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## (54) Stopper rod

(57) The invention relates to a stopper rod for controlling the flow of molten metal from a metallurgical vessel like a tundish. The stopper having a gas channel (22) which is larger than the distance defined by a straight line between its ends (22i,22o).

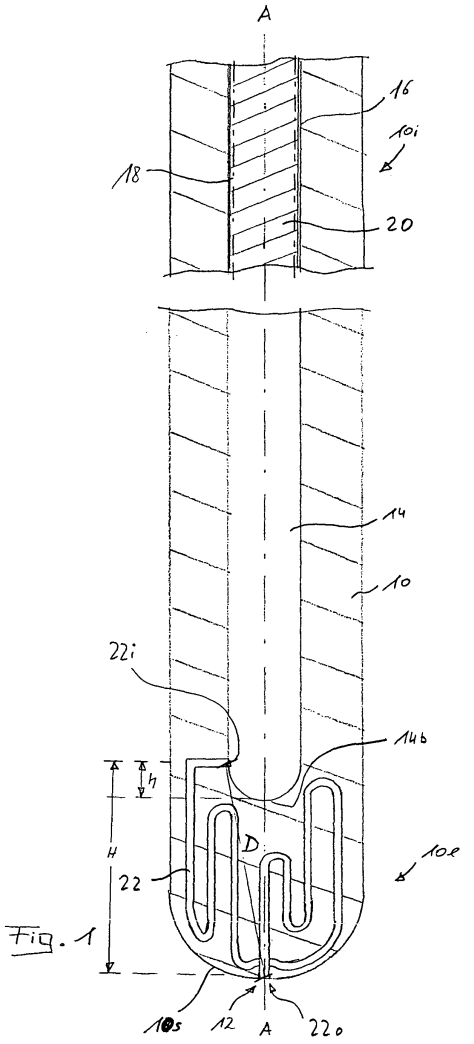


Fig. 1

EP 1 736 260 A1

## Description

**[0001]** The invention generally relates to a stopper for controlling the flow of molten metal from a metallurgical vessel like a tundish. Any references made hereinafter, relating to the design, construction and/or function of the stopper, refer to the typical use position of such stopper, i.e. a vertical oriented position.

**[0002]** It is well known in steel casting to employ such a stopper device, which in several cases is a one-piece refractory stopper rod, having a so called "nose position" at its lower end, means for fixing a metal rod at its upper end and being moved vertically by a lifting mechanism in order to close or vary the cross-sectional area of an outlet opening of the corresponding metallurgical vessel.

**[0003]** Further details of the general stopper design and its fixing means to the lifting mechanism are described, i.a. in EP 0 358 535 B2 as well as the prior art cited in said European patent. Thus the corresponding disclosure is made part of the disclosure of this description.

**[0004]** Stoppers of the kind described have also been used to introduce a gas, often an inert gas, such as argon, into the molten steel. These gases are injected into the metallurgical melt to improve its quality by, i.a., providing a floatation means for non-metallic inclusions in the melt.

**[0005]** EP 1 401 600 B1 discloses such mono-block stopper adapted to deliver gas during pouring of molten metal. Said stopper has a bore connecting an internal chamber (running coaxial to the longitudinal axis of said stopper rod) and a gas discharge port at the lowermost end of the stopper rod, being part of the nose portion of the stopper. There exists a risk that, during the casting operation, the gas flow introduced to the stopper will not be enough to equal or exceed the extraction potential of a vacuum created at the stopper nose by the flowing steel, the so called "water pump effect".

In this case the vacuum at the stopper tip will pull all the supplied inert gas from within the stopper bore and feed system, creating an under-pressure within the system.

If there are any imperfect joints in the system air will be sucked in to satiate this under-pressure and then be injected into the steel flow at the stopper tip. This is the point where it will have maximum detriment to both the cast steel quality and the operational stability of the casting process.

It is not possible to increase the feed rate of the inert gas to exceed the extraction potential of the "water pump effect" as this will create unacceptable quality problems such as excessive turbulence in the mould, entrapment of inclusions, or "pin holes" in solidified steel products.

**[0006]** Calibrating means are shown in EP 1 401 600 B1, namely a rod with one or more axially-extending gas passages, which means are provided in said bore to offer a predetermined resistance to flow. The rod must be implemented in the stopper design, thereby extending above the lower floor of the internal chamber. In practice it is very difficult to predetermine the resistance to flow and to manufacture a corresponding stopper. Extra process steps are necessary to introduce the rod into the part finished stopper and there are associated difficulties of ensuring both an effective fixing and gas tight joint to avoid changes in restriction behaviour in operation.

**[0007]** Therefore an object of the present invention is to provide a stopper device of the kind described before which is easy to produce and provides effective means for the transport and ejection of a suitable gas.

**[0008]** The invention is based on the general idea of introducing a restricted channel for inert gas flow within the stopper to provide a predetermined overpressure which will prevent a vacuum created at the stopper tip under any combination of service conditions being transferred to the stopper bore and gas feed system. The predetermined overpressure characteristic will be dependant on

a) the gas-flow (amount/pressure) provided externally
b) the length of the gas channel,
c) the cross section of said gas channel,
d) the arrangement of the gas channel within the stopper body.

**[0009]** Investigations to establish the preferred gas purging performance have shown that gas channels below a certain diameter are not capable of providing a consistent resistance through an operational sequence due to risks of either blockage by debris from within the system, or by small changes associated with the thermo mechanical character of the ceramic materials creating a significant change in section at operating temperatures. Restrictor channels less than 1 mm in diameter have been shown to have increased risk of such variable performance. It has been found that channels greater than 1 mm in diameter minimise these risks.

**[0010]** It has further been found that resistance is depending from the wall friction effects which result from the channel length and its corresponding surface conditions.

**[0011]** It has been found that the length of a corresponding gas channel must be significantly larger than the "thickness" of the refractory material in the corresponding area and/or its wall sections should provide a more or less rough surface at least sectionally.

**[0012]** In its most general embodiment the invention relates to a stopper rod for flow control of molten metal from a metallurgical vessel, comprising:

- an elongated body with a longitudinal axis (A) and made of a refractory ceramic material,
- a bore hole, extending from an upper surface of said body towards its opposite lower end and ending at a distance to an outer surface of said lower end of said body,
- at least one gas channel, having a cross-sectional area which is smaller than that of the average cross-

sectional area of the bore hole and extending from a lower end of the bore hole to at least one outer surface section at the lower end of the body, whereby

- the length of said gas channel is larger than the distance defined by a straight line between its ends.

**[0013]** The restricted channel within the stopper creates a predetermined overpressure within the stopper bore and feed system at the desired gas throughput rates. This predetermined overpressure must ensure that any vacuum established at the stopper tip during casting by the "water pump effect" will not be able to overcome the resistance of the said channel and draw all the supplied gas from the system.

**[0014]** The degree of restriction and predetermined overpressure of the stopper system must therefore be matched to actual casting conditions and the geometrical configuration of both the stopper tip and nozzle throat, which may actually change during a cast sequence.

**[0015]** Along the bore hole, (mostly along its open upper end) which favouritely is arranged coaxially to the longitudinal axis of the stopper body, the above-mentioned fixing means are arranged, which fit with corresponding means of a metal rod inserted with one end into said bore hole and fastened with its other end to the said lifting mechanism.

**[0016]** The bore hole, also in general referred to as an internal chamber, and any means inserted therein are designed in such a way as to allow a gas like an inert gas to pass along the length of said bore hole and to enter the gas channel, which extends from the lower end of the bore hole to the lower surface area of the refractory stopper device.

**[0017]** The length of said gas channel may be at least two or three times the length of the corresponding shortest distance between its inlet and outlet end or as the distance between its ends in the direction of the longitudinal axis of the rod respectively.

**[0018]** This includes a design, according to which the length of the gas channel is between 5 and 30 times greater than one of the distances as defined before. There may be 2 or more gas channels provided.

**[0019]** To provide a corresponding long channel within a refractory ceramic stopper section of limited size the channel may be designed for example in a helical manner or in a meander like manner respectively. All other designs may be used as far as the channel length follows the above-mentioned formula.

**[0020]** The channel may be provided by any suitable material which burns off during increased temperature treatment especially during sintering of the refractory stopper. As an example: A plastic helical shape is integrated in an isostatic pressure device, which device is then filled with a suitable ceramic material, surrounding the said shape. After processing and remoulding the prefabricated stopper is sintered. At this time the plastic helical shape burns off and provides the desired helical gas channel. Obviously the said gas channel may as well be provided by a prefabricated pipe of a corresponding design.

**[0021]** The gas channel may be arranged so that it enters the bore hole at a distance from the lowermost end (floor) of the bore hole. This not only increases the distance to the lower free end of the stopper rod but avoids any danger of blockage by solid materials entering the gas channel (debris).

**[0022]** Typically the channel starts between 10 to 100 mm above the bottom end of the bore hole, but this may be different for specific uses.

**[0023]** According to one embodiment the gas channel may provide an average cross-sectional area of between 0,5 and 4 $mm^2$. The gas channel may have nearly any shape. Its cross-sectional area, perpendicular to the gas flow, may define a circle, a triangle, a square or it may be rectangular for example.

**[0024]** The at least one gas channel may be arranged at least partly within or around a refractory shaped part positioned within or affixed to said body. For example the channel may be designed within or on the surface of a refractory shaped part arranged along a corresponding opening of the stopper or the refractory body respectively. This separate part may be fixedly secured to the refractory body, e.g. by screwing, bolts or the like. The shaped part can as well be fixed to the body by a mortar or an adhesive. This part may be an isostatically pressed part, unfired or fired. The channel may be provided within said part, on its surface and/or by a groove in the corresponding body area.

**[0025]** As already mentioned above the cross-sectional area of the gas channel may vary along its length. For example it may be enlarged at certain intervals along its length. This increases the backpressure and avoids any danger of interruption of gas flow. The gas channel may be provided with protrudings, making the gas passage smaller or/and with recesses, enlarging the gas passage. Protrusions and recesses may be discrete ones. They may extend like a ring around the gas passage area. They may have any design. They may follow the regular wall portions by sharp edges or smooth corners (or intermediate sections respectively).

**[0026]** According to one embodiment the total length of a gas channel between its inlet and outlet end is between 50 and 1.000 mm. While its orientation, inclination, shape and cross section may vary as described above one embodiment provides a design according to which the gas channel extends along the longitudinal axis of the body from the lower most surface section of the body into said body. In other words: The very last end of the gas channel (in the direction of gas flow) is parallel and coaxial to the longitudinal axis of the stopper rod. Together with a typically rotational symmetry of the whole stopper device this enables a central gas flow into the outlet nozzle and thus optimized flow conditions and an optimized treating effect of the melt. As an alternative the gas channel may be provided with 2 or more outlet ends.

**[0027]** In the following example shows the effect of the

inventive design. Starting from a stopper design as for Fig. 1 of EP 0 358 535 B2 and a constant applied gas pressure and flow rate, there is an increase in the resultant internal system pressure of 0,3 bar when the gas channel 12 is redesigned from the original, having a diameter 1,4 mm and length 100 mm, to a one having the same 1,4 mm diameter but a length of 400 mm.

**[0028]** Two embodiments of the invention will now be described by way of examples with reference to the companying drawings in which figures 1 and 2 are schematic views of different parts of two stoppers according to different embodiments of the invention. In both figures the rods are shown in a vertical cross-sectional view.

**[0029]** In figure 1 reference 10 depicts a refractory ceramic body, shaped as a rod. Its longitudinal axis is marked A-A.

**[0030]** The lowermost end of the stopper is marked by reference numeral 12. This is part of a lower end 101, the so called nose portion of the stopper. At a distance above 12 (here: about 80 mm) a bore hole 14 (here: with a diameter of about 40 mm) extends up to the upper end of the stopper, which upper end being conventional in its design and not shown.

**[0031]** Between the upper end and lower part 101 of the stopper body 10 there is provided an intermediate section 10i, along which the bore hole 14 is provided with a threaded wall 16, which fits a corresponding outer thread 18 of a metal rod 20, inserted into said bore hole 14 to fixedly secure the stopper 10 to a corresponding lifting mechanism.

**[0032]** At a distance (h) from a bottom end 14b of bore hole 14 a gas channel 22 starts with its inlet port 22i. On its way to its outlet port 22o at the lowermost body portion 12 gas channel 22 is designed in a meander like manner as schematically shown in figure 1. By this meander like design the channel length is increased characteristicly compared with the axial distance H (along the longitudinal axis A) between inlet port 22i and outlet port 22o or compared with the straight distance between inlet port 22i. and outlet port 22o, marked by "D" in figure 1. While "D" or "H" respectively vary between 60 and 100 mm in typical stopper rods, the total length of the gas channel 22 will be - in accordance with the invention - typically between 120 and 1000 mm, but may be even more.

**[0033]** Figure 2 shows one (lower) end, in particular the nose portion of an alternative configuration according to the invention, for which the main differences will be discussed hereinafter. Instead of a meander like design the gas channel 22 is arranged in a helical like manner and ends in a slightly enlarged end portion 22o, which is again coaxial with a longitudinal axis A so as to avoid or minimize any turbulences in the metal melt when the said stopper is arranged coaxially above a corresponding outlet nozzle.

**[0034]** Again by means of the helical design of gas channel 22 its length will be significantly greater than the axial distance from its inlet and outlet positions, 22i and 22o. The resistance to flow of any gas passing along the gas channel 22 will be increased accordingly, allowing the potential problems associated with unrestricted gas flow and vacuum effects during operation to be avoided.

**[0035]** Figure 3 shows the lower end 101 of a stopper, which nose portion comprises a separate shaped part 30, screwed into a corresponding opening 32 of the nose portion. Part 30 comprises a helically arranged gas channel 22 with its inlet end 22i in fluid connection to bore hole 14 and its outlet end 22o ending in the outer surface 10s of stopper 10 at its lower most end. Channel 22 may also be provided between the corresponding surfaces of part 30 and body 10 as indicated by dotted lines 23 by depressions in either or both surfaces.

## Claims

1. Stopper rod for flow control of molten metal from a metallurgical vessel, comprising

   a) an elongated body (10) with a longitudinal axis A and made of a refractory ceramic material,
   b) a bore hole (14), extending from an upper surface of said body towards its opposite lower end (101) and ending at a distance to an outer surface (10s) of the lower end (101) of said body (10),
   c) at least one gas channel (22), having a cross-sectional area which is smaller than that of the average cross-sectional area of the bore hole (14) and extending from a lower end (14b) of the bore hole (14) to at least one outer surface section at the lower end (101) of the body (10), whereby
   d) the length of said gas channel (22) is larger than the distance defined by a straight line between its ends (22i, 22o).

2. Stopper rod according to claim 1, wherein the length of the gas channel (22) is between 5 and 30 times greater than the distance defined by a straight line between its ends (22i, 22o).

3. Stopper rod according to claim 1, wherein the gas channel (22) is arranged in a helical manner.

4. Stopper rod according to claim 1, wherein the gas channel is arranged in a meander like manner.

5. Stopper rod according to claim 1, wherein the gas channel (22) enters the bore hole at a distance from the lower most end (14b) of bore hole (14).

6. Stopper rod according to claim 5, wherein the said distance is between 20 and 200 mm.

7. Stopper rod according to claim 1, wherein the gas channel provides an average cross-sectional area

of between 0,5 and 4 $mm^2$.

**8.** Stopper rod according to claim 1, wherein the cross-sectional area of the gas channel (22) varies along its length.

**9.** Stopper rod according to claim 1, wherein the gas channel (22) has a total length between 50 and 1.000 mm.

**10.** Stopper rod according to claim 1, wherein the gas channel (22) extends along the longitudinal axis A of the body from the lowermost surface section (12) of the body (10) into said body (10).

**11.** Stopper rod according to claim 1, wherein the at least one gas channel (22) is arranged at least partly within or around a refractory shaped part (30) positioned within and/or affixed to said body (10).

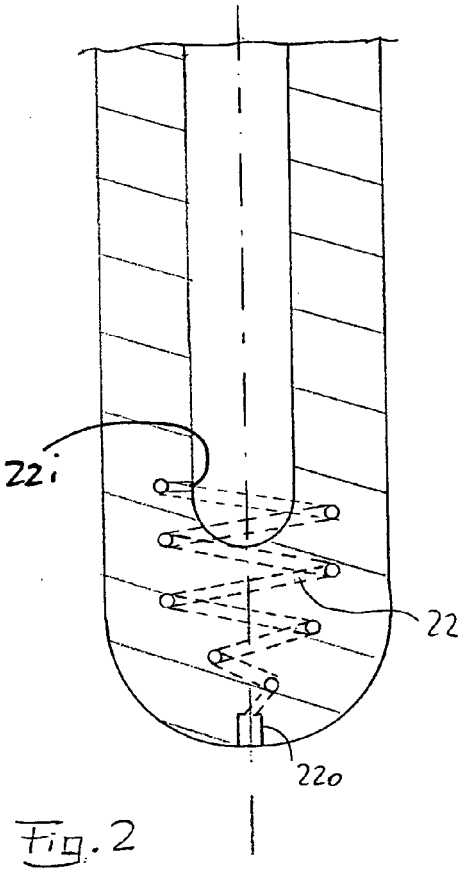


Fig. 2

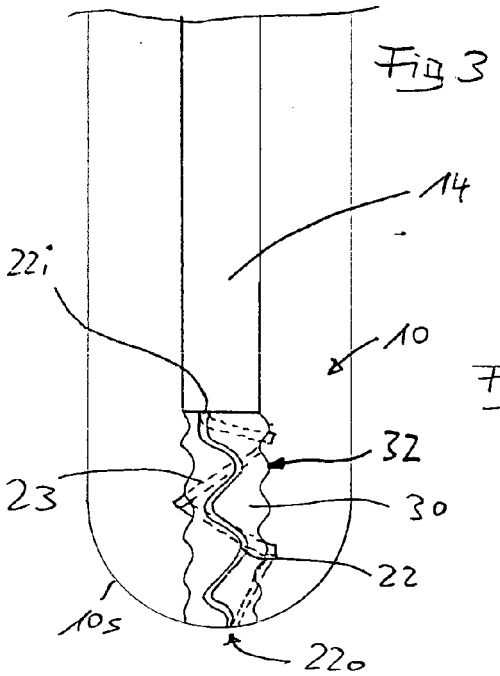


Fig 3

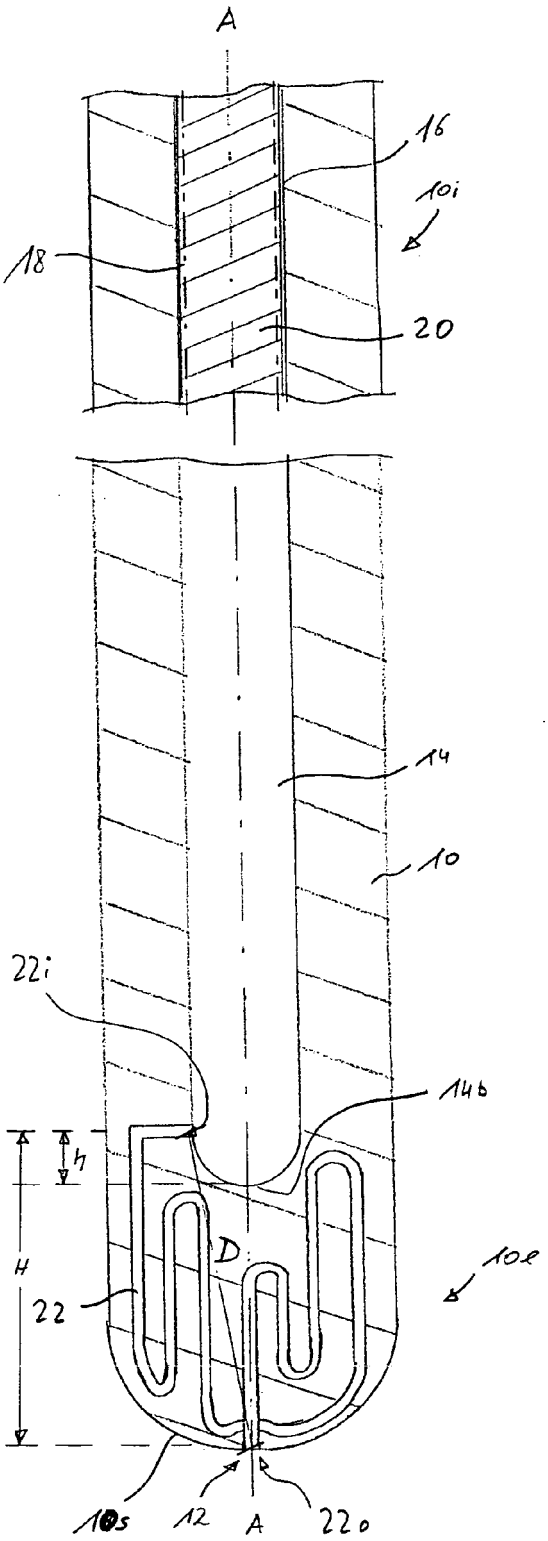


Fig. 1

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# EUROPEAN SEARCH REPORT

Application Number
EP 05 01 3320

## 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) |
|---|---|---|---|
| Y,D | EP 1 401 600 B (VESUVIUS CRUCIBLE COMPANY) 31 March 2004 (2004-03-31)<br>* figures 1-4 *<br>* paragraphs [0001], [0004], [0013] *<br>----- | 1-11 | B22D41/18 |
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B22D
F27D
C21C

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 3 October 2005 | Scheid, M |

CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 01 3320

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03-10-2005

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## REFERENCES CITED IN THE DESCRIPTION

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