June 17, 1969 E. VALLAK ETAL 3,450,188

CONTINUOUS CASTING METHOD AND ARRANGEMENT

Filed Aug. 23, 1966 Sheet 1 of 2

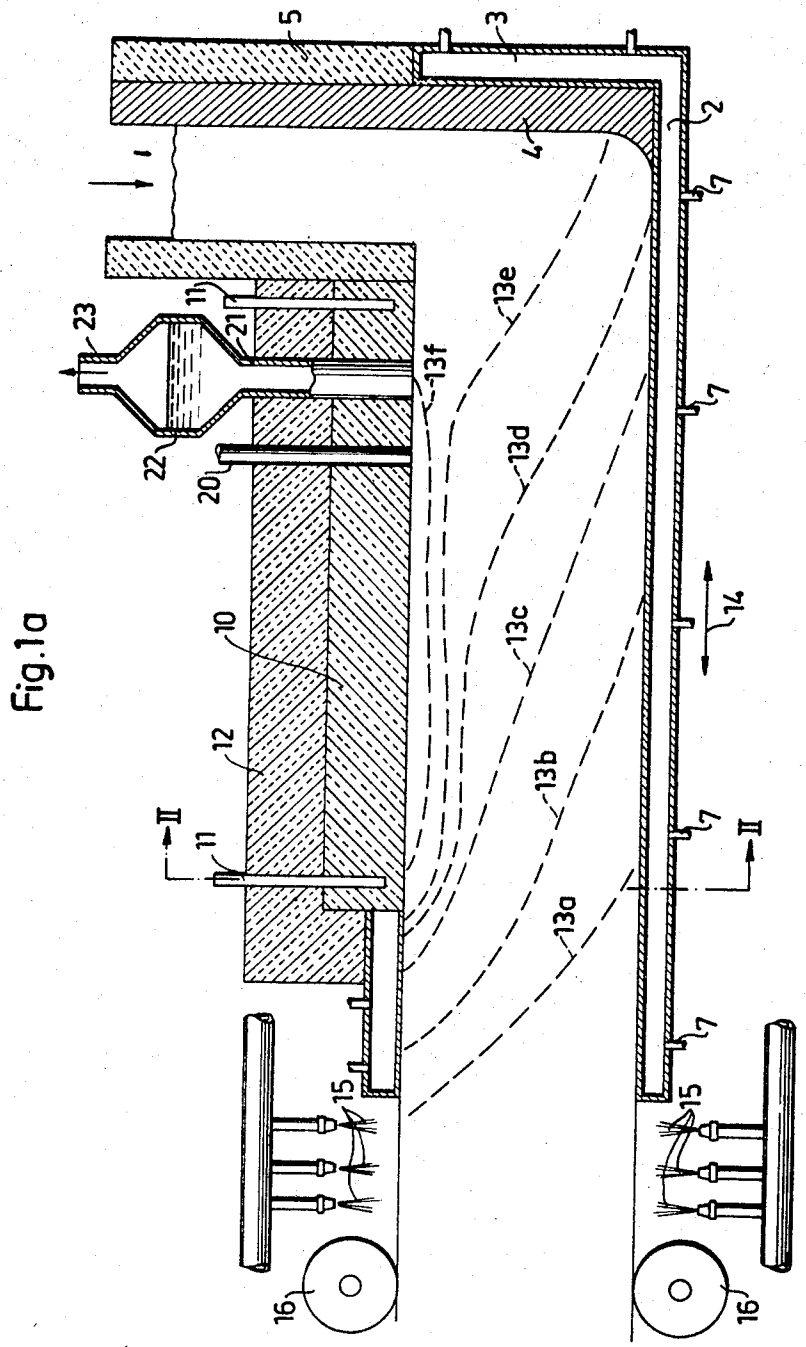


Fig.1a

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Fig.1b

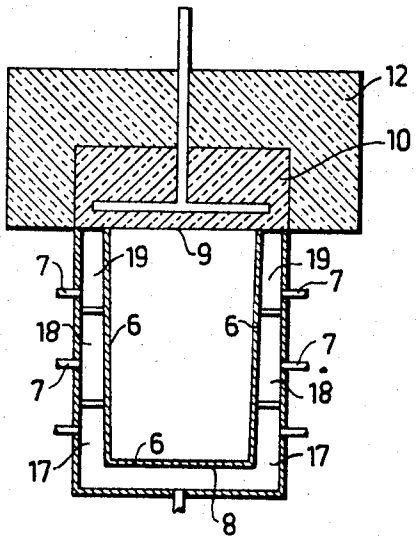


Fig.2a

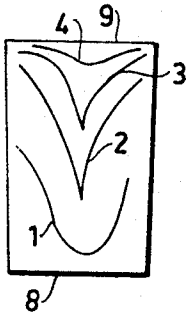
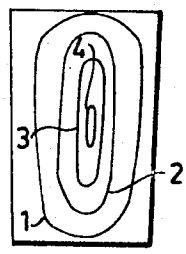


Fig.2b



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CONTINUOUS CASTING METHOD AND ARRANGEMENT

Enn Vallak, 82, route de Florissant, Geneva, Switzerland, and Sven Gustaf Harald Eketorp, Karsta, Sweden; said Eketorp assignor to said Vallak

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U.S. Cl. 164—82 11 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for the continuous horizontal casting of metal billets are provided, wherein molten metal is continuously poured into a vertical pouring-in section and then fed through an essentially horizontal mold section. The sides and bottom of the horizontal mold section are cooled, while the top side thereof is heated so that the sequence in solidification of the billet is from the bottom to the top. This eliminates pipes in the billet and allows dross, slag and gases to rise to the molten surface rather than being entrapped in the center of the casting.

Known methods for continuous casting of metals, especially those applied in steel casting, have among other inherent drawbacks the following ones:

(1) Dross appearing in the liquid metal bath, and formed during the solidification process of the metal, has little chance to be separated from the bath, because of the pouring of the metal being performed at the surface of the bath of the liquid metal. Hereby the dross passes down into the metal bath and becomes solid within the interior of the cast billet. The center portion of the billet therefore tends to become more contaminated than other portions and also usually contains pipe formations due to the center portion of the billet being the last one to solidify.

(2) The crust formed by the metal at the walls of the mould (which is oscillated in one way or the other) tends to form an interspace between itself and the walls of the mould at a certain stage of the formation, whereby the cooling is made difficult and the production will be reduced.

(3) Continuous casting plants hitherto known are of vertical type, which either involves great structural height or complicated arrangements for bending the billet to a horizontal plane.

The object of the present invention is to eliminate these qualitative and economical inconveniences. The invention relates to an essentially horizontal continuous casting machine especially useful in casting sheet billets (slabs), in which the billet during the solidification process will stand on its edge and the cooling is arranged in a manner so as to get the top surface of the billet to be the last portion to become solidified. If the billet has a four sided cross-sectional configuration, three sides will be exposed to the cooling action, while the fourth side—the top surface—will be insulated (protected against the cooling action by means of some kind of insulation) or will be heated to prevent this side from getting cooled too quickly. In this way the dross will float in direction towards the top surface and be separated. As will be described below this separation can be further improved by the addition of dross material to said top surface.

In order to provide a good contact with a minimum of interspace between the molten billet and the mould, the latter may be given a slightly conical vertical cross-section gradually getting wider towards its top, so that the billet by its own weight will sink down into the mould providing a good contact between the billet and the walls of the mould.

Due to the fact that according to the invention the mould preferably is horizontal the total structural height of the machine or plant will be reduced and as a result there will be obtained great savings in the capital outlay for the construction cost of the installation. The billet cast as a continuous elongated strand in accordance with this invention is pure to a great extent, and possibly occurring impurities or contaminations will be concentrated to the top surface of the billet (the top edge of the sheet billet), which in any case will be cut off in the subsequent rolling operation.

In the following the process and arrangement according to the invention will be described more in detail with reference to the accompanying drawings. Because of the fact that the greatest difficulties will be involved in the continuous casting of steel, among other things because of the comparatively low thermal conductivity of iron, an example will be described of continuous strand casting of steel billets, but other metals may of course also be cast in a similar way. In the drawings:

FIG. 1*a* shows a longitudinal sectional view of an embodiment of an installation according to the invention;

FIG. 1*b* shows a cross sectional view of the same installation along the line II—II in FIG. 1*a*;

FIG. 2*a* shows diagrammatically a vertical sectional view of the solidification fronts of the billet cast according to the invention, and

FIG. 2*b* is a similar view of the solidification fronts when cast according to a method known in the art.

According to FIG. 1*a* the molten steel is poured into the machine. The top surface of the molten steel bath is maintained at a certain level above the level of the top surface of the cooled billet or strand in order to create a certain hydrostatic pressure in the liquid metal bath. The pouring-in section constitutes part of the chilled mould **2**, but in order to prevent the metal from getting cooled down too quickly at the rear wall **3**, this wall is insulated against direct contact with the molten metal for example by means of a ceramic lining **4**. The top portion of the pouring-in section of the pouring gate can be made entirely of ceramic material **5**. As shown in FIG. 1*a* the mould continues from a vertical pouring section into a horizontal section where the metal solidifies.

The pouring-in section constitutes an integrated part of the mould according to FIGS. 1*a* and 1*b*. If the mould cavity has a four sided cross section three of these sides **6** of the mould are watercooled by means of some suitable arrangement known in the art, for example by introducing water at **7** into the jacket structure of the mould for enabling a coolant circulation. The cross section of the mould has a trapezoidal configuration, the short base of which is at the bottom of the mould, its vertical walls thus sloping gradually inwards in direction towards the bottom **8**. The width at the bottom **8** is thus slightly smaller than at the top **9**. Thereby the solidifying metal billet or strand descends in its corresponding mould section during the solidification process and is permitted to shrink for example by 3 to 4%.

The top surface of the horizontal portion of the mould is not water-cooled in its first section, the mould cavity instead being closed by a heated plate **10**. This plate can be made of some material, which readily can be heated by some simple and convenient arrangement. For example a block of graphite electrically heated directly by resistance elements incorporating two electric connections **11** would be a suitable arrangement. The heating could also be effected by induction or in other ways. Also a ceramic block can be used, which can be heated in some suitable manner, by way of example by built-in resistance coils or loops to increase the temperature up to approximately 1600° C. for example by employing elements of the Kanthal Super material. The heated block is surrounded

by an insulation **12**. The heat supply to the top surface of the billet in order to retard or delay its solidification, resulting in a later solidification at this place than in any other portion of the billet or strand, may be reduced or in certain cases entirely omitted, depending upon the quality of steel to be cast, and upon super-temperature above the melting point of the steel maintained in the pouring-in stage.

By variation of the heat supply—and also of the cooling—the solidification process of the billet or strand can be controlled. In principle the position of the temperature front or zone is illustrated in FIG. 1*a* in which some curves **13**, **13***a*–**13***f* are shown, representing equal temperatures (isotherms or zones of equal temperature). It is assumed that the temperatures increase from **13***a* to **13***f*.

The mould can be moved horizontally in conventional manner as shown by the arrow **14**, this movement preferably being effected so as to make its speed for a short predetermined interval of time equal to or slightly greater than the speed of the billet or strand and the return stroke will be effected at a speed twice or three times the speed of the billet. The billet is water-cooled outside the mould by conventional means as indicated at **15** and the withdrawal operation is effected by means of a roller drive **16**.

The method described is especially useful for casting sheet billets (slabs). In this case the section of the surface of the billet or the strand last of all to be solidified represents only a small part of the total surface of the billet. After leaving the roller drive the billet can readily be turned over 90° before the sheet rolling operation will take place. Instead of such turning over operation the continuously cast billet or strand can be cut off or severed by known methods, for example by oxygen flame. The invention is of course suitable also for sections with a smaller relation between height and width respectively square sections, but its advantages are most important when casting typical sheet billets or slabs.

The refrigeration of the mould as shown in FIG. 1*b* can also be varied by subjecting different longitudinal sections of the billet to different intensity in cooling effect. Thus, the inferior portion **17** of the mould may for example be cooled down very intensely by passing a large quantity of water, the overlying section **18** being cooled less intensely, and the top section **19** being cooled by means of steam or oil, so that the temperature of the cooling fluid can be maintained at a higher level than when employing water.

One of the most essential features of the invention is to cool the billet or slab (if a product of four-sided section is being cast) only from three sides and to present the top surface from solidifying before the inferior portions of the billet or strand. The solidification front is thus situated as shown in FIGS. 2*a* and 2*b* where the numerical figures indicate the time sequence of the solidification process, the zone **1** solidifying earlier than zone **2**, and the latter one solidifying earlier than zone **3**, **4** etc. FIG. 2*a* shows how the solidification process takes place according to the invention. FIG. 2*b* shows the solidification process according to known methods of continuous casting. The solidification process according to the invention enables that an open molten surface may be maintained available for a considerable time. This results in the following advantages:

(1) One can effect additional pourings of molten steel thereby compensate for the shrinkage taking place in the inferior portion of the metal during the solidification process.

(2) One can maintain an open bath surface to which dross and gases can rise and be separated from the steel.

This heated top portion of the mould thus has substantially the same function as a so called hot top in the batch casting operation in a chilled mould.

The dross floating up to the top surface of the bath will be situated on the top surface of the billet and be kept in molten state by the heated graphite block. The dross layer performs three distinct positive functions, viz.

(1) To serve as "reservoir" for dross and slag floating up in the steel bath,

(2) To give the continuous billet or strand a flat and smooth top side;

(3) To serve as a sealing agent between the billet and the mould and between the heated section and the mould.

Additional dross material may be supplied at a certain superpressure through a hole **20** in the heated graphite block **10**. It is no disadvantage if the billet or slab is coated with a thin layer of dross at its top surface when leaving the mould.

When the cross sectional shape of the billet is rectangular, it is often of great advantage to be able to effect the feeding operation (withdrawal operation) at the horizontal part of the casting machine with the billet standing upended edgewise (see FIG. 1*b*). For the rest, however, the cross sectional shape may vary. If desired the walls **2** (and **10**) themselves may also be caused to move in relation to the billet.

If dross and overconcentrations (segregations) of certain elements, for example sulphur, phosphorus etc. should not be completely removed in spite of the procedure described (the smallest dross particles for example take a long time to float to the surface), they will in any case be found in the top-most portion of the billet and not at its center. This means that possible impurities and faults will be found at one edge of the sheet after the rolling operation. As the edges anyhow have to be clean cut, this results in a higher degree of purity of the finished sheet being obtained by this method than if the center portion would be the last one to solidify.

It is often desirable to eliminate gases such as oxygen gas from the molten metal. This is readily effected in the horizontal continuous casting process, shown for example by means of a gas discharge **21** arranged at the top surface of the billet and communicating with a receptacle **22** from which gases from the free metal surface can be drawn off, the discharge pipe **23** being connected to a source of suction or vacuum.

What we claim is:

1. A method for the continuous horizontal casting of metal billets, comprising the steps of continuously feeding molten metal horizontally in billet form through a mold; and effecting solidification of the molten billet by cooling the sides and bottom while heating the top of the billet so as to maintain a temperature differential therebetween ensuring that the top surface of the billet will solidify last, thereby allowing dross and gases to rise to the molten top surface and escape from the billet, rather than being entrapped therein.

2. A method for the continuous horizontal casting of metal billets in accordance with claim **1**, wherein dross-forming material is supplied to the top surface of the molten metal billet so that an insulating layer of dross will be formed on the said top surface, to inhibit heat dissipation therefrom.

3. A method for the continuous horizontal casting of metal billets in accordance with claim **1**, wherein the top of the molten billet is heated by conduction and direct heat transfer from a heating surface in contact therewith.

4. A method for the continuous horizontal casting of metal billets in accordance with claim **1**, wherein the bottom of the molten billet is cooled to a greater extent than the sides, to ensure that the sequence of solidification is from the bottom to the top.

5. An apparatus for the continuous horizontal casting of metal billets, comprising a vertical pouring-in section; a closed horizontal mold section for continuously moving the molten billet in a horizontal direction towards a discharge point for the cast billet; means for cooling the sides and bottom of the horizontal mold; and means for heating the top surface of the horizontal mold, so that the top side of the billet will solidify last, thereby eliminating pipes in the billet and allowing dross and gases to rise to the molten top surface of the billet rather than being entrapped in the center of the casting.

6. A continuous horizontal casting apparatus in accordance with claim 5, in which the top surface of the horizontal mold section is provided with means for supplying dross-forming material to form an insulating layer of dross on the top surface of the billet, to inhibit heat dissipation.

7. A continuous horizontal casting apparatus in accordance with claim 5, in which the cooling means for the sides and bottom of the horizontal mold section comprises a plurality of annular cooling jackets on the exterior of the mold; the cooling jacket adjacent the bottom portion of the billet passing a greater amount of cooling fluid than the cooling jackets adjacent the sides of the billet, to ensure that the sequence of solidification is from the bottom to the top.

8. A continuous horizontal casting apparatus in accordance with claim 5, in which the top surface of the horizontal mold section is provided with means for withdrawing gases contained in the molten metal.

9. A continuous horizontal casting apparatus in accordance with claim 5, in which the top side of the horizontal mold section is heated electrically by means of a block of graphite incorporating resistance elements.

10. A continuous horizontal casting apparatus in accordance with claim 5, in which the horizontal mold section has a slightly wider cross section at its top portion than at its bottom portion, to prevent the formation of voids between the mold and the casting.

11. A continuous horizontal casting apparatus in accordance with claim 5, in which the horizontal mold section has a rectangular cross-section.

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J. SPENCER OVERHOLSER, *Primary Examiner.*

R. S. ANNEAR, *Assistant Examiner.*

U.S. Cl. X.R.

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(5/65)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,450,188 Dated June 17, 1969

Inventor(s) Enn Vallak et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 41, "inferior" should read --interior--.

Column 3, line 50, "present" should read --prevent--.

Column 3, line 51, "inferior" should read --interior--.

Column 3, line 66, "inferior" should read --interior--.

SIGNED AND
SEALED
APR 7 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents