PATENT SPECIFICATION (11) 1 583 096

1 583 096

(21) Application No. 33961/77 (22) Filed 12 Aug. 1977
(31) Convention Application No. 2636667 (32) Filed 14 Aug. 1976 in
(33) Fed. Rep. of Germany (DE)
(44) Complete Specification Published 21 Jan. 1981
(51) INT. CL.^{3} B22D 11/128
(52) Index at Acceptance
B3F 1G2R 1G2V 1G3G2A 1G3G2G 1G3G2S
1G3G2W

(19)

(54) IMPROVEMENTS IN CONTINUOUS CASTING

(71) We, MANNESMANN DEMAG AKTIENGESELLSCHAFT (Formerly DEMAG AKTIENGESELLSCHAFT), a Body corporate organised under the laws of the Federal Republic of Germany of Wolfgang-Reuter-Platz, 4100, Duisburg, Germany do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to continuous casting.

In continuous casting, for example of steel, a strand is continuously cast in a mould and is led away from the mould through a roll stand. During its passage through the roll stand, the strand is cooled. Initially, the strand has a liquid core enclosed by a thin shell of solidified material which increases in thickness with distance from the mould.

The roll stand may include support, driving and straightening rolls, the difference between these types of rolls depending upon the function which is performed. Thus, a driving roll, as the name implies, is associated with some means for driving the roll in rotation to assist in carrying the strand away from the mould. A straightening roll is associated with means for causing a pressing force to be applied to the strand. A roll which is associated with neither driving means nor means for pressing the roll against the strand is a support roll. Each roll may possess more than a single function, so that a combined driving and straightening roll may be employed.

The mould may be arranged so that the strand issues from it in the vertically downwards direction whereafter it is guided by the roll stand along a curved path until it travels horizontally whereupon it is made to follow a straight path. The liquid core may extend from the mould to the vicinity of the straightening rolls, with the result that substantial forces produced by the head of liquid metal within the core and mould are applied to the rolls. The rolls are further stressed by temperature fluctuations, despite internal and external cooling. Assuming the rolls to be supported only at their ends, in bearigs located ouside the width of the strand, the diameter of each roll is determined to a large extent by the bending stress and the elastic deflection of the roll, and is therefore a function of the material used and the distance between the bearings. Hitherto, the distance between the bearings has generally exceeded the maximum width of the strand. Desirably, however, the roll diameter should be as small as possible so as to minimise the cost both of the rolls and of the structure for supporting the rolls. To make possible the achievement of a small roll diameter, it is necessary to minimise the length of the roll consistent with providing the strand with adequate support.

Accordingly, the present invention provides when in use, a continuous casting apparatus including a mould from which a strand emerges continuously to pass through a supporting, driving and straightening roll stand including a plurality of segments, each segment comprising two relatively adjustable frames, on one of which is journalled a plurality of rolls contacting one wall of the strand and on another of which is journalled a plurality or rolls contacting the opposite wall of the strand, and constituting counter-rolls, wherein the length (L) of the strand-contacting surface of at least one of the rolls is less than the width of the strand and is determined by the equation:

$$L = BB - (2.5 \text{ to } 5.0\ SD) \text{ millimetres}$$

where:-

BB is the maximum strand width of the continuous casting apparatus, and SD is the thickness of one of the unsupported walls of the strand measured at the location where the strand is contacted by the roll having a strand-contacting portion of length L.

By using this equation to determine the roll surface length in accordance with empirical values, metallurgical laws can be satisfied better than with various known stands. The cooling behaviour of the cast metal determines the length of the strand-contacting surface of the roll as a function of the particular support position. It is therefore made possible by the invention to reduce roll surface length at places where hitherto a roll surface length equal to the width of the strand or determined in accordance with a constant factor had been used hitherto. This ability to reduce roll surface length is of particular advantage in connection with wide strands, ie. those having a width of at least 2600 millimetres, to which the invention is especially applicable.

By designing rolls in accordance with the invention it is possible for a saving to be made in the cost of the rolls. This saving leads to other advantages since the shortening of the rolls results in better access to the continuous strand, so that, for example, devices for cooling can be more easily incorporated.

The rolls contacting one surface of the strand may have their strand-contacting surfaces determined by the equation whereas those of the rolls contacting the other surface are equal in length to the width of the strand. However, it is also possible for both the rolls and counter-rolls to be provided with strand-contacting surfaces of lengths determined by the equation.

In accordance with one embodiment of the invention, the length of the strand-contacting surface of each roll of the strand is determined by the equation. Because the thickness of the walls of the strand increase progressively with distance from the mould, it follows that the strand-contacting portions of the rolls become shorter with increasing distance from the mould.

A simplified arrangement allowing a reduction in the costs of bearing supports is attained by constructing all the rolls of a segment with a strand-contacting surfaces of equal lengths, the length of the said surface of one of the rolls being determined by the equation. Preferably, it is the roll nearest to the mould which has the length of its strand contacting surface determined in this way. Alternatively, all the rolls of a number of successive segments may have strand-contacting surfaces of equal length, one of the rolls having the length of its strand-contacting surface determined by the equation.

For the case where there is a risk of puncturing of the shell at several points along the path of the strand, so that liquid metal could flow out of the strand and render the continuous casting apparatus unserviceable in many places, it is advantageous if, between groups of rolls each having strand-contacting surfaces determined by the equation, there is arranged at least one roll having a strand-contacting surface equal in length to the width of the strand. The rolls having strand-contacting surfaces of length equal to the full width of the strand then act between the remaining rolls of reduced surface length.

To transmit the conveying forces, it is of advantage for those rolls which have a surface length corresponding to the strand width to be connected to a rotational drive. The rotational drive transmission is therefore effected with the maximum possible frictional force onto the continuously cast metal.

In a further alternative arrangement depending upon the required cooling curves and the resultant intensity of cooling, one or more groups of rolls having strand-contacting surfaces of length corresponding to the full width of the strand are followed by one or more groups of rolls having strand-contacting surfaces of length L determined by the equation.

In the event that the apparatus includes a driving and straightening stand incorporating a series of driving rolls and a series of straightening rolls arranged downstream of a support stand, the invention may be applied to the driving and straightening stand. Although in these regions the continuously cast strand is largely solidified throughout, nevertheless, when very high casting speeds are used, liquid portions still occur in the cross-section of the strand, both in the region of the driving rolls and also in the region of the straightening rolls. The equation may be used to determine the lengths of the strand-contacting portions of the rolls in the zone where the strand ceases to follow a curved path and begins to follow a straight path, that is, in mutually adjacent regions of the driving and straightening series. In these regions, rolls with a surface length corresponding to the full width of the strand may be provided, the remaining rolls of the driving and straightening stand having surfaces determined by the equation.

The driving and straightening stand may be still further simplified by giving the strand-contacting surface of the counter-roll to a driven roll a length corresponding to the full width BB of the strand and by giving the strand-contacting surface of the non-driven roll a length determined by the equation.

Owing to the predominant solidification of the exterior of the continuously cast strand, it is possible for only the rolls which are located in the zone where the strand begins to follow a straight path to have the lengths of their strand-contacting surfaces determined by the equation.

The rolls of the driving and straightening stand may be constructed in known manner with strand-contacting surfaces of lengths corresponding to the full width of the strand, but with the rolls in the regions upstream and downstream of the point at which the curved and straight paths meet having strand-contacting surfaces with lengths determined by the equation.

In a further alternative, all the rolls of the driving and straightening stand as far as the start of the straight path may have the lengths of their strand-contacting portions equal to the full width of the strand. These rolls then act as smoothing rolls for the largely straightened continuous strand.

As discussed above, it is possible within the scope of the invention for all the rolls in a group of rolls to have strand-contacting surfaces which are equal in length, the length of the said surface of one of the rolls of the group being determined by the equation. The principle may be applied in particular to the driving and straightening stand wherein all of at least some of the rolls have strand-contacting surfaces of equal lengths, the length of the driving roll nearest to the mould being determined by a modified equation. According to another aspect of the invention, therefore, there is provided, when in use, a continuous casting apparatus including a mould from which a strand emerges continuously to pass successively through a supporting roll stand and a driving and straightening roll stand including a plurality of segments, each segment comprising two relatively adjustable frames, on one of which is journalled a plurality of rolls contacting one wall of the strand and on another of which is journalled a plurality of rolls contacting the opposite wall of the strand and constituting counter-rolls, wherein the length (L) of the strand-contacting surface of each of at least some of the rolls of the driving and straightening stand is less than the width of the strand and is determined by the equation:

$$L = BB - (3.5 \text{ to } 4.0\ SD) \text{ millimetres}$$

wherein:

BB is the maximum strand width, and SD is the thickness of one of the unsupported walls of the strand measured at the location of the driving roll which is nearest to the mould.

Throughout the specification, all dimensions of length are expressed in millimetres.

A number of embodiments of this invention are illustrated diagrammatically in the drawings and are described in more detail below.

The drawings show:

Figure 1 is a side view of a supporting roll stand of a curved continuous casting installtion for steel blooms,

Figure 2 a section through the strand comprising a pair of backing rolls along I-I of Figure 1.

Figure 3 to *8*, roll layouts for six different examples of application of the invention, the direction of viewing being that of arrow A in Figure 1,

Figure 9 a side view of the driving and straightening roll stand,

Figure 10 to *13* roll layouts for four different methods of application of the invention, viewed in direction A (Figure 1).

Referring to the drawings, metal is continuously poured in batches or in sequence into a continuous casting mould 1, mounted on an oscillating table 2. A continuously cast strand 3 having a solid shell and molten core descends from the mould 1 and is cooled by water or other coolant discharged from spray nozzles, not shown, while it travels through a support roll stand 4. The roll stand 4 includes an arcuate banana-shaped beam 5, resting upon foundation bearings 6 and 7 and carrying individual segments 8*a* to 8*f* which are replaceably attached to the beam 5.

Each of the segments 8*a* to 8*f* consists of two segment frames 9 and 10, bearing rows of rolls 11*a* and counter-rolls 11*b* respectively. Usually, the segments 8*b* to 8*f* have the same number of rolls as one another while the segment 8*a* which follows the continuous casting mould 1 has a greater number of rolls. Depending upon the radius of the curved continuous casting apparatus, fewer or more segments or rolls and counter-rolls may be provided. At least one of the segment frames 9 or 10 is adjustable relative to the other segment frame. The rolls 11*a* and counter-rolls 11*b* when in their operating position form the path followed by the cast strand.

As shown in Figure 2, the strand has a solid shell 3*a* Herein, "SD" will be used to refer to the shell thickness 12 shown in Figure 2. This shell thickness increases more or less continuously with increasing distance from the casting mould and also increases at a varying rate for different casting metal properties (steel analysis) and different casting speeds. The width of the strand is designated BB and the length of a roll body (ie. the surface which contacts the strand) is designated L. The hatched area 3b indicating the molten metal core decreases in size with progressive cooling and solidification according to cooling curves which depend upon the chemical composition of the casting metal and are used as the basis for designating the continuous casting apparatus. In one embodiment of the invention shown in Figure 3, the length of the strand-contacting surface of each of the rolls of 11a and/or counter-rolls 11b is calculated in accordance with the equation L = BB − (2.5 to 5.0 SD), with the thickness SD determined at the location of the roll in question. Since the thickness SD increases in a wedge-like manner with distance from the mould, the lengths of the strand-contacting surfaces of the rolls decrease progressively with distance from the mould.

For strands which initially cool slowly, then more rapidly, an alternative embodiment of roll stand is shown in Figure 4 and has a segment 8*a* equipped with rolls 11*a* and 11*b*, either or both of lwhich have strand-contacting surfaces of lengths equal to the width BB of the strand. Segment 8*a* is followed by segment 8*b* with a series of rolls having strand contacting surfaces all of equal length which is less than the width of the strand. One of these rolls (preferably that nearest to the mould) has the length of its strand-contacting surface determined by the equation, and the length of this roll determines that of the remainder. The series of rolls of segment 8*b* is followed by rolls of segment 8*c*, again all with strand-contacting surfaces of equal length determined by the application of the equation to one of the rolls, preferably the leadig roll. The lengths of the strand-contacting surfaces of these rolls therefore decrease stepwise.

In a further example (Figure 5) the segment 8*a* having rolls with strand-contacting surfaces corresponding in length to the full width BB of the strand is followed by a central portion constituted of like segments 8*b*, 8*c*, 8*d* having rolls with strand-contacting surfaces all of equal length preferably determined by applying the equation to that roll of segment 8*b* which is nearest the mould.

For metals which are particularly sensitive and slow-cooling the rolls may be arranged as shown in Figure 6. The rolls in segments 8*a*, 8*b*, 8*c* have strand-contacting portions all equal in length to the width of the strand, whereas only the segment 8*d* has rolls having strand-contacting portions of reduced length determined by applying the equation to one of the rolls. Consequently, the first step of roll-shortening is delayed still further by comparison with the example shown in Figure 5.

In the embodiment shown in Figure 7, all of the segments 8*b* to 8*c* have rolls with strand-contacting surfaces of length less than the width of the strand and determined by applying the equation to that roll of segment 8*b* which is nearest the mould. However, each segment includes one roll 11*a* and/or 11*b* with a strand-contacting surface of length BB.

As shown in Figure 8a roll stand 4, includes segmens 8*a*, 8*b* and 8*d* having rolls 11*a* and/or 11*b* with a surface length corresponding to the width BB of the strand, and segments 8*c* and 8*e* between the segments 8*a*, 8*b* and 8*d* with rolls having surface lengths L determined by applying the equation to one of the rolls of these segments.

As shown in Figure 9 a driving and straightening roll stand 13 is subdivided into a driving region 13*a* and a straightening region 13*b*. These two regions together constitute, in a transition area, a bending zone 14. Driven rolls within the driving region 13*a* and straightening region 13*b* are designated by 15.

The roll layout according to Figure 10 provides, for all driving and straightening rolls 11*a* and/or 11*b*, the same shortened roll surface length L, calculated by the above mentioned equation L = BB− (3.5 to 4.5 D). This arrangement therefore corresponds to a single-stage, permanent shortening of the roll surface lengths within the driving and straightening roll stand.

The roll layout according to Figure 11 provides, ahead of and behind the strengthening point 16, driving and straightening rolls, the roll surface lengths of which correspond to the width BB of the strand. Ahead of and behind the bending zone 14, there are groups 17 and 18 comprising driving and straightening rolls 11*s* and/or 11*b* the surface lengths L of which are calculated according to the above mentioned equation.

In the arrangement shown in Figure 12, of the driving region 13*a* and of the straightening region 13*b* (Figure 12), only non-driven driving and straightening rolls 11*a* and/or 11*b* have lengths determined by the above mentioned equation whereas driven, driving and straightening rolls 19 have a roll surface length corresponding to the width BB of the strand.

According to Figure 13, a uniform roll surface length L of the partially driven and partially non-driven driving and straightening rolls 11*a* and/or 11*b* is provided ahead of and behind the bending point 16, that is also inside the bending zone 14. The rolls in the last group each have a roll surface length corresponding to the width BB of the strand. This group 20 serves for smoothing the straightened strand which here is normally fully solidified right through.

WHAT WE CLAIM IS:

1. When in use, a continuous casting apparatus including a mould from which a strand emerges continuously to pass through a supporting, driving and straightening roll stand including a plurality of segments, each segment comprises two relatively adjustable frames, on one of which is journalled a plurality of rolls contacting one wall of the strand and on another of which is journalled a plurality of rolls contacting the opposite wall of the strand and constituting counter-rolls, wherein the length (L) of the strand-contacting surface of at least one of the rolls is less than the width of the strand and is determined by the equation;

$$L = BB - (2.5 \text{ to } 5.0\ SD) \text{ millimetres}$$

where:-

BB is the maximum strand width of the continuous casting apparatus and SD is the thickness of one of the unsupported walls of the strand measured at the location where the strand is contacted by the roll having a strand-contacting portion of length L.

2. Apparatus as claimed in Claim 1, wherein downstream from the mould are arranged successively a series of support rolls, a series of driving rolls, and a series of straightening rolls.

3. Apparatus as claimed in Claim 2, wherein the only roll or rolls to have a strand-contacting surface of length L determined by the equation is that roll or are those rolls located immediately upstream of the driving rolls.

4. Apparatus as claimed in Claim 2, wherein the strand follows a curved path from the mould through the roll stand and straightening of the strand takes place in adjacent regions of the driving and straightening series of rolls, and wherein in said regions are arranged rolls each having a strand-contacting surface of length BB, the remaining rolls of the driving and straightening series of rolls each having a strand contacting surface of length L determined by the equation.

5. Apparatus as claimed in Claim 2 wherein the strand follows a curved path from the mould and the only rolls to have a strand-contacting surface of length L determined by the equation are rolls in a region where the curved path merges into a straight path.

6. Apparatus as claimed in Claim 2 wherein the strand follows a curved path from the mould, wherein rolls in the region upstream and downstream of the position at which the curved path merges into a straight path have strand contacting surfaces of length L determined by the equation.

7. Apparatus as claimed in Claim 1 or Claim 2 wherein the length of the strand-contacting surface of each of the rolls of the stand is determined by said equation.

8. Apparatus as claimed in Claim 1 or Claim 2 wherein the strand-contacting surface of each of the rolls of a segment are of equal length, the length of said surface of one of the rolls of the segment being determined by the said equation.

9. Apparatus as claimed in Claim 8, wherein that roll of the segment nearest the mould is that which has the length of its strand-contacting surface determined by the equation.

10. Apparatus as claimed in Claim 1 or Claim 2 wherein all of the rolls of a plurality of successive segments have strand-contacting surfaces of equal lengths, one of said rolls having the length of its strand-contacting surface determined by the equation.

11. Apparatus as claimed in Claim 1 or Claim 2 including a plurality of groups of rolls having strand-contacting surfaces of equal lengths, the strand-contacting surface of one of said rolls being determined in accordance with the equation and wherein between each such group and that next to it is disposed at least one roll having a strand-contacting surface of length BB.

12. Apparatus as claimed in Claim 1 or Claim 2 including at least one roll having a strand-conacting surface of length BB disposed between groups of rolls having strand-contacting sufaces of length L determined by the equation.

13. Apparatus as claimed in Claim 11 or Claim 12 wherein the rolls having strand-contacting portions of lengths BB are driven rolls.

14. Apparatus as claimed in Claim 1 or Claim 2 including at least one group of rolls each having a strand-conacting surface of length BB and wherein a group of rolls have strand-contacting surfaces of equal lengths, that of one of the rolls of said group being determined in accordance with the equation being arranged immediately downstream of the or each such group.

15. Apparatus as claimed in Claim 1 or Claim 2 including at least one group of rolls each having a strand-contacting surface of length BB and wherein rolls having strand-contacting surfaces determined in accordance with the equation are arranged immediately downstream of each such group.

16. Apparatus as claimed in Claim 1 or Claim 2 wherein at least one driven roll is

associated with a counter-roll having a strand-contacting surface of length BB and wherein the non-driven roll has strand-contacting surface determined by the equation.

17. When in use, a continuous casting apparatus including a mould from which a strand emerges continuously to pass successively through a supporting roll stand and a driving and straightening roll stand including a plurality of segments, each segment comprising two relatively adjustable frames, on one of which is journalled a plurality of rolls contacting one wall of the strand and on another of which is journalled a plurality of rolls contacting the opposite wall of the strand and constituting counter-rolls, wherein the length (L) of the strand-conatcting surface of each of at least some of the rolls of the driving and straightening stand is less than the width of the strand and is determined by the equation:

$$L = BB - (3.5 \text{ to } 4.0\ SD) \text{ millimetres}$$

wherein:

BB is the maximum strand width, and

SD is the thickness of one of the unsupported walls of the strand measured at the location of that driving roll which is nearest to the mould.

18. When in use, a continuous casting apparatus substantially as herein before described with reference to and illustrated in Figures 1 and 2 of the accompanying drawings taken together with any of Figure 3 to 8 or 10 to 13.

BROOKES & MARTIN,
Chartered Patent Agent,
High Holborn House,
52,/54 High Holborn,
London WC1V 6SE.
Agents for the Applicants.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1980.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1583096 COMPLETE SPECIFICATION

12 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1

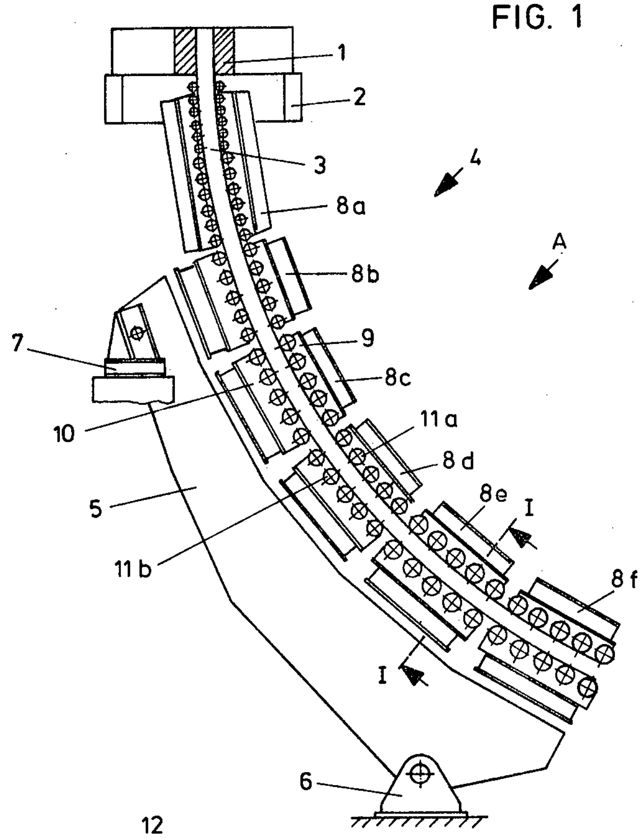

FIG. 2

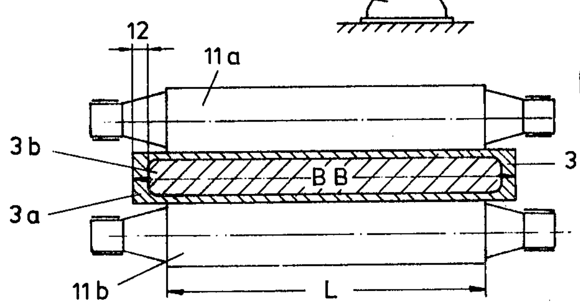

FIG.3

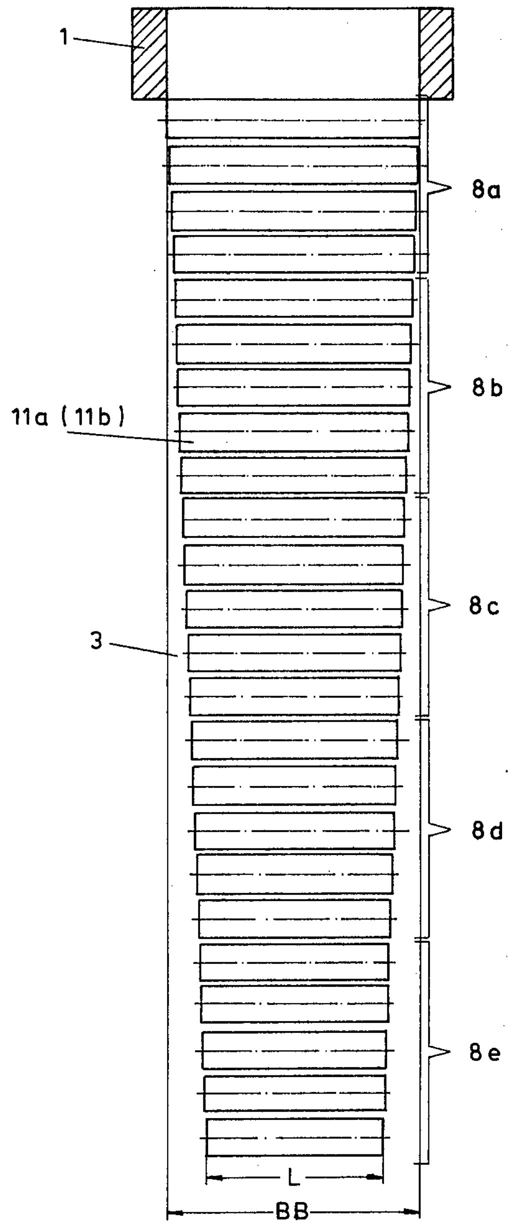

FIG. 4

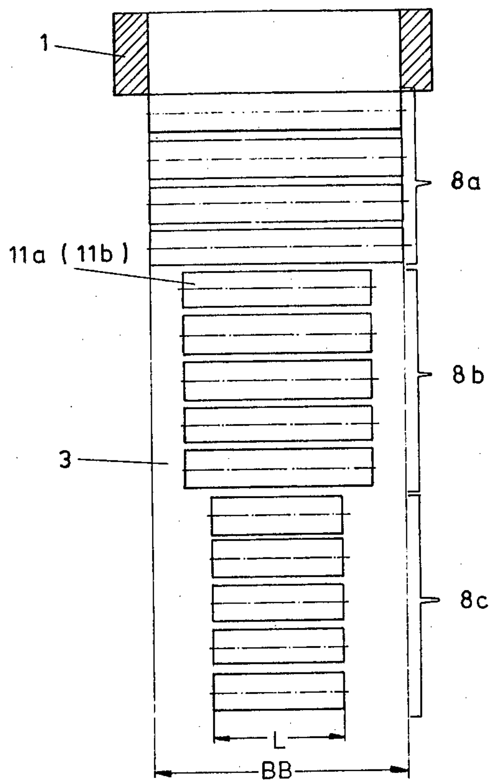

FIG. 5

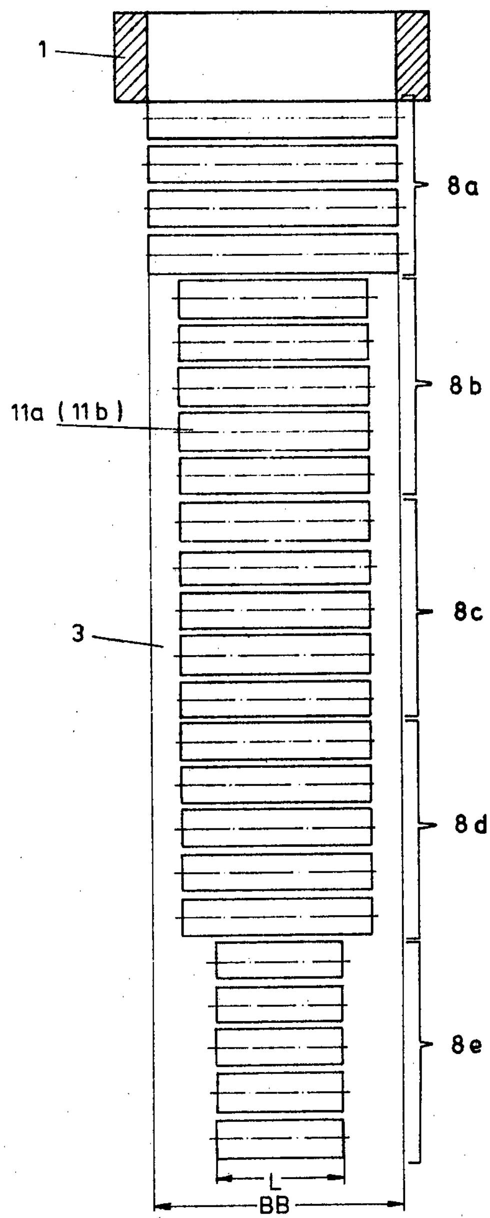

FIG. 6

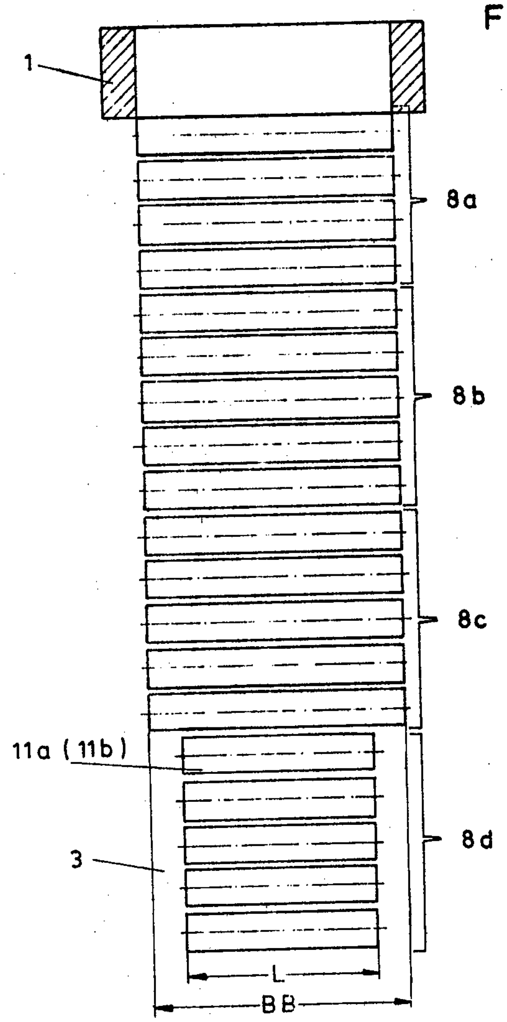

FIG. 7

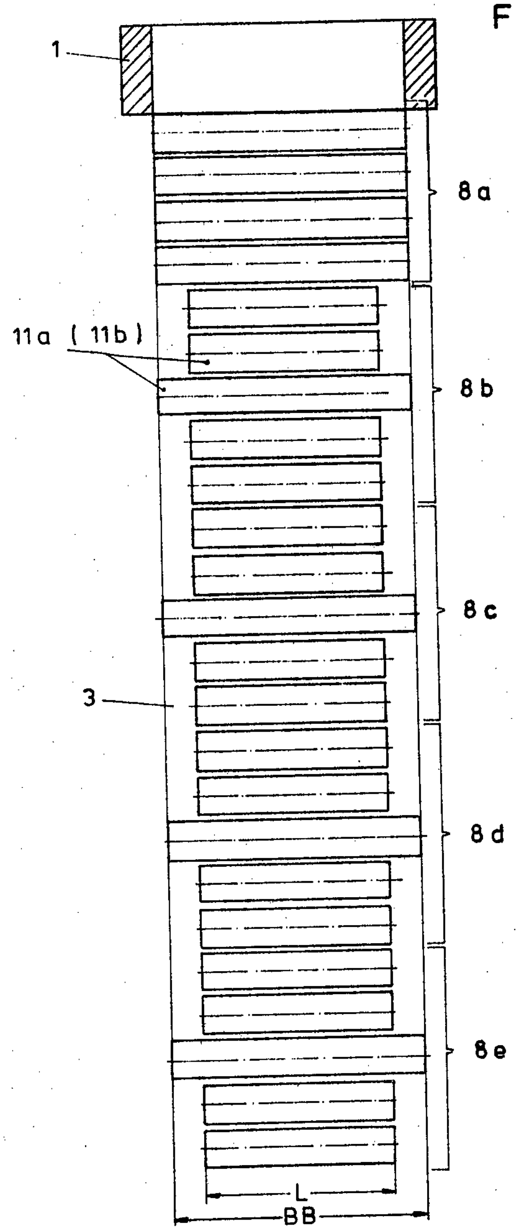

FIG. 8

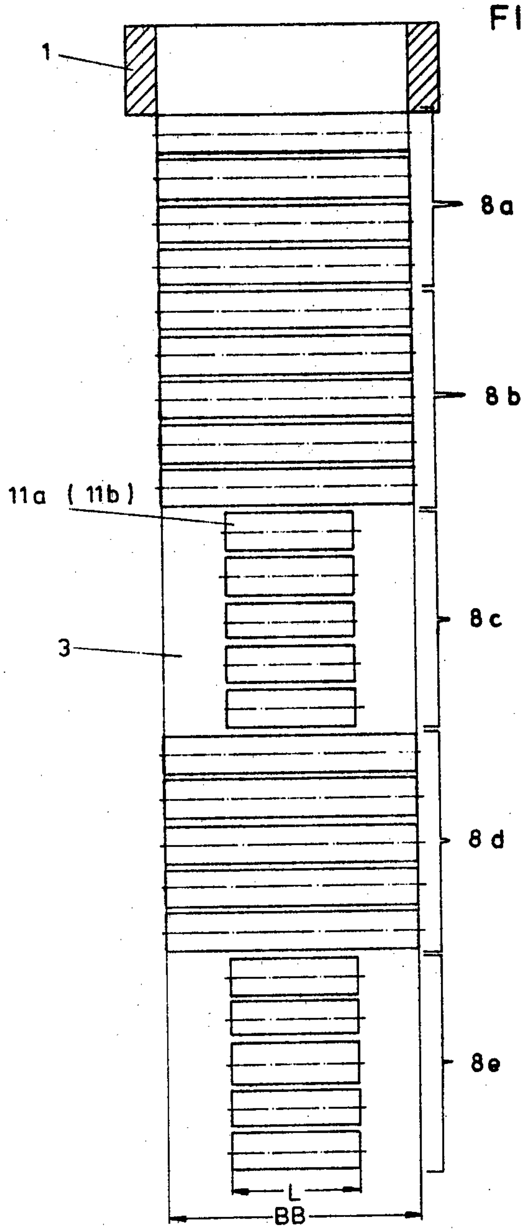

FIG. 9

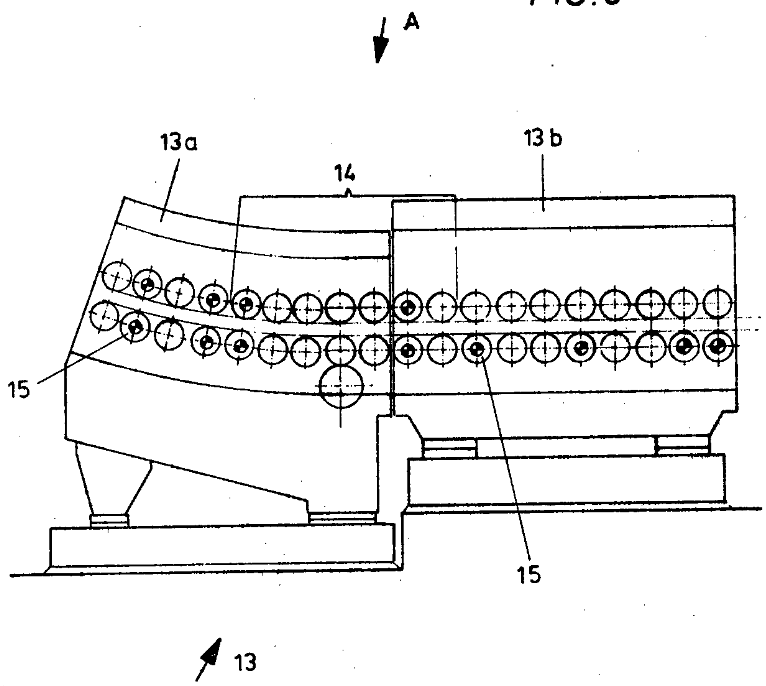

FIG. 10

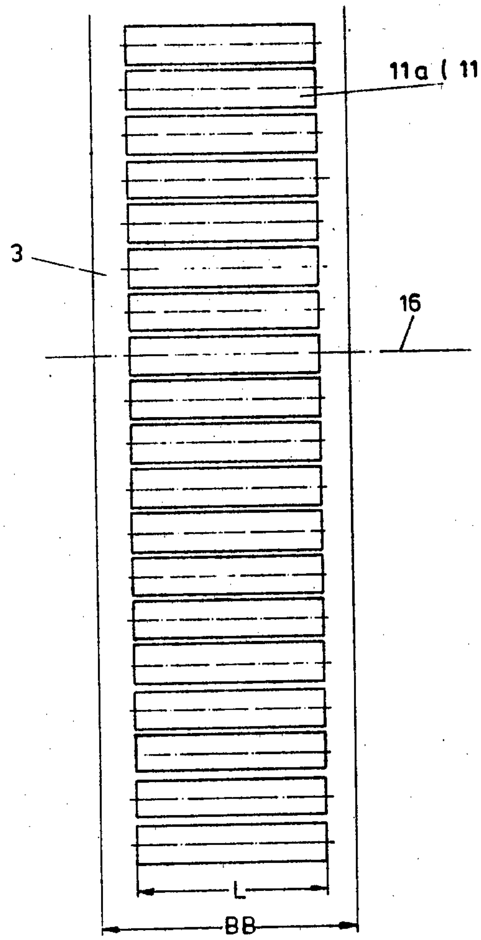

FIG. 11

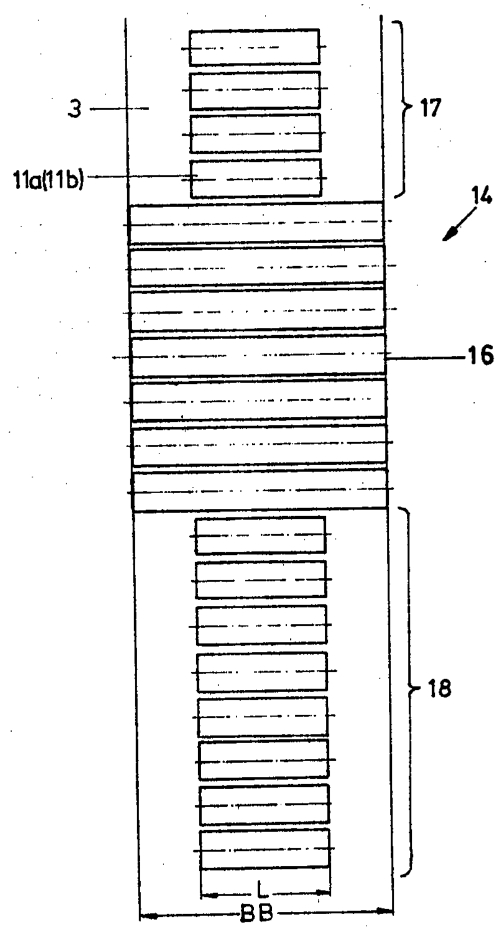

FIG. 12

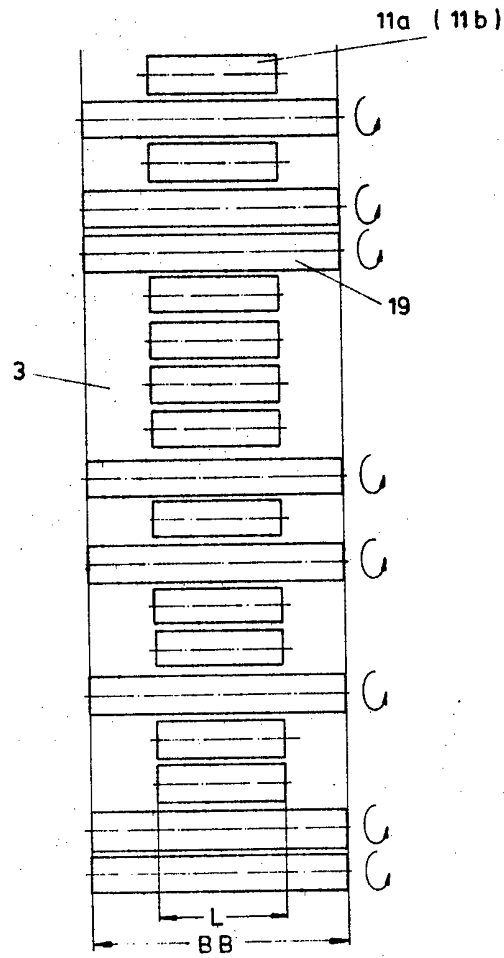

FIG. 13