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(54) Apparatus for producing ingots of nonferrous metals by continuous casting

(57) An apparatus for producing ingots of nonferrous metals, comprising a continuous casting machine (2) provided with a moving casting shell composed of a plurality of segments (3) arranged in succession, each segment having a portion, with bottom (3a) and side walls (3b,3c), of the casting shell formed therein and being open on the sides directed toward the contiguous segments. The segments are movable along a closed path that has at least one substantially straight portion at the casting region. The segments, along the at least one portion (4) of path, are substantially aligned and form a casting shell that is continuous and substantially straight and is closed, along at least one portion of path downstream of the casting region, by closure means at its side that is arranged opposite with respect to the bottom.

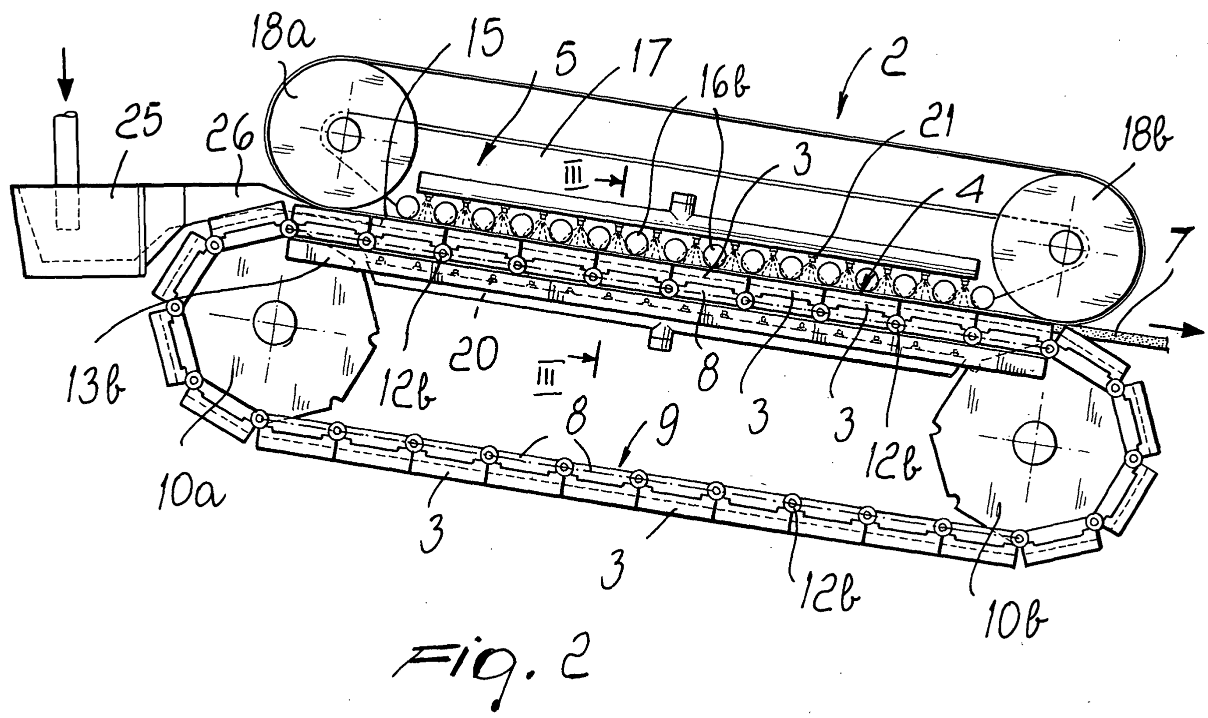

Fig. 2

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Description

[0001] The present invention relates to an apparatus for producing ingots of nonferrous metals by continuous casting.

[0002] In general, all metals are extracted from mined minerals or are obtained by recycling scrap and, after many steps of pyrometallic refinement and/or electrolysis, are provided in commercial form, i.e., reduced to suitable sizes. These forms, depending on their type, have various names, such as for example wire bars, billets, T-bars, pigs or ingots, and the metals that constitute them can be pure or alloyed.

[0003] The present invention relates to the ingot type, i.e., to the "handy" format suitable for remelting and having a weight comprised for example between 1 and 25 kg.

[0004] Ingots are required, according to their use, in various dimensions in terms of transverse cross-section and therefore of weight, and must have characteristics that ensure the intended quality of the molten metal.

[0005] By way of example, the characteristics of some ingots are cited hereafter:

-- primary aluminum ingots (obtained by electrolysis): weight 10-25 kg, length approximately 650-750 mm;
-- alloyed aluminum ingots (from scrap): weight 5-10 kg, length approximately 650-750 mm;
-- brass ingots: weight 10-15 kg, length approximately 450-550 mm;
-- ingots of zinc alloys for pressure die-casting: weight 1-5 kg, length approximately 400-600 mm.

[0006] The cross-sections and lengths of the ingots are the ones best suited for subsequent storage and shipping. In general, the ingots are stacked so as to obtain packs that are convenient for transport, generally weighing between 500 and 1000 kg.

[0007] The packs or piles or stacks are tied and kept together by two or more bindings provided by means of straps made of metal or plastics.

[0008] Currently, the most common ingot production methods are the following:

-- method A: casting in open shells, to be filled one by one and placed on a moving belt or on a wheel having a vertical axis (such as a Walker wheel);
-- method B: continuous casting through shells (cooled collars) which are fixed or oscillate and are vertical and horizontal, so as to obtain billets that have a generally rectangular cross-section with rounded edges, which are then cut to size by means of a cropping head with a rotating blade;
-- method C: continuous casting on a machine of the wheel and belt type, for example of the type disclosed in US Patent Application 08/245,404 in the name of this same Applicant, which produces a continuous bar having a trapezoidal cross-section which is then cut to size by means of in-line shears.

[0009] These production methods have problems and drawbacks.

[0010] In the case of method A, the discontinuous pouring of the metal performed individually, shell by shell, also due to the high speeds required, has never reached the sought reliability. Filling of the shell is never constant and therefore produces variable ingot heights, with consequent problems in stacking the ingots.

[0011] Furthermore, the upper surface of the ingot that is exposed to the atmosphere and to the turbulence of the pouring is highly oxidized and contains inclusions of impurities and slag that float on the molten metal during its solidification.

[0012] This phenomenon has been solved only partially with more or less automated foaming operations (a process that is always incomplete and unsatisfactory) and produces losses of metal in foaming and in the subsequent melting of the ingots.

[0013] Furthermore, with this method cracks and cavities can occur during solidification, which is slow, produces a coarse grain and generates concentrated gas. This is a severe danger, since any infiltrations of rainwater in the cracks or cavities can cause a powerful explosion when the ingot is immersed in a bath of molten metal where remelting occurs.

[0014] Finally, again with this method, the dimensions of the ingot are closely correlated to the dimensions of the shell, and changing them is very onerous.

[0015] As regards method B, the casting system is very complicated both structurally and in terms of its management, since in order to achieve industrially convenient production levels it is necessary to arrange in parallel (side by side) many casting lines that must operate simultaneously. The cooling-solidification shell, by being a collar (a semi-oval or rectangular one with rounded edges) that is cooled with water and has a limited length (approximately 200-400 mm), has a very small heat exchange surface, and this causes low solidification rates and therefore low production per hour.

[0016] Furthermore, the cropping of the billets, in addition to requiring a very complicated movable disk cutter, generates a large quantity of chips, which must be first recovered and then returned to the furnace for remelting.

[0017] The ingot obtained with this method has a very rough surface that can trap moisture and therefore cause explosions when it is returned into the casting furnace.

[0018] Method C has solved the problems of methods A and B, since with said method the continuous casting of the ingot is free from slag and oxides and high production levels are achieved on a single machine because the shell is long (at least as long as half the circumference of the wheel) and therefore the heat exchange surface is large and it is possible to change the length of the ingot simply by varying the cropping pitch, and it is also possible to vary the cross-section of the ingot by changing only the casting ring.

[0019] However, even this method is not devoid of drawbacks.

[0020] With this method, the bar in fact solidifies on the wheel and cannot be removed from said wheel (and therefore straightened) if it has not solidified fully. This requires a very long shell and therefore large dimensions for the casting wheel.

[0021] Moreover, as a consequence of this fact, there are high equipment and foundation costs. Wheel dimensions of more than four meters in diameter may in fact be required. Since the wheel must be arranged on a vertical plane and is fed with liquid metal that arrives from the furnace, in the highest point, a very deep foundation pit is required for the casting machine.

[0022] Another drawback is constituted by the fact that the bar that exits from the machine has to be straightened. This requires a rather expensive straightening machine because of the cross-section of the ingots and because the machine must comprise a pinch-roll assembly and a series of straightening rollers that are motorized synchronously with the casting machine.

[0023] The aim of the present invention is to solve the problems and obviate the drawbacks mentioned above, by providing an apparatus for producing, by continuous casting, ingots of nonferrous metals that has all the advantages of the method of continuous casting on a machine of the wheel and belt type but is simpler as regards both production and installation.

[0024] Within this aim, an object of the invention is to provide an apparatus that is easy to operate.

[0025] Another object of the invention is to provide an apparatus that is capable of producing a straight metal bar and therefore does not require the adoption of complicated ingot straightening machines.

[0026] This aim and these and other objects that will become better apparent hereinafter are achieved by an apparatus for producing, by continuous casting, ingots of nonferrous metals, which comprises a continuous casting machine provided with a moving casting shell, characterized in that said shell is composed of a plurality of segments arranged in succession, each segment having a portion, with bottom and side walls, of said casting shell formed therein and being open on the sides directed toward the contiguous segments; said segments being movable along a closed path that has at least one substantially straight portion at the casting region; said segments, along said at least one portion of path, being substantially aligned and forming a casting shell, with a bottom and side walls, that is continuous, substantially straight and closed, along at least one portion of path downstream of the casting region, by closure means at its side that is arranged opposite with respect to the bottom; downstream of said substantially straight portion said segment path having a change in direction for the gradual exit from said casting shell of the metal bar produced by the solidification of the metal in the casting shell.

[0027] Further characteristics and advantages of the invention will become better apparent from the following detailed description of a preferred but not exclusive embodiment of the apparatus according to the invention, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

Figure 1 is a schematic side elevation view of the apparatus according to the invention;

Figure 2 is a schematic side elevation view of the continuous casting machine;

Figure 3 is an enlarged-scale sectional view of Figure 2, taken along the line III-III.

[0028] With reference to the figures, the apparatus according to the invention, generally designated by the reference numeral 1, comprises a casting machine 2 provided with a moving casting shell.

[0029] According to the invention, the shell is composed of a plurality of segments 3, which are arranged in succession and can move along a path that has at least one straight portion 4 at the casting region 5.

[0030] A portion of the casting shell, with a bottom 3a and side walls 3b and 3c, is formed in each segment 3 and is open on its sides directed toward the contiguous segments 3 as well as on its side that lies opposite with respect to the bottom 3a.

[0031] Along the portion 4, the segments 3 are substantially aligned and form a moving, continuous and rectilinear casting shell that is closed, along a portion arranged downstream of the casting region, by closure means 6 at its side that lies opposite with respect to the bottom 3a of the various segments 3.

[0032] Downstream of the portion 4, the path of the segments 3 has a change in direction that produces a gradual exit from the casting shell of the bar 7 produced by the solidification of the metal in the casting shell.

[0033] Conveniently, in the segments 3, at the portion 4, the side that lies opposite the bottom 3a is directed upward.

[0034] The portion 4, proximate to the casting region 5, is preferably inclined downward in the direction in which the segments 3 advance along the corresponding path.

[0035] In greater detail, the segments 3 are connected to the links 8 of a chain 9 that is closed in a loop and winds around at least two sprockets 10a and 10b that have horizontal and mutually parallel axes and are supported by the supporting structure of the casting machine 2, which is not shown for the sake of simplicity.

[0036] The segments 3 are preferably made of copper-silver alloy or copperchromium-zirconium alloy, and the length of each segment 3 is exactly identical to the pitch of the chain 9.

[0037] The portion 4 of the path of the segments 3 is formed by the upper portion of the chain 9 that lies between the sprockets 10a and 10b. At least one of the sprockets 10a and 10b can be actuated with a rotary motion about its own axis in a per se known manner in order to produce the advancement of the chain 9 and therefore of the segments 3 along the path formed by the chain 9.

[0038] The links of the chain 9 are mutually articulated by way of pivots 11, whose axes are parallel to the axes of the sprockets 10a and 10b and mesh with the central region of the pivots 11.

[0039] Conveniently, along the portion 4 of the path of the segments 3 there are resting and guiding means for the chain 9 that supports the segments 3.

[0040] More particularly, two idler wheels 12a and 12b are mounted on the pivots 11, proximate to their axial ends, laterally to the links of the chain and on mutually opposite sides, and two mutually parallel profiles 13a and 13b are provided at the portion 4, and the wheels 12a and 12b rest thereon.

[0041] At least one of the wheels, the wheel 12a in the illustrated case, has a race 14 that has a V-shaped cross-section and the corresponding profile 13a with which it engages is shaped correspondingly, so as to prevent the chain 9 from moving laterally at least along the portion 4.

[0042] The profiles 13a and 13b ensure the perfect alignment of the segments 3 along the portion 4.

[0043] The means 6 for closing the side of the casting shell that lies opposite the bottom 3a comprise a belt element 15, which is preferably made of steel, is slightly wider than the shell formed by the segments 3, and can move along a path that faces, with one of its portions, the portion 4. Engagement means act on the belt element 15 and press said belt element 15 against the edges of the upper side of the casting shell formed by the segments 3 along the portion 4.

[0044] The engagement means are constituted by rollers 16a and 16b, whose axes are parallel to the axes of the pivots 11. The rollers 16a and 16b are supported, so that they can rotate about their own axes, by a supporting structure 17, which can move toward or away from the portion 4 and is pushed toward the same portion 4 by means of springs or fluid-actuated cylinders of a known type, not shown for the sake of simplicity, in order to press, by means of the rollers 16a and 16b, the belt element 15 against the segments 3 along the portion 4.

[0045] As an alternative, the pressing action of the belt element 15 against the upper side of the segments 3 can be obtained by means of sliding blocks instead of by means of rollers.

[0046] The pressing action of the belt element 15 against the shell formed by the segments 3 along the portion 4 performed by the rollers 16a and 16b or sliding blocks helps to push the wheels 12a and 12b against the profiles 13a and 13b, thus ensuring the perfect alignment of the segments 3 along the portion 4 in all directions.

[0047] The belt element 15 is closed in a loop and winds, so as to be tensioned conveniently, around two pulleys 18a and 18b that have horizontal axes that are parallel to the axes of the sprockets 10a and 10b and are supported by the structure 17. Both of said pulleys are movable in order to tension the belt element 15 and allow to replace it. The belt element 15 is normally moved by friction by contact against the segments 3, or at least one of the pulleys 18a and 18b is actuated with a rotary motion about its own axis in order to produce the advancement of the belt element 15 concordantly with the advancement of the segments 3 along the common portion of path.

[0048] Advantageously, there are means for cooling the metal poured into the casting shell and the elements of the machine that are in contact with the poured metal. Said cooling means comprise a plurality of nozzles 20 for dispensing a cooling fluid (generally water), which face in a downward region and laterally the segments 3 along the portion 4, so as to affect their lower side and their side walls with the cooling liquid.

[0049] The cooling means also comprise a plurality of nozzles 21 for dispensing a cooling fluid, which face in an upper region the portion of the belt element 15 that in each instance engages the segments 3 along the portion 4 so as to strike, with the cooling fluid, the upper face of the belt element 15 that engages the segments 3.

[0050] The portion of the casting shell formed in each one of the segments 3 preferably has, in a transverse cross-section with respect to the direction of the advancement of the segments 3 along the path set by the chain 9, the shape of an isosceles trapezoid that is open at its longer parallel side.

[0051] Conveniently, the apparatus according to the invention comprises, downstream of the casting machine 2 along the advancement direction of the bar that exits from the casting machine 2, a first cooling station 31, preferably of the tunnel type.

[0052] Downstream of the first cooling station 31 there is a cropping unit 32, preferably of the rotary type, for cutting into ingots of preset length the produced metal bar, and downstream of the cropping unit 32 there is conveniently a second cooling station 33 of the tunnel or tank type.

[0053] In output from the second cooling station 33 there is a station 34 for the automatic stacking, weighing and binding with straps of the ingots.

[0054] The apparatus can be completed by a system for the continuous marking of the ingots in order to mark thereon all the intended identification data.

[0055] The operation of the apparatus according to the invention is as follows.

[0056] The molten metal is fed continuously into the crucible 25, wherein the level of said metal is controlled and kept constant with means of a known type, for example of the type currently used in continuous casting machines of the wheel and belt type.

[0057] From the cauldron, the metal is poured and fed into the moving shell, which is formed by the segments 3 along the portion 4, by way of the casting channel 26 in a manner similar to what occurs currently in continuous casting machines of the wheel and belt type.

[0058] In the moving shell, the metal is cooled gradually by way of the jets of cooling fluid emitted by the nozzles 20 and 21 and solidifies, generating the bar 7, which leaves the shell in the region of the sprocket 10b.

[0059] It should be noted that the bar that exits from the shell is straight and that in order to make it leave the shell no expulsion elements that would cause plastic deformation of the bar are required, as instead occurs in continuous casting machines of the wheel and belt type.

[0060] By virtue of this fact, it is possible to limit the length of the portion 4 and therefore obtain a casting machine that has reduced dimensions, since the presence of a central part that has not yet solidified inside the bar 7 is acceptable.

[0061] Passage through the first cooling station 31 completes the solidification of the bar 7 and its temperature is brought to the level most suitable for the subsequent cropping operation, i.e., to the optimum temperature for reducing to a minimum the shearing stress to the extent compatible with the solidification and uniformity of the bar 7.

[0062] In the station 31, the cooling of the bar 7 can be of the spray type, which by having a direct action has a high efficiency and therefore requires shorter times.

[0063] After cropping, the bar segments 7 or ingots are cooled further in the second cooling station 33 at a temperature that is close to the ambient temperature and are then stacked, weighed and bound with straps in the station 34. The straps would in fact loosen owing to the thermal contraction of the ingots if they were bound at a high temperature.

[0064] The ingots obtained with the apparatus according to the invention have a rectilinear structure that is not subjected to plastic deformation after solidification, which occurs in a continuous shell formed by a sequence of concatenated segments and closed by a continuous belt element. Metallographic discontinuities are detectable in said ingots in the sections that correspond to the contact surfaces of the various segments that compose the shell.

[0065] In practice it has been found that the apparatus according to the invention fully achieves the intended aim and objects, since its performance is similar to that of apparatuses with a continuous casting machine of the wheel and belt type but with significantly smaller dimensions and lower costs.

[0066] In particular, the foundations of the casting machine of the apparatus according to the invention are considerably shallower and therefore far cheaper than the foundations required by continuous casting machines of the wheel and belt type.

[0067] The apparatus according to the invention, moreover, allows to produce a straight continuous bar that does not require the use of complicated ingot straightening machine with a pinch roll and motorized straightening rollers synchronized with the speed of the line.

[0068] Another advantage of the apparatus according to the invention is that it is possible to vary the cross-section of the produced ingots and the required level of hourly production simply by replacing the segments that form the casting shell and optionally by extending the chain of segments.

[0069] The apparatus thus conceived is susceptible of numerous modifications and variations, all of which are within the scope of the inventive concept; all the details may furthermore be replaced with other technically equivalent elements.

[0070] In practice, the materials employed, as well as the dimensions, may be any according to requirements and to the state of the art.

[0071] The disclosures in Italian Patent Application No. MI2001A002556 from which this application claims priority are incorporated herein by reference.

[0072] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

Claims

1. An apparatus for producing, by continuous casting, ingots of nonferrous metals, comprising a continuous casting machine provided with a moving casting shell, **characterized in that** said shell is composed of a plurality of segments arranged in succession, each segment having a portion, with bottom and side walls, of said casting shell formed therein and being open on sides directed toward contiguous segments; said segments being movable along a closed path that has at least one substantially straight portion at the casting region; said segments, along said at least one portion of path, being substantially aligned and forming a casting shell, with a bottom and side walls, that is continuous, substantially straight and closed, along at least one portion of path downstream of the casting region, by closure means at its side that is arranged opposite with respect to the bottom; downstream of said substantially straight portion said segment path having a change in direction for a gradual exit from said casting shell of a metal bar produced by solidification of the metal in the casting shell.

2. The apparatus according to claim 1, **characterized in that** along said substantially straight portion the side of said casting shell that lies opposite the bottom is directed upward.

3. The apparatus according to claim 1, **characterized in that** said substantially straight portion of the path of the segments, proximate to said casting region, is inclined downward in a direction in which the segments advance along said path.

4. The apparatus according to claim 3, **characterized in that** said segments are connected to links of a chain that is closed in a loop and winds around at least two sprockets, which have mutually parallel horizontal axes; said substantially straight portion of the path of the segments being formed by the upper portion of said chain; at least one of said sprockets being actuatable with a rotary motion about its own axis in order to produce advancement of said segments along said path.

5. The apparatus according to claim 1, **characterized in that** said closure means comprise a belt element that can move along a path that faces, with one of portions thereof, said substantially straight portion of the path of said segments; engagement means being provided which are suitable to press said belt element against said segments at said substantially straight portion of the path of the segments.

6. The apparatus according to claim 5, **characterized in that** said belt element is closed in a loop and winds around at least two pulleys with horizontal axes that are parallel to the axes of said sprockets.

7. The apparatus according to claim 6, **characterized in that** at least one of said two pulleys can be actuated with a rotary motion about its own axis in order to produce advancement of said belt so as to match advancement of said segments along the common portion of the path.

8. The apparatus according to claim 5, **characterized in that** it comprises means for cooling the metal poured into said segments along said substantially straight portion of the path of the segments.

9. The apparatus according to claim 8, **characterized in that** said cooling means comprise a plurality of nozzles for dispensing a cooling fluid, which are suitable to strike said segments with said fluid.

10. The apparatus according to claim 8, **characterized in that** said cooling means comprise a plurality of nozzles for dispensing a cooling fluid which are suitable to strike, with said fluid, a portion of said belt element that is pressed against said segments.

11. The apparatus according to claim 4, **characterized in that** means for resting and guiding the chain that supports said segments are provided at said substantially straight portion of the path of the segments.

12. The apparatus according to claim 4, **characterized in that** the links of said chain are mutually articulated by way of pivots whose axes are parallel to the axes of said sprockets; two wheels being mounted on each one of said pivots, proximate to their axial ends, and being suitable to rest, along said substantially straight portion of the path of the segments, on resting and guiding profiles.

13. The apparatus according to claim 6, **characterized in that** said pulleys that support said belt element are mounted on a structure that can move toward and away from said substantially straight portion of the path of the segments.

14. The apparatus according to claim 1, **characterized in that** the portion of said casting shell formed in each one of said segments has, in a transverse cross-section with respect to the direction of the advancement of said segments along the corresponding path, a trapezoidal shape that is open at the longer parallel side.

15. The apparatus according to claim 1, **characterized in that** it comprises, downstream of said continuous casting machine along the direction of the advancement of said segments along said substantially straight portion of their path, a first station for cooling the metal bar that exits from said continuous casting machine.

16. The apparatus according to claim 15, **characterized in that** it comprises, downstream of said first cooling station along the direction of advancement of the metal bar, a station for cropping said bar into segments.

17. The apparatus according to claim 16, **characterized in that** it comprises, downstream of said cropping station along the advancement direction of the metal bar, a second station for cooling the metal bar.

18. A nonferrous metal ingot obtained by cropping a continuous bar, **characterized in that** it has a rectilinear structure free of plastic deformation after solidification, which occurs in a continuous shell formed by a sequence of concatenated segments of ingot mold and closed by a continuous belt element, metallographic discontinuities being detectable in said ingot in the sections that correspond to the contact surfaces of the various segments that compose said shell.

19. A method for producing, by continuous casting, ingots of nonferrous metals, **characterized in that** it comprises the steps of:

- continuously casting the molten metal within a continuous and substantially rectilinear moving casting shell that is composed of a sequence of concatenated segments of an ingot mold;
- cooling said casting shell for the at least partial solidification of the cast metal;
- extracting continuously the bar produced by the solidification of the metal from said casting shell without producing plastic deformations of said bar;
- cropping said bar into segments.

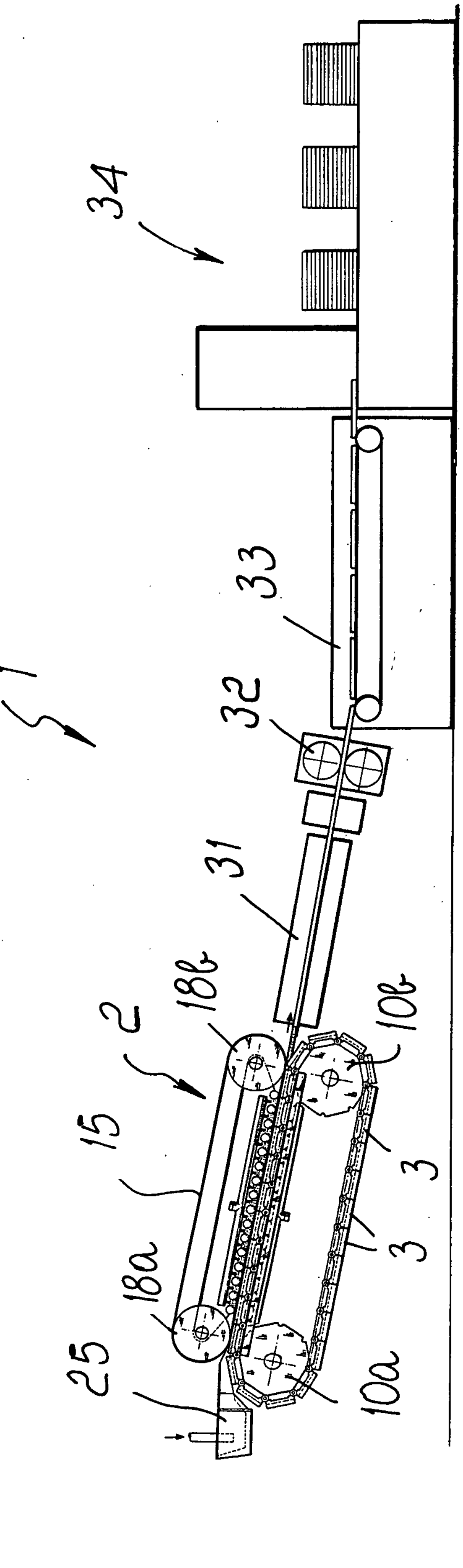
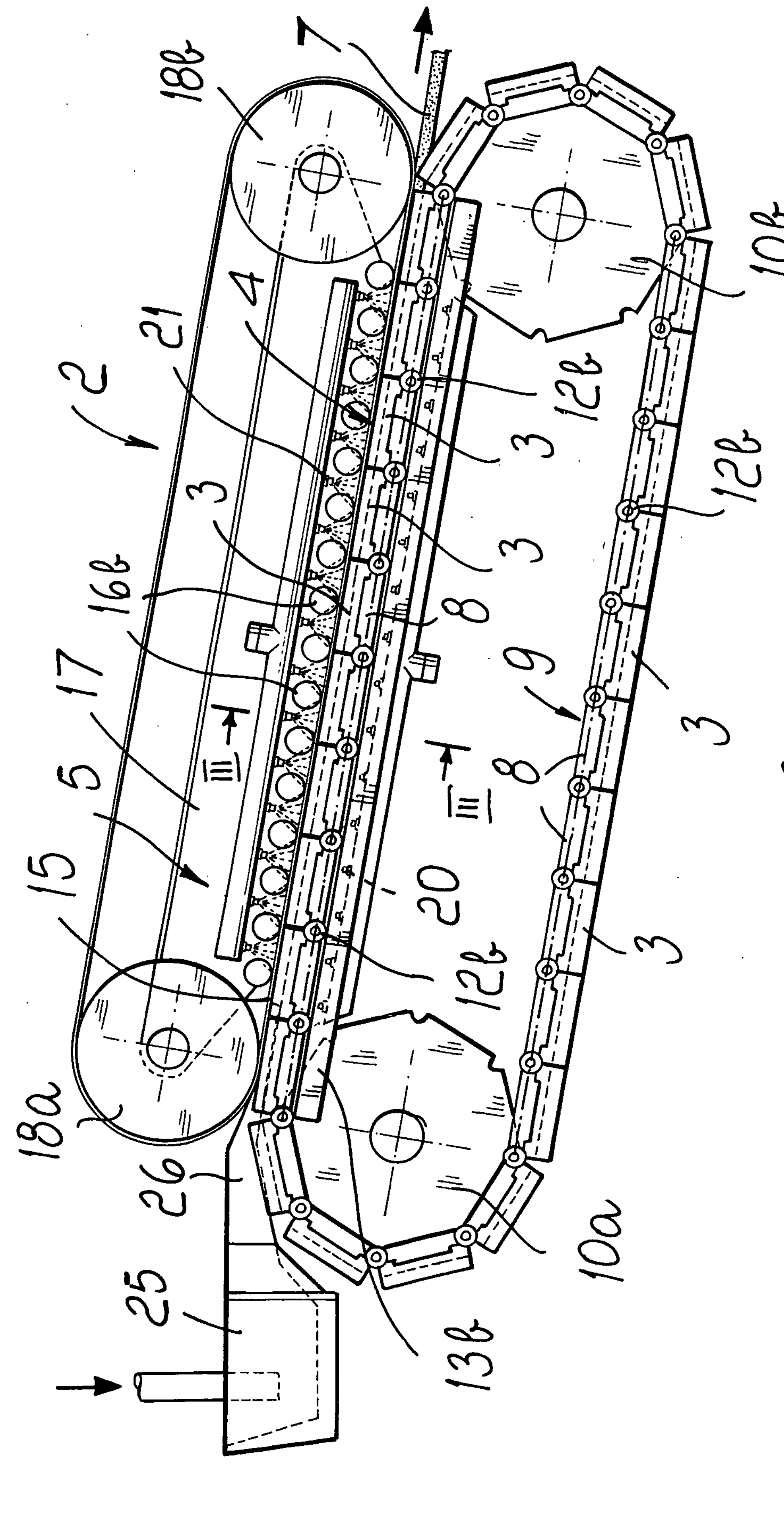


Fig. 1


7
18b
10b
12b
3
3
12b
3
8
9
8
3
3
12b
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III
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4
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3
16b
17
5
15
18a
26
25
13b
10a

Fig. 2

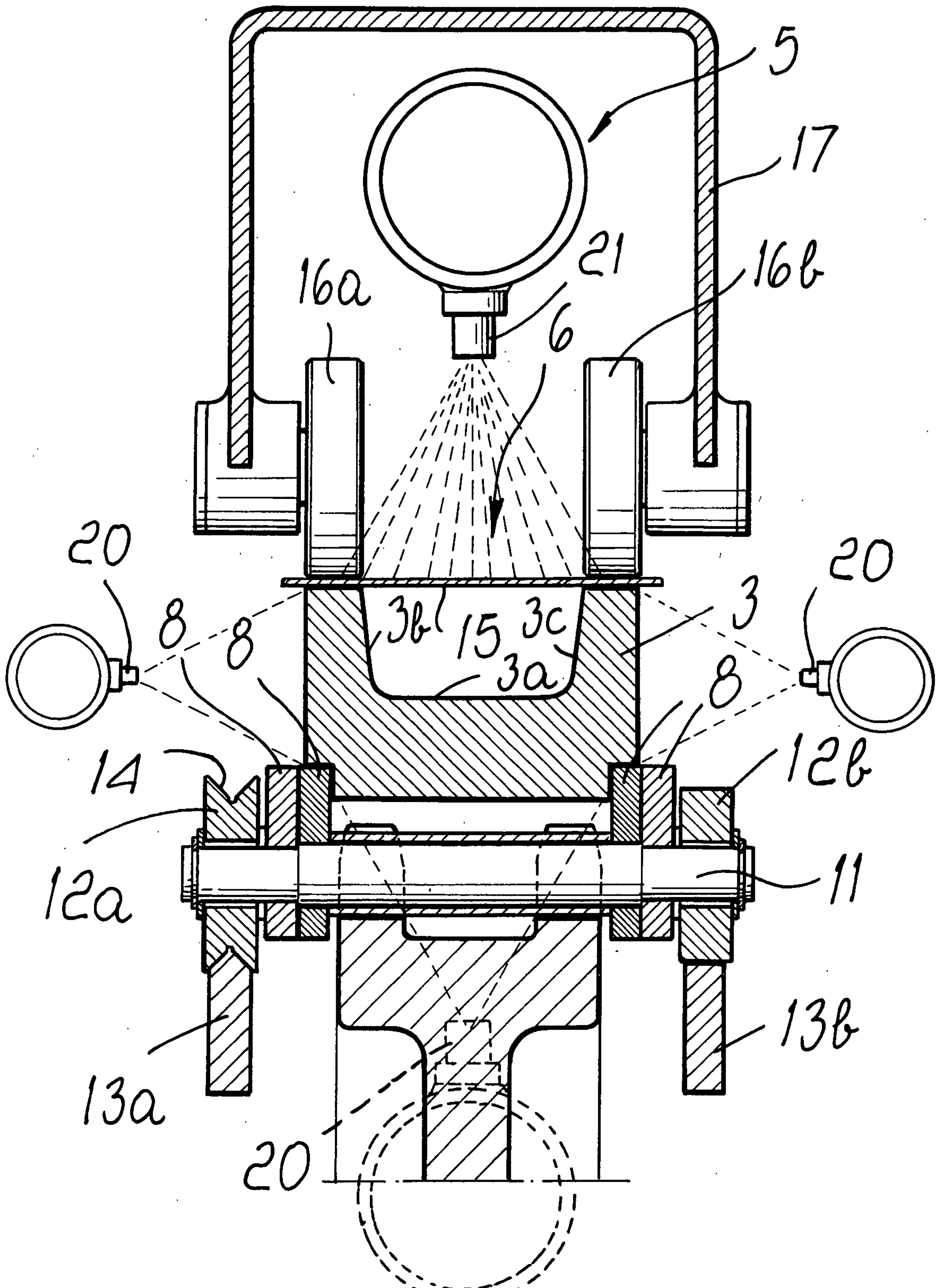

Fig. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 02 5598

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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X A	US 4 331 195 A (WEBBER C EUGENE) 25 May 1982 (1982-05-25) * abstract; figure 1 * ---	19 3	
X	US 1 841 297 A (GEORGE RAMSEY ET AL) 12 January 1932 (1932-01-12) * page 2, line 85 - page 4, line 127; figures 1-12 * ---	1-19	
A	US 5 377 744 A (MADDOCK BRIAN) 3 January 1995 (1995-01-03) * figure 2 * ---	14	
A	"BANDGIESSEN - TECHNOLOGIE DER ZUKUNFT" TECHNISCHE RUNDSCHAU, HALLWAG VERLAG. BERN, CH, vol. 91, no. 9, 7 May 1999 (1999-05-07), page 16 XP000873067 ISSN: 1023-0823 * figure * -----	15,17	TECHNICAL FIELDS SEARCHED (Int.Cl.7) B22D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	8 January 2003	Mailliard, A

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 02 02 5598

This annex lists the patent family membersrelating to the patent documents cited in the above-mentioned European search report.
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