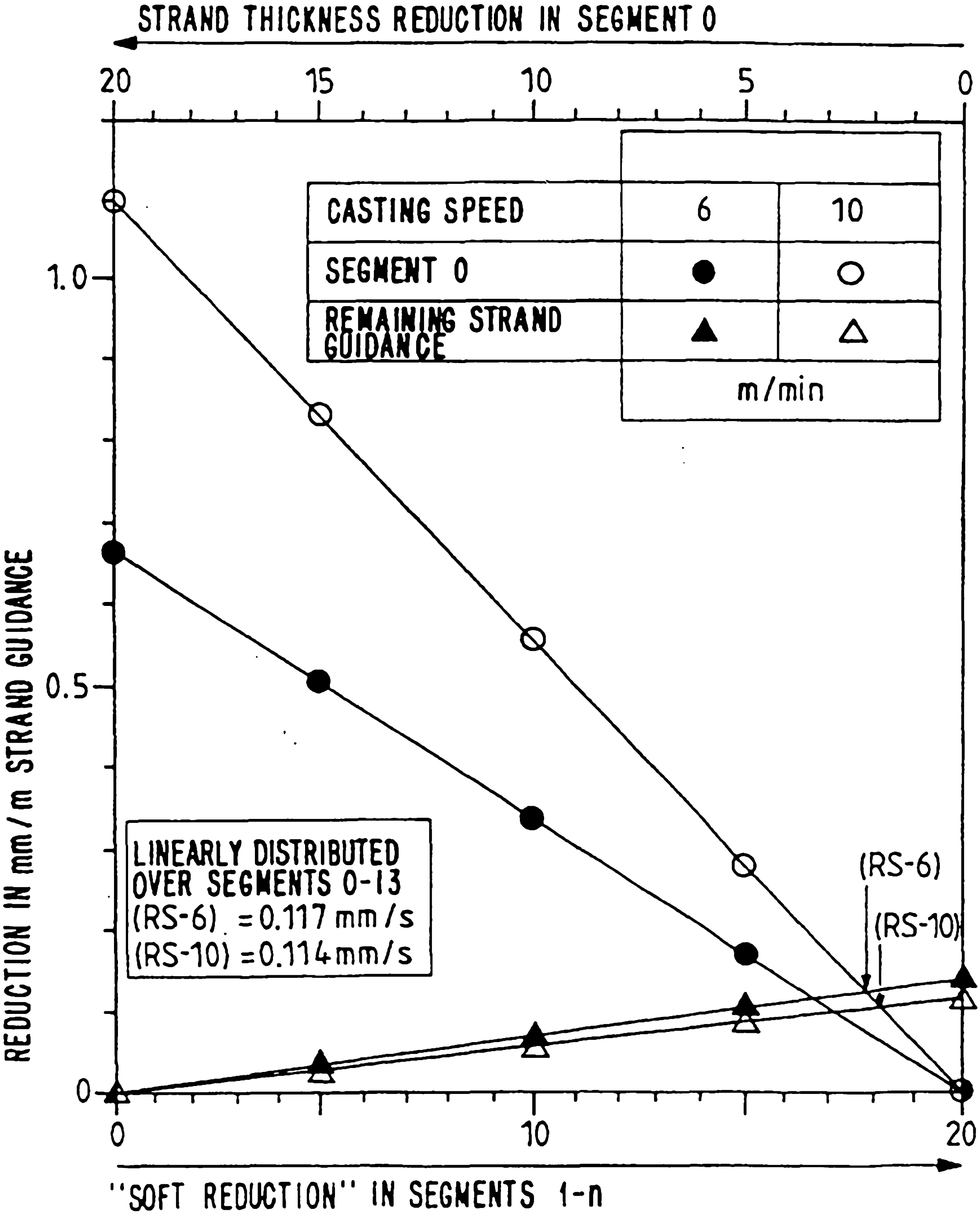

STRAND THICKNESS REDUCTION IN SEGMENT 0
20
15
10
5
0
CASTING SPEED
6
10
SEGMENT 0
REMAINING STRAND GUIDANCE
m/min
1.0
0.5
0
REDUCTION IN mm/m STRAND GUIDANCE
LINEARLY DISTRIBUTED OVER SEGMENTS 0-13
(RS-6) =0.117 mm/s
(RS-10) =0.114mm/s
(RS-6)
(RS-10)
0
10
20
"SOFT REDUCTION" IN SEGMENTS 1-n

FIG.4

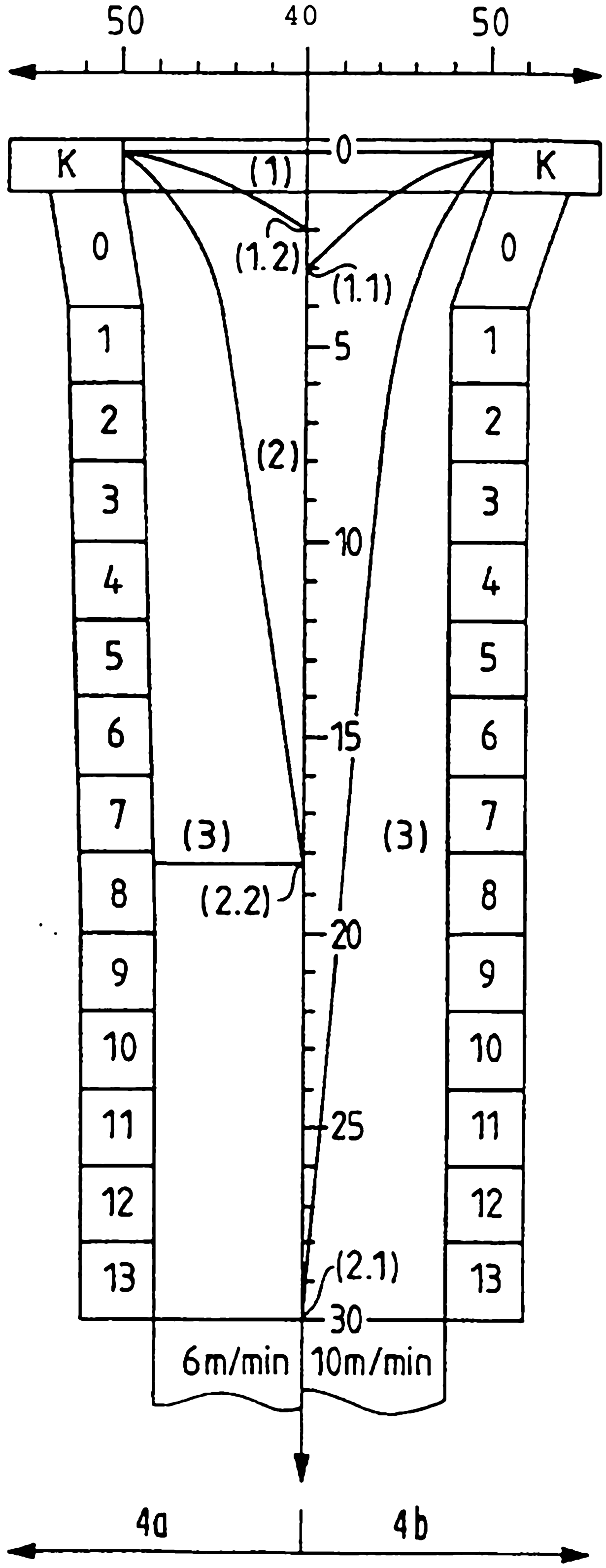

50
40
50
K
(1)
0
K
0
(1.2)
(1.1)
0
1
5
1
2
(2)
2
3
3
10
4
4
5
5
6
15
6
7
(3)
(3)
7
8
(2.2)
8
20
9
9
10
10
11
25
11
12
12
13
(2.1)
13
30
6m/min
10m/min
4a
4b

FIG.5A
PRIOR ART

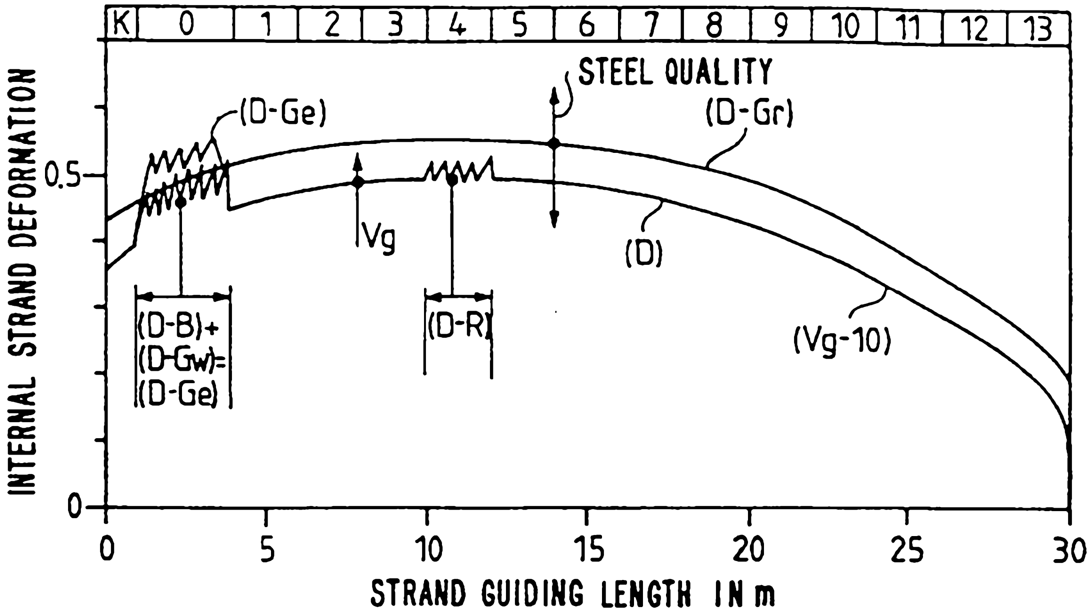
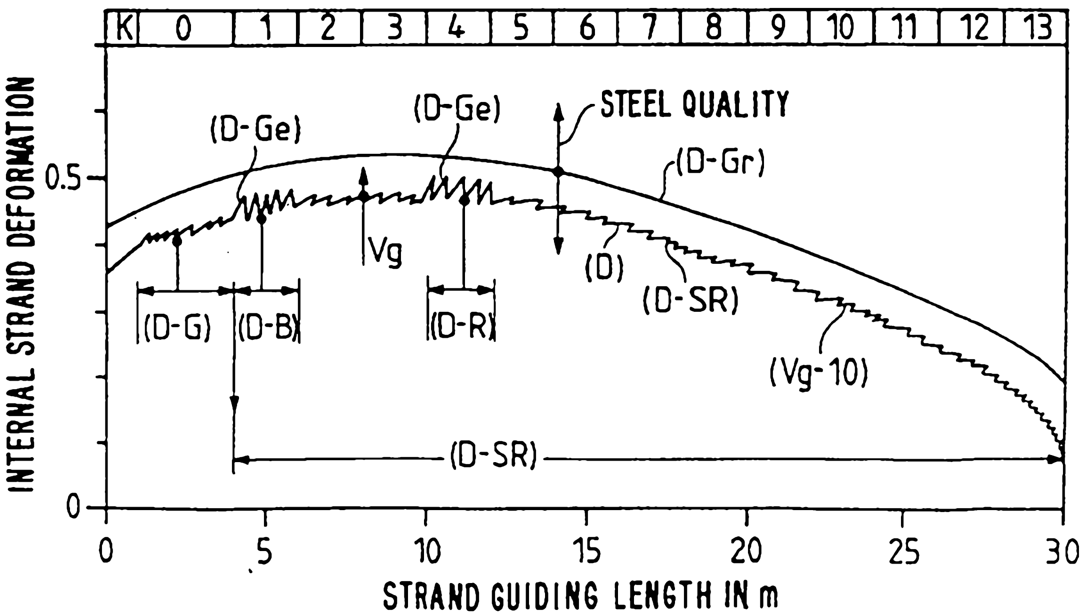


FIG.5B



12 01 98 51080

Fig. 6

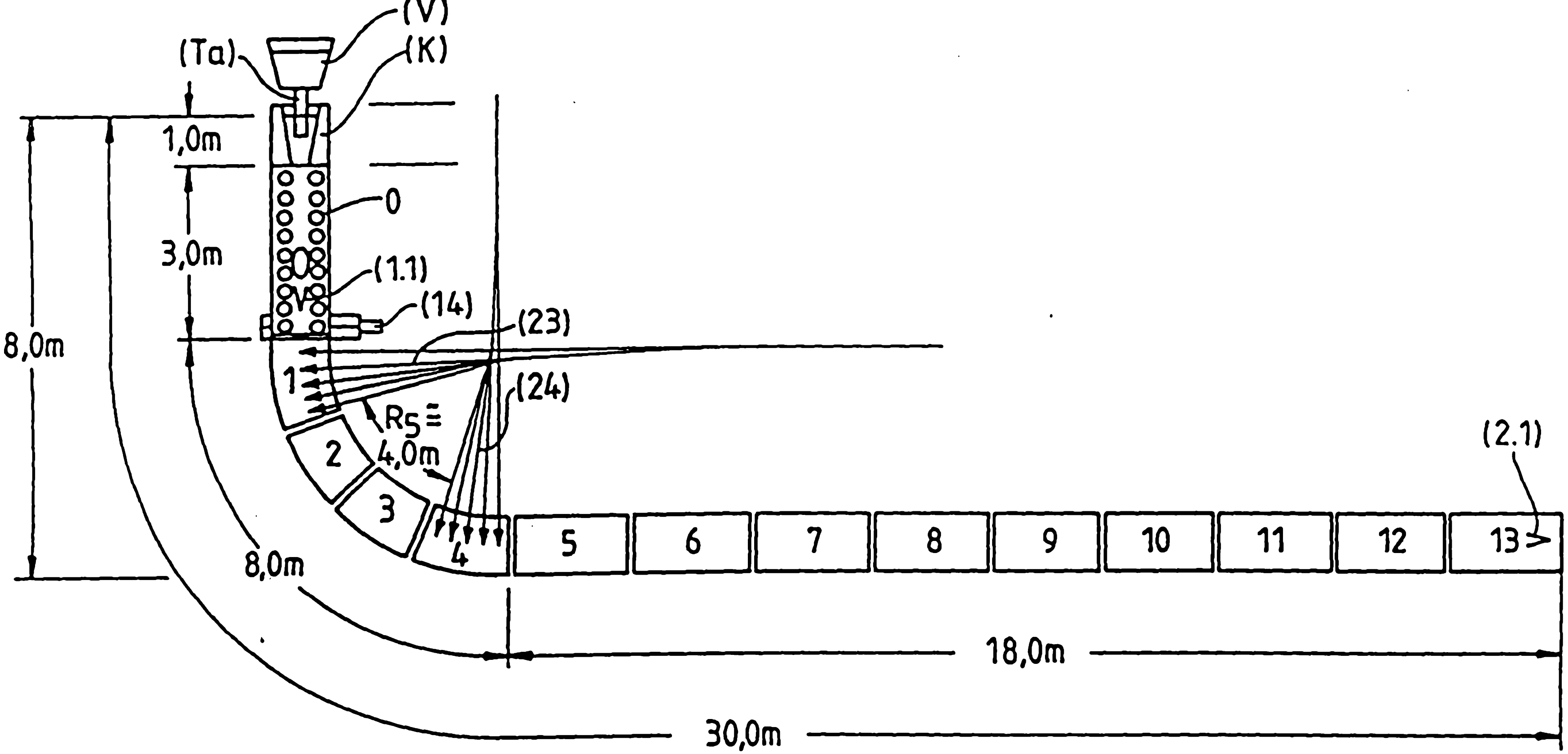


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FIG. 7

SCHEMATIC ILLUSTRATION OF SEGMENTS 1-n (eg 1 to 13)