(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 036 777 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 81301231.7

(22) Date of filing: 23.03.81

(51) Int. Cl.³: B 22 D 11/04, B 22 D 11/14

(30) Priority: 26.03.80 US 133969
23.12.80 US 219225

(43) Date of publication of application: 30.09.81
Bulletin 81/39

(84) Designated Contracting States: AT DE FR GB IT SE

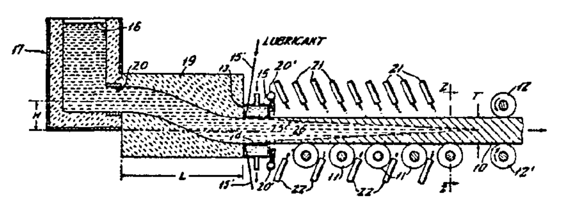
(71) Applicant: Rossi, Irving, 175 South Street, Morristown
New Jersey 07960 (US)

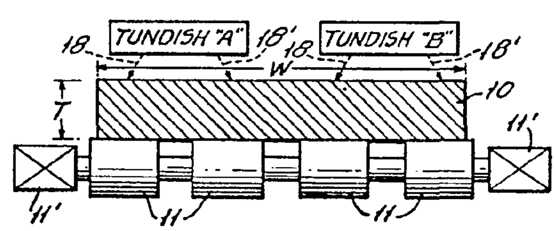
(72) Inventor: Rossi, Irving, 175 South Street, Morristown
New Jersey 07960 (US)

(74) Representative: Warden, John C. et al, R.G.C. Jenkins & Co. Chancery House 53/64 Chancery Lane, London WC2A 1QU (GB)

(54) Horizontal continuous casting machine.

(57) The invention contemplates horizontal continuous casting of steel strands (10) using a relatively short water-cooled horizontal mold passage (13) from which there is continuously and horizontally withdrawn an embryo casting having a solidified outer shell (25) surrounding a molten metal core (26). To assure continuous flow of molten steel to the cooled mold, a supply passage (18) is provided of refractory material impervious to liquid steel. This supply passage (18) is so formed that there is such a drop (H) in elevation between entrance and exit as will enable a head of ferrostatic pressure to exist, to maintain a condition of peripherally continuous pressure contact with the cooled mold (13), i.e. intensified cooling of the casting shell formed in the mold. Immediate water-cooling of the existing embryo casting assures against such reheating of the shell (after it leaves the mold) as might otherwise give rise to bulging or other deformation of the casting.





EP 0 036 777 A1

HORIZONTAL CONTINUOUS CASTING MACHINE

The invention relates to a method and apparatus for the continuous casting of metal strands, such as billets, blooms or slabs of steel.

In processes for the continuous casting of metal strands, molten metal is continuously poured into the upstream end of an elongate chilled open-ended mold which is generally vertical and in which the molten metal makes only brief contact with the mold at the meniscus, being characterised by a shrunken shell around a molten metal core and being therefore in clearance relation with the mold for the greatest fraction of its passage through the mold. This circumstance presents problems of support and guidance of the still largely molten strand as it is caused to travel an arcuate course from its initial vertical to its ultimately straightened condition on the horizontal, to the cut-off or other operations. Necessarily, most of the cooling takes place during the travel from vertical to cut-off, and for the larger slabs at production rates which the industry demands today, large-diameter support rolls are needed throughout the course, to maintain shape until the casting has solidified. Necessarily also, the larger the size of the casting, the greater the vertical height and horizontal distance needed to complete solidification, so that ferrostatic pressure imposes problems of assuring casting quality as well as mechanical problems of casting guidance and support to the point of cut-off.

Various schemes have been proposed to reduce overall height and attendant ferrostatic pressure, but without much success, except for small billets. The obvious solution would be a horizontal continuous-casting machine which would eliminate the ferrostatic pressure. A horizontal machine could be much less costly, and it would enable substantial reduction in the cost of the melt shop in which it is installed. Another advantage would be that the casting, particularly a slab casting, could be rolled, at great saving of energy, using the heat of the liquid steel.

In the horizontal continuous casting of steel, the supply problem is to cause molten metal to fill the mold fully and to press against the upper face of the mold. In prior attempts to solve this problem, the molten metal is caused to fill this upper space, by employing an intermittent casting-withdrawal rate - a stop-and-go withdrawal. When casting-withdrawal is briefly halted, the momentum of continuously flowing molten steel reacts against the halted casting, causing the molten steel to rise high enough to fill an air gap just below the upper face of the mold. This intermittent technique does not lend itself to the casting of large heavy cross-sections, due to the inertia of the casting and the problems of repeated start/stop movement; moreover, the casting process is not truly continuous.

In the present invention a relatively short cooled horizontal mold passage or nozzle is provided, and liquid metal is continuously and constantly forced into filling contact with the mold; the constant force is achieved by a head of ferrostatic pressure in the molten metal within the mold, assuring pressure around the entire metal surface of the cooled mold, to thereby form an embryo shell.

The supply of liquid metal to the cooled mold is assured by having it travel through a supply passage in a material impervious to liquid metal. The passage is so defined that the metal-inlet end is higher than the metal-outlet end (at entrance to the mold), and this difference in height between the two ends is chosen so that the ferrostatic head is operative in the mold-end of the passage.

A preferred embodiment of the invention will be illustratively described in conjunction with the accompanying drawings, in which:

Fig. 1 is a simplified vertical sectional view of a horizontal continuous-casting machine of the invention;

Figs. 2 and 3 are simplified sectional views taken at 2-2 of Fig. 1, to respectively illustrate slab casting and billet casting; and

Figs. 4 and 5 are simplified diagrams similar to Fig. 1 to illustrate modifications.

The drawing depicts steps and apparatus along a traverse path in the continuously-cast production of a solidified metal slab 10 of rectangular section, having a horizontal-width dimension W (Fig. 2) which may substantially exceed its thickness dimension T; the solidified slab is continuously delivered to rolls 11 for horizontal support (via end bearing 11') and is horizontally withdrawn by drive rolls 12-12' to a cut-off or other operating stage (not shown). Casting occurs within a relatively short open-ended horizontal mold 13 having a liner 14 which defines a mold passage with an exit end of desired-section shape, the liner 14 is suitably of high-conductivity metal, such as copper, and is encased by a cooling jacket 15 adapted for continuous application of a flow of cooling water over the outer surface of liner 14.

Molten metal 16 is continuously supplied to the upstream end of mold 13, via a tundish 17 and via a broken passage 18 in a conduit member 19 of suitable refractory material, such as graphite, or other material impervious to a flow of liquid steel. The term "broken" is employed to describe the preferred directional change in the flow path determined by passage 18; passage 18 is inclined below the horizontal, to establish a net vertical head or drop H from its upstream end to its downstream end, the upstream end is curved to receive a continuous horizontal discharge of molten metal 16 at exit from tundish 17, while the downstream end is similarly but oppositely curved, to permit the casting to form and to exit in horizontal alignment with the support and conveyor means 11-12-12'. The length L of conduit member 19 and the steepness of downward slope of passage 18 will be understood to be such as to assure ferrostatically pressurised delivery of molten metal to the full periphery of the mold liner 14.

During operation of the machine, molten metal is supplied to tundish 17 in sufficient quantity to enable continuous flow via passage 18 to the mold liner 14, and the solidified slab 10 is withdrawn by rolls 12-12' at a rate commensurate with the rate at which molten metal enters the mold at 18. Also, oil or other lubricant to ease embryo-shell passage through mold 13 is supplied via conduit means (schematically suggested at 15') exposed to jacketed mold coolant for cooling immediately prior to emergence through peripherally distributed apertures at the upstream end of the mold surface of liner 14.

As the embryo casting leaves the mold, it moves through a secondary cooling zone wherein coolant is applied directly to the strand to complete solidification of the casting. As shown, this involves first application of partial vacuum at 20', to assist in evacuation of burnt lubricating oil as soon as the cast surface emerges from contact with the mold surface; the secondary cooling proceeds to completion through application of multiple sprays of cooling water from upper and lower cooling-jet elements 21-22. Significantly, in casting passage from initial cooling contact with the mold surface, (a) there need be no interruption of cooling action, and (b) the casting is fully exposed to any given point in the path of movement of the casting.

To commence operation with the described machine, a dummy bar (not shown) is engaged by rolls 12-12-12' and extends upstream through the secondary cooling zone and into removable plugging relation within the exit opening of the mold. Molten metal is introduced into the mold into full contact with the end of the dummy bar and into filling peripherally continuous contact with the inner surface of the mold liner 14. As soon as the mold has filled, and with all cooling flows established, drive rolls 12 are started at a rate such that the exit of the mold remains constantly filled; and the dummy bar is withdrawn once solid product 10 reaches the drive means 12-12'. The embryo casting develops as a shell 25 conforming to the sectional dimensions of the mold and, as seen from Fig. 1, this shell becomes progressively thicker in its short course within the mold passage, but at least to the point where, at exit from the mold, the shell 25 has solidified enough around a still molten core 26 to retain the cast-section shape. In the cooling zone of jet sprays 21-22, solidification proceeds to completion, permitting a solid casting to be handled by means 11-12-12'.

It will be seen that in the described process, the outside surface of the casting is always forced outward into contact with the mold wall, thereby assuring a brief period of intense cooling.

While the invention has been particularly described in connection with slab production from the single mold 13 and its supply passage 18, it will be understood that other configurations may be similarly cast, as suggested by Fig. 3.

Also, by way of example, Figs. 4 and 5 illustrate further refractory-passage configurations which embody the ferrostatic-head principle discussed, corresponding reference numerals being used where applicable. In Fig. 4, the function of the refractory conduit member 19' is to provide the head or drop H within a short length L so as to avoid as much as possible any cooling within the refractory passage 18', all for the situation in which upstream supply from the tundish is horizontal, and in which discharge to mold 13 is on the horizontal alignment of the mold liner 14. In Fig. 5, the refractory conduit member 19' further reduces refractory-passage length for the requisite ferrostatic head which is operative within the mold, by accepting vertically downward discharge of molten metal from the tundish, provision being made at 30 for flow regulation as may be needed for achievement of correct supply of metal to the mold.

From the foregoing description and drawings, several important features of the invention will be noted, particularly when contrasted with the structural nature and design of a conventional vertical continuous slab caster. For example, in one such vertical casting machine which now produces 100-inch slabs at the rate of 1 million tons per year, it is known that:

a) the repair and maintenance cost applicable to the many rolls required to support the slab (against bulging from ferrostatic pressure) and to guide the casting, as it proceeds on its arcuate course, from vertically down to horizontally out, amounts to about $3.00 per ton of slabs cast, or about $3 million per year;

b) the casting leaves the caster at about 400°F., the product of slow cooling over an extensive arcuate course followed by an extensive horizontal course; the slow cooling is dicated by the number and proximity of rolls needed for casting support and for casting-shape control, in an environment of high ferrostatic pressure.

In contrast, the horizontal caster of the invention does not require the wide-face (i.e., large-diameter) rolls which obstruct and preclude cooling access to as much as 85 percent of a vertically cast slab surface, so that therefore the horizontal-caster product is immediately and fully exposed and accessible. And quick-cooling is not only tolerable but desirable. Horizontal casting therefore offers a major saving both in number and size of rolls and in roll maintenance, as well as ideal cooling conditions (i.e. accessibility for cooling) for every grade of steel.

The machine and method of the invention is applicable to the production of a full range of size and shape of cast strands, including slabs. In the continuous casting machine a substantial part of the heat of the molten steel is available for rolling.

CLAIMS

1. A continuous-casting apparatus for continuous casting of metal in which molten metal (16) is flowed continuously from a molten-metal source and into the upstream end of a chilled mold (13) having a mold passage of substantially constant section extending therethrough and in which an embryo casting having a solidified outer shell (25) surrounding a molten core (26) is withdrawn continuously from the downstream end of the mold passage, characterised in that a confining through-passage (18) connects the source (16) with the downstream end of the mold (13), the discharge axis at the downstream end of the mold being oriented substantially horizontal and at such elevation below the elevation of source discharge into said passage as will enable ferrostatic pressure to achieve a continuous condition of peripherally continuous casting contact with the mold at substantially the location of casting exit from the mold.

2. Apparatus according to claim 1, in which said mold (13) is a relatively short and water-cooled, and in which said through-passage (18) is a conduit (19) of refractory material that is impervious to liquid steel.

3. Apparatus according to claim 1 or claim 2, in which substantially the entire drop (H) in elevation between said source and said mold (13) is in said conduit.

4. Apparatus according to any preceding claim, in which said mold (13) is straight and horizontal.

5. Apparatus according to any preceding claim, in which said source is a tundish (17) connected for molten metal dishcarge into said through-passage (18).

6. Apparatus according to any preceding claim, further comprising guide and support rolls (11) horizontally aligned with said mold (13) to maintain the horizontal alignment of the embryo casting, and secondary-cooling means (21,22) external to said mold and operative on the cast shell immediately upon its emergence from said mold.

7. Apparatus according to claim 6, in which said mold (13) is of rectangular section with two vertically spaced horizontal surfaces and two horizontally spaced vertical surfaces, the support plane of said support-roll means (11) being substantially

that of the lower horizontal surface of said mold.

8. Apparatus according to claim 6 or claim 7, in which in the region of secondary cooling the guide and support rolls (11) are entirely beneath the casting, whereby the upper surface of the casting is entirely exposed for secondary cooling.

9. Apparatus according to any preceding claim, in which lubricant-supply means diposed for lubricant discharge at the upstream end of said mold (13) includes a supply conduit (15') passing through and exposed to mold coolant just prior to lubricant discharge.

10. Apparatus according to any preceding claim, in which said conduit means (19',19") includes a region of substantially vertically guided downward molten-metal flow disch arging into a region of substantially horizontally guided discharge in horizontal alignment with the mold passage.

11. Apparatus according to claim 10, including selectively operable throttling means (30) operative at the connection of said tundish (17) to said through-passage for so controlling the flow of molten metal as to maintain pressurised molten-metal contact with

the mold (13).

12. The method of continuously casting steel to a given sectional size and contour, which comprises selecting a water-cooled mold characterised by a relatively short mold passage of said sectional size and contour between inlet and outlet ends of said mold passage, establishing a supply passage to the inlet end of said mold passage, and withdrawing an embryo casting having a solidified outer shell (25) surrounding a molten core (26) from the downstream end of the mold passage, characterised in that the mold passage is horizontally orientated, the supply passage (18) is of length and orientation to establish a range of downward elevation drop through said supply passage to said mold passage and is continuously filled with liquid steel (16) to maintain a ferrostatic loading head (H) upon steel in the mold passage while withdrawing cast steel from the outlet of the mold passage, whereby the cast steel emerges from the mold passage virtually as soon as its embryo shell (25) forms.

13. The method of claim 12, in which the embryo shell (25) is subjected to secondary cooling immediately upon its emergence from the mold (13).

14. The method of claim 13, in which secondary cooling proceeds to a limit where the maximum heat of the liquid steel is available for rolling.

15. The method of any of claims 12 to 14, and including the further step of continuously guiding and supporting the emerging casting (25,26) in substantially the same horizontal plane as that in which the embryo shell is initially defined.

16. The method of any of claims 12 to 15, and including the further step of continuously supplying liquid lubricant to the upstream end of the mold surface via heat-exchange with mold coolant immediately prior to lubricant discharge at the mold surface.

FIG. 1.

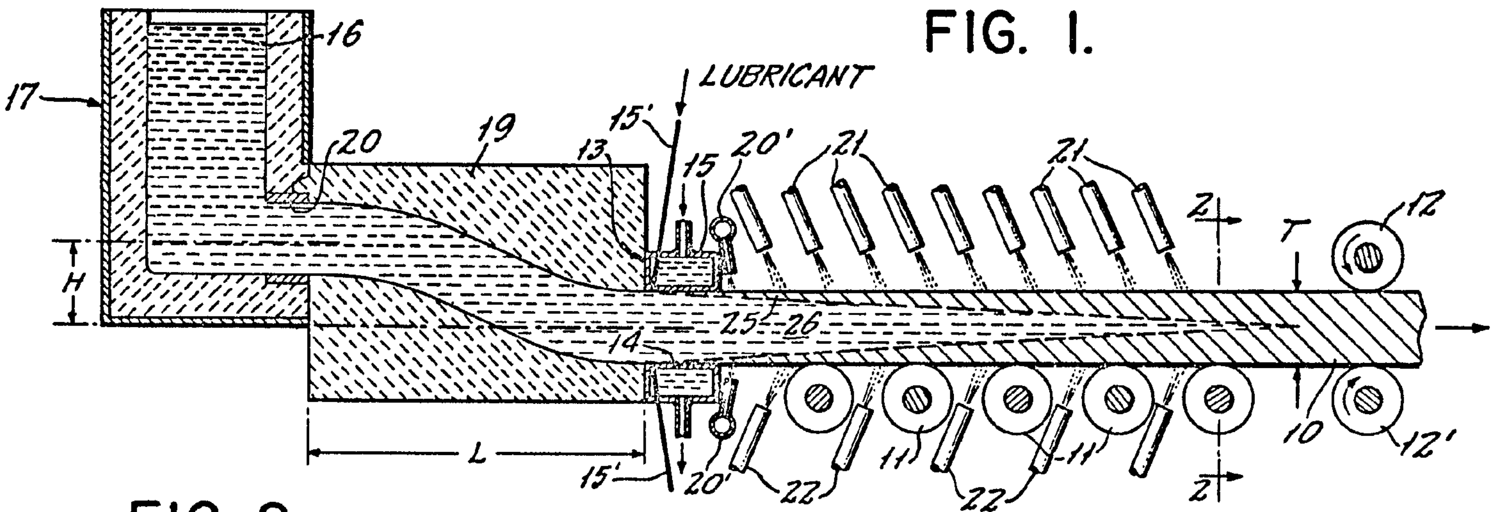


FIG. 2.

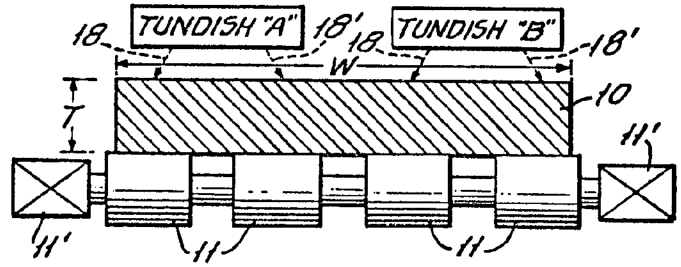


FIG. 3.

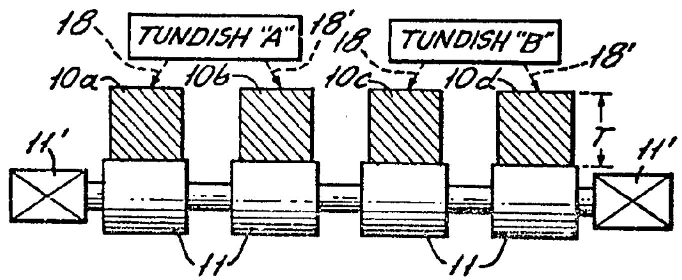


FIG. 4.

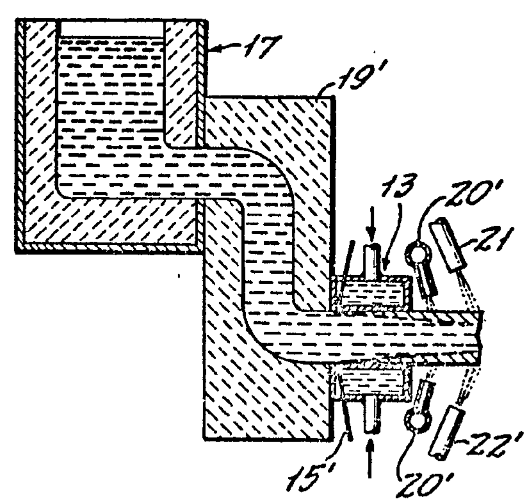
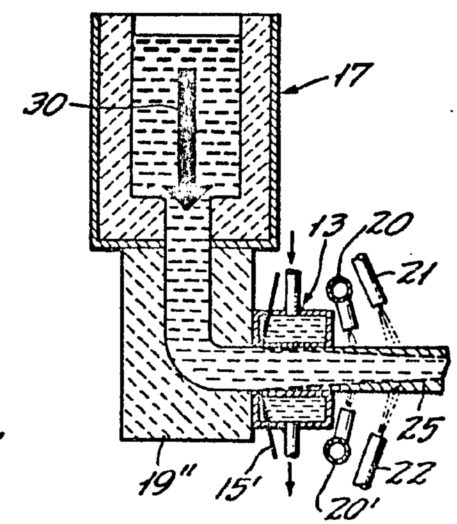


FIG. 5.



European Patent Office

EUROPEAN SEARCH REPORT

0036777

Application number

EP 81 30 1231.7

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	FR - A - 1 441 119 (E. OLSSON AG) * fig. *	1	B 22 D 11/04 B 22 D 11/14
A	CH - A - 440 571 (MACHIN ANSTALT) * fig. 1 *	1	
A	FR - A - 1 350 174 (V. ROLL AG) * fig. 1 *	1	TECHNICAL FIELDS SEARCHED (Int. Cl.3)
A	DE - A1 - 2 756 112 (CONCAST AG) * fig. 1, 2 * & FR - A1 - 2 374 113 & US - A - 4 146 078	1	B 22 D 11/00
A	DE - A - 2 062 127 (VOEST AG) * fig. 1 * & GB - A - 1 339 918 & FR - A - 2 076 003	1	

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	22-06-1981	GOLDSCHMIDT