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[72] Inventors Fritz Harders
Post Ergste uber Schwerte (Ruhr);
Franz Oeters, Dortmund, Germany
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[73] Assignee Dortmund-Horder Huttenunion Aktiengesellschaft, Dortmund, Germany
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[54] **APPARATUS FOR THE CONTINUOUS CASTING OF METAL**
4 Claims, 3 Drawing Figs.

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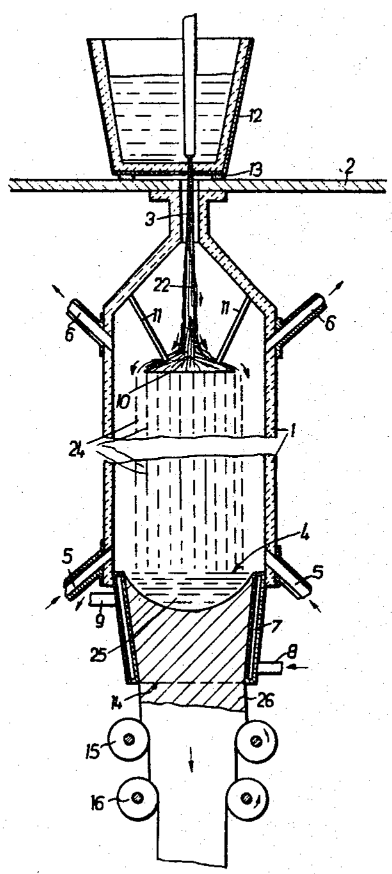
Primary Examiner—J. Spencer Overholser
Assistant Examiner—R. Spencer Annear
Attorney—Curt M. Avery

ABSTRACT: Described is apparatus for continuous casting of metal comprising a tower with a restricted inlet at its upper end for introduction of the melt and a relatively large discharge opening. The tower has inlet and outlet ports for circulatory flow of a coolant gas, means for feeding the molten metal through the inlet, distributing means at the upper end onto which the molten metal falls and whereby it is dispersed as droplets which reunite in the discharge section prior to issuing therefrom as a solid mass.



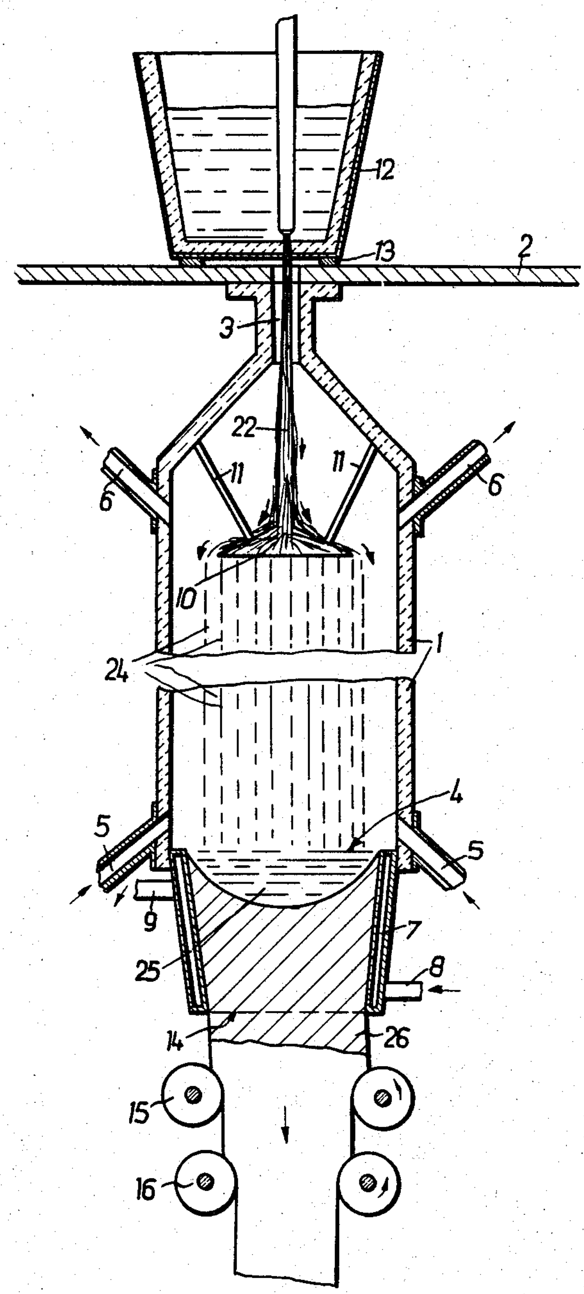


Fig. 1

Inventors:
Fritz Harders
and
Franz Peters

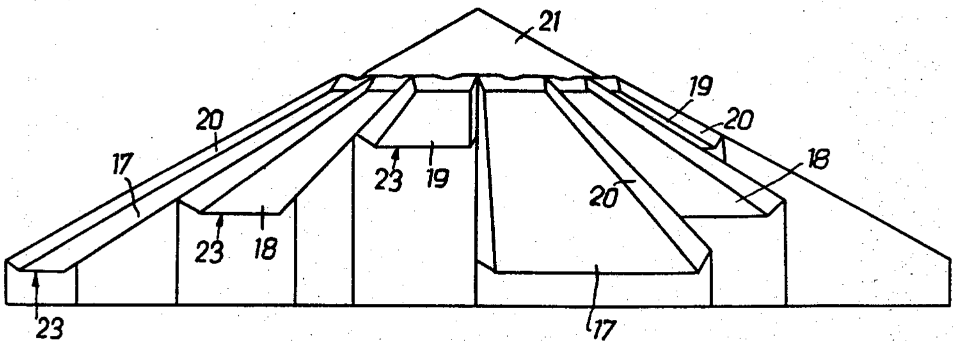


Fig. 2

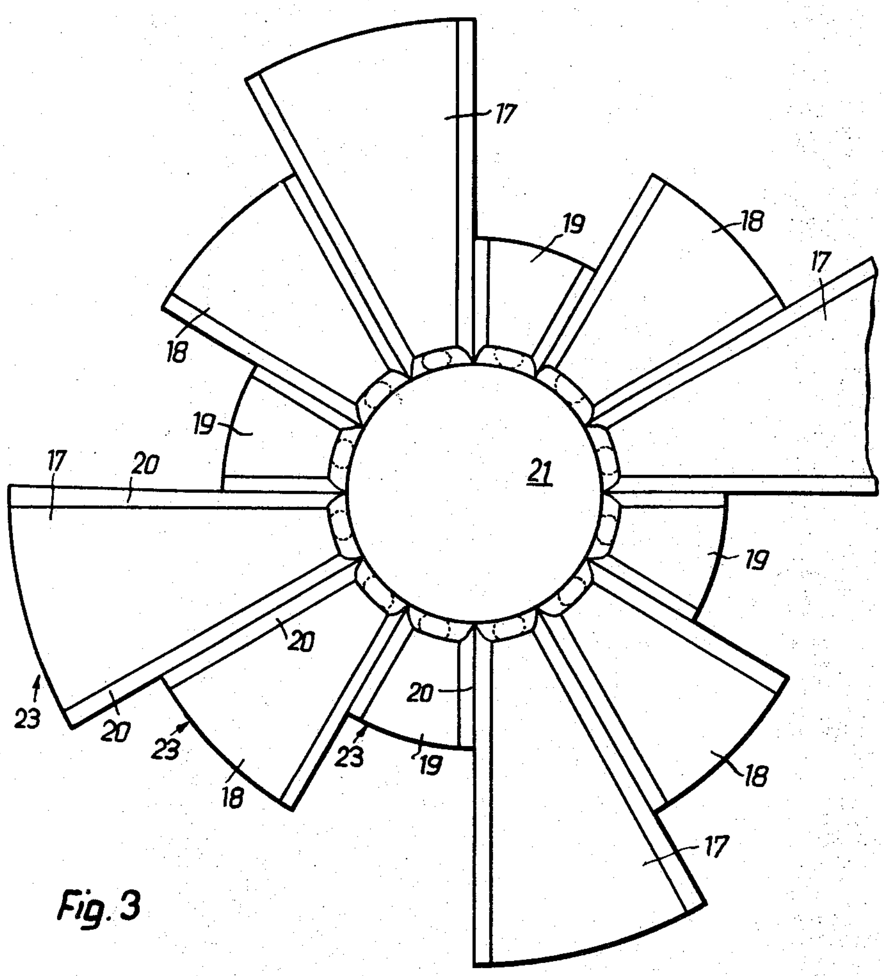


Fig. 3

Inventors:
Fritz Harders
and
Franz Peters

APPARATUS FOR THE CONTINUOUS CASTING OF METAL

This invention relates to apparatus for continuous casting of metal and is a division of U.S. Pat. Application Ser. No. 484,796, filed Sept. 3, 1965, now U.S. Pat. No. 3,399,715 issued Sept. 3, 1968.

In a continuous casting, the temperature distribution when measured at different points of its cross section is so irregular that it is impossible to roll it with the aid of the same heat. On the contrary, the casting must be cut up and re-heated before rolling and in this respect, the continuous casting method has no advantage over ingot casting.

The method of this invention which seeks to obviate this disadvantage has in common with the known continuous casting methods the feature that molten metal is poured into a cooling tower or other chamber from which it passes out at the bottom in the form of a partly solidified bar.

According to the present invention the molten metal on introduction to the cooling chamber or housing is dispersed into individual droplets and these droplets are cooled by a current of gas and combined into a bar at the mouth of the container, the bar being thereupon compressed. By being subdivided into droplets, on cooling of the latter, practically the same temperature is obtained at all points on the cross-section of the metal bar obtained on resolidification.

Having regard to temperature distribution a bar produced in this manner has substantially the same properties as a heated ingot and can therefore be directly subjected to further processing.

Moreover, after passing out from the cooling tower a bar having these properties can be deflected along a horizontal path *i.e.* out of the vertical, with a substantially smaller radius of curvature than is possible in the case of continuous casting. This results from the material being in a plastic condition. This results from the facilitates every type of deformation. The furnaces previously required for re-heating can be dispensed with and the compressed bar can be transferred directly in a continuous movement to a rolling mill, without being divided up.

The method is especially applicable to the continuous casting of steel. In this case the coolant gas is advantageously one which reacts only slightly or not at all with the surface of the steel droplets. Suitable gases have been found to be blast furnace gas, optionally with additions of carbon monoxide and/or hydrogen, as well as water gas, and partly oxidised natural gas. Hydrogen, or a gas which contains large quantities of hydrogen, in addition to carbon monoxide is particularly advantageous for cooling because owing to its high thermal conductivity hydrogen permits particularly rapid and intensive cooling of the droplets of steel. In addition, hydrogen has the advantageous property that although during the cooling of the droplets it dissolves to a certain extent in the latter, as a rule it subsequently separates almost completely from the solid steel.

Blast furnace gas is suitable for cooling the droplets particularly if its high nitrogen content does not result in either any noteworthy absorption of nitrogen, as in the case of unkilled steel, or if absorption of nitrogen is not harmful, as in the case of basic converter steel. Blast furnace gas has the advantage of being cheaper than the above-mentioned gases.

In the case of the continuous casting of steel it is advisable for the degree of cooling of the steel droplets in the cooling tower to be so controlled that, depending on the size of the drops, about 2 to 20 percent of the mass solidifies. It is then advisable for the melt to be broken up into droplets of a size between 0.3 and 10.0 mm, preferably between 1.0 and 6.0 mm, which can be achieved through suitable shaping of the distributor device effecting dispersal and breaking up of the molten metal and by suitable proportioning of the quantity of steel fed per minute. If cooling is effected with a gas not containing hydrogen, the upper limit of droplet size should be of the order of 3.0 mm, while in the case of hydrogen or a cooling gas containing hydrogen the upper limit may be 6.0 mm. With this size and when the above-mentioned cooling gases are used, there is practically no contamination of the steel by oxygen (oxidation) or possibly nitrogen. Unkilled and killed steels may be cast in this manner.

An apparatus suitable for carrying out the method of this invention comprises a cooling tower having at its upper end an inlet for introduction of the melt, a distributor or dispersing device disposed beneath said inlet and composed of refractory material, on to which the melt falls and so arranged that the melt is broken up into individual currents made up of small particles or droplets of molten metal and a discharge outlet at or in passage through which the droplets from the individual currents are re-united to form a compact mass together with connections for cooling gas pipes. The distributor device may consist of a conical deflector the narrow end of which faces the inlet opening and which is sub-divided into sectors having different radial lengths. When a cone of this type is used, it is advisable for the quantity of melt introduced to be such as to provide a layer thickness over the surface of the cone not appreciably in excess of 4 mm.

One embodiment of the invention is diagrammatically illustrated in the accompanying drawings, in which:

FIG. 1 is a longitudinal vertical section of an apparatus suitable for carrying out the method of this invention,

FIG. 2 is a view in elevation, on an enlarged scale of a distributor device such as is used in the apparatus shown in FIG. 1,

FIG. 3 a plan view of the distributor device of FIG. 2.

Referring to FIG. 1 the apparatus comprises a relatively wide cylindrical housing 1 which functions as the cooling tower in the sense originally referred to hereinabove, the tower having at its upper end a relatively narrow inlet opening 3, and at its lower end a wide discharge opening 4, the width of which is a multiple of that of the top opening.

Leading into the housing 1 adjacent its lower end are a number of pipes 5 for the entry of a cooling gas, which discharges through corresponding pipes 6. A relatively short chamber or continuous casting mold 7 is connected to the bottom opening 4 for operation as a cooling jacket, for which purpose it has a hollow wall 7′ into which water enters at 8 and passes out again at 9.

Molten metal is fed to the housing 1 from a ladle 12 traversable over a platform 2 so that it can be run into position above the opening 3, an annular seal 13 if necessary being provided between the platform and the ladle when the latter has been brought into position. Beneath the mouth 14 of the continuous casting mold 7, are independent sets 15 and 16 of rollers.

In alignment with and beneath the opening 3 is a conical diverter plate 10 having its lateral area facing upwards and supported by struts 11. The plate 10, which forms the initially mentioned distributor is composed of refractory material.

In the embodiment illustrated in FIGS. 2 and 3 the cone forming the distributor 10 is divided into a large number of sectors of different radial lengths, a total of 12 such sectors being provided in the example illustrated and having three different lengths, the longest sectors being designated at 17, those of medium length at 18 and the shortest sectors at 19. Each sector is bounded along its radial sides by rims or beads 20, which together with the surface of the sector form a channel. The beads 20 extend from outside to inside as far as the edge of a smooth conical surface 21.

In operation the ladle 12 is brought into position over the opening 3 and after the seal 13 has been made the ladle is opened to allow a casting jet 22 to flow into the container 1 where it impinges on the distributor disc 10. The effect of the disc 10 is to distribute the metal over the individual sectors 17, 18, and 19 and thereby divide it into 12 individual currents, which flow down in a thin layer outwards and over the perimeter 23.

The speed of pouring is controlled, preferably being selected so that the metal layers are not thicker than 4 mm. Under the action of surface tension, the layers at the edge of the distributor break up into drops, which fall through the cooling tower as a broad current or curtain 24.

The cooling gas entering the housing at **5** and leaving at **6** flows in counter-current and under the action of the gas, the drops, which are cooled more or less intensively according to size, collect partly as a pool **25** of still liquid and partly in the plastic state beneath the opening **4**, before finally passing out of the hopper **7** as a solid mass or bar **26**. The cooling action due to the hopper merely serves the purpose of effecting the complete solidification of a thin edge layer of the still uncompressed bar.

The bar **26** consists of drops which at their solidified surfaces become welded to one another. In passage between the two pairs of rolls **15** and **16**, the bar is compressed and has imparted to it the shape of a flat slab. Cavities existing between the drops are closed after this deformation and the gas contained in them passes out in an upwards direction. The bar can then be deflected through 90° and subjected to further processing in a horizontal direction. Further shaping is possible and can readily be performed when the bar is to be rolled out into a sheet. In this case a continuous flow through the subsequent shaping rolls is possible without the bar having to be cut up into individual portions.

It is also possible however to produce billet material and sections if the plastic bar passing out of the hopper **7** is at the outset compressed in two directions perpendicular to one another. The bar can then again be deflected into the horizontal and subjected to further processing. Because of its great plasticity, fewer roll passes are necessary for the profiling than in the case of deformation in the solid condition.

It is known that in order to obtain a homogeneous grain structure in solid steel a degree of deformation in the solid condition of at least 5 to 6 is necessary. For a sheet having a final thickness of say 10 mm this means that it may be deformed in the plastic condition to a thickness of 6 cm. Maintenance of the plastic condition is merely a question of removing heat. It has been found that with a fraction of 20 percent of solid material and 80 percent of liquid substance in the bar passing out of the cooling jacket **7**, and in the case of the conversion of the bar into sheet, the plastic deformation must be completed within a period not substantially exceeding two minutes.

A suitable size of cooling tower has for example a diameter of about 1 metre and a height of 4 metres. Having regard to the time required by the drops to fall, the minimum height should generally be 3 metres. In the upward direction the height is limited by the speed of impingement of the drops.

The casting of killed open hearth steel containing 0.25 percent of carbon, 0.3 percent of silicon, 0.05 percent of phosphorus and 0.05 percent of sulphur will be described as an example. The steel is poured into the container **1** from a ladle having a capacity of 80 tons at a speed of 5 tons per minute. Through the action of the distributor **10**, drops of a size between 0.8 and 5 mm will be produced. The cooling gas used can contain 20 percent of blast furnace gas and 80 percent of a natural gas partly oxidised with oxygen, thus consisting of 2 percent of carbon dioxide, 33 percent of carbon monoxide, 54 percent of hydrogen, remainder nitrogen. The gas is blown in at room temperature. The gas consumption amounts to 240 normal cubic metres per minute and the outlet temperature amounts to about 1000°C. The solidification amounts on the average to 20 percent.

It may be added that other forms of distributor may be used, for example an annular slot or nozzle in which the steel is divided up by a sharp gas current, or a sieve-like structure or else a refractory spray.

We claim:

1. Apparatus for continuous casting of metal comprising a tower having a restricted inlet at its upper end for introduction of the molten metal and a relatively large discharge opening, said tower having inlet and outlet ports for circulatory flow of a coolant gas, means for feeding molten metal through said inlet, distributing means at the upper end of the tower on to which the molten metal falls for dispersing the molten metal as droplets in free fall, said tower including a cooled, tubular discharge section for solidifying the droplets and causing them to reunite prior to issuing from the discharge opening as a solid mass.

2. Apparatus as claimed in claim **1**, in which the distributing means comprises a plate of conical formation.

3. Apparatus as claimed in claim **2**, in which the mass of metal on discharge from the bottom of the tower is subjected to pressure by passage through at least one pair of rollers.

4. Apparatus as claimed in claim **2**, comprising a conical distributor sub-divided into sectors of varying radial length.