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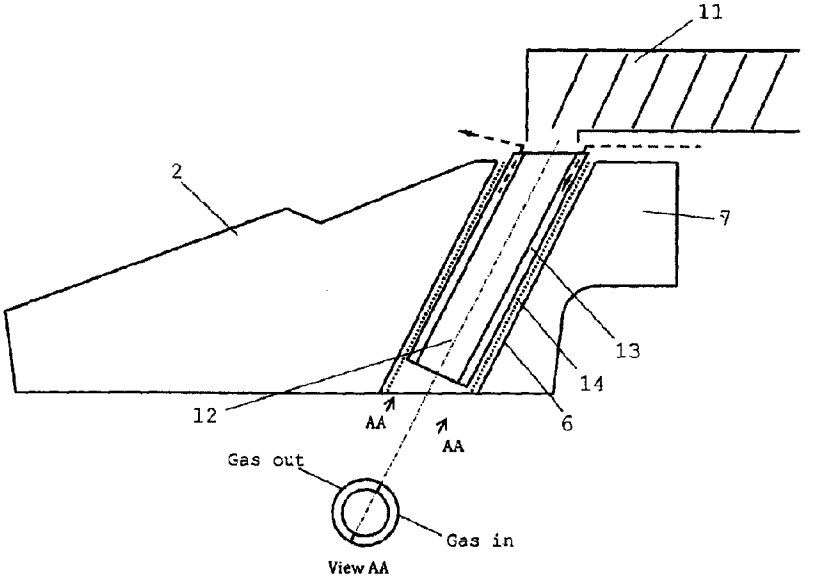
(54) Titre : PROCESSUS DE COULEE CONTINUE DE METAL
(54) Title: CONTINUOUS CASTING PROCESS OF METAL



(57) Abrégé/Abstract:
The present invention relates to a continuous casting process of a steel semi-product comprising: - a step of casting using a hollow jet nozzle located between a tundish and a continuous casting mould, said nozzle comprising, in its upper part, a dome for deflecting a liquid metal arriving at an inlet of said nozzle towards an internal wall of the nozzle, thus defining an internal volume with no liquid metal, - a simultaneous step of injection of powder through a hole of the dome, said powder having a particle size inferior to 200 µm and said dome comprising first means to inject said powder without any contact with said dome, said first means comprising a hollow body, and second means to avoid sticking or sintering of said powder onto said first means.

ABSTRACT

CONTINUOUS CASTING PROCESS OF METAL

The present invention relates to a continuous casting process of a steel semi-product comprising:

- a step of casting using a hollow jet nozzle located between a tundish and a continuous casting mould, said nozzle comprising, in its upper part, a dome for deflecting a liquid metal arriving at an inlet of said nozzle towards an internal wall of the nozzle, thus defining an internal volume with no liquid metal,
- a simultaneous step of injection of powder through a hole of the dome, said powder having a particle size inferior to 200 µm and said dome comprising first means to inject said powder without any contact with said dome, said first means comprising a hollow body, and second means to avoid sticking or sintering of said powder onto said first means.

CONTINUOUS CASTING PROCESS OF METAL

[0001] The invention relates to a continuous casting process. In particular, the invention relates to a continuous casting process, called Hollow Jet Casting, in which powder is injected into a hollow jet of metal. The term metal will be understood in the rest of the text as including pure metals or metal alloys.

[0002] The continuous casting of steel is a well-known process. It consists in pouring a liquid metal from a ladle into a tundish intended to regulate the flow and then, after this tundish, in pouring the metal into the upper part of a water-cooled bottomless copper mould undergoing a vertical reciprocating movement. The solidified semi finished product is extracted from the lower part of the mould by rollers. The liquid steel is introduced into the mould by means of a tubular duct called a nozzle placed between the tundish and the mould.

[0003] Document EP 0 269 180 B1 describes a specific continuous casting process called "Hollow Jet Casting" in which the liquid metal is poured onto the top of a dome made of a refractory material. The shape of this dome causes the metal to flow towards its periphery, the flow being deflected towards the internal wall of the nozzle or of an intermediate vertical tubular member. Said intermediate vertical tubular member can be a copper tube cooled by a water jacket and topped by a refractory ring. What is thus created, in the central part of the nozzle

beneath the tundish member, is a volume without any liquid metal within which it is possible to carry out additions via an injection channel. The device thus described is referred to as a "Hollow Jet Nozzle (HJN)".

[0004] A powder can be injected in the center of the hollow jet created by the refractory dome. This injection technique is disclosed in the document EP 0 605 379 B1. This powder injection aims to create an additional cooling of the liquid steel by the melting of the metallic powder or to modify the composition of the steel during casting by addition of other metallic elements such as ferro-alloys. As disclosed in document EP 2 099 576 B1, the powder can be transported via a mechanical screw feeder and is fed by gravity in a hole going through the refractory dome. Generally, the hole goes through one of the support arms of the dome intended for securing the dome to the vertical tubular member.

[0005] However problems occur when powder with a size range inferior to 200 µm is injected. Indeed after a short time injection means are plugged and injection cannot be longer performed.

[0006] The invention aims to provide a continuous casting process in which plugging of the powder injection means is avoided and powder can be injected during the full casting sequence.

[0007] The present invention discloses a continuous casting process of a steel semi-product comprising:

- a step of casting using a hollow jet nozzle located between a tundish and a continuous casting mould, said nozzle comprising, in its upper part, a dome for deflecting a liquid metal arriving at an inlet of said nozzle towards an

internal wall of the nozzle, thus defining an internal volume with no liquid metal,

- a simultaneous step of injection of powder through a hole of the dome, said powder having a particle size inferior to 200 µm and said dome comprising first means to inject said powder without any contact with said dome, said first means comprising a hollow body, and second means to avoid sticking or sintering of said powder onto said first means.

[0008] In further embodiments, taken alone or in combination the process may also comprise the following features:

- second means are able to apply mechanical stresses to the powder particles in contact with said hollow body;
- said hollow body comprises a double wall in which gas is circulating;
- said gas is nitrogen;
- a powder feeder is partly disposed in the hollow body;
- the powder feeder goes through a support arm of the dome;
- said second means comprise means for rotating the hollow body about its longitudinal axis;
- said second means comprise means for vibrating the hollow body inside the hole;
- said means for vibrating the hollow body comprise a mechanical vibrator or an ultrasound vibrator;
- an insulating layer is disposed inside the hole between the dome and the hollow body to create a thermal barrier;
- said insulating layer comprises ceramic fibers;
- said hollow body is a tube with a circular section;
- the inner diameter of said tube ranges from 8 to 30 mm.

[0009] The present invention also discloses a continuous casting apparatus for continuously casting a steel semi-product, the continuous casting apparatus comprising a hollow jet nozzle located between a tundish and a continuous casting mould, said nozzle comprising, in its upper part, a dome for deflecting a liquid metal arriving at an inlet of said nozzle towards an internal wall of the nozzle, the dome comprising a hole for injecting a powder in the liquid metal deflected by the dome, the dome further comprising first means to inject said powder without any contact with said dome, said first means comprising a hollow body, and second means to avoid sticking or sintering of said powder onto said first means.

[0010] Other features and advantages of the invention will become apparent on reading the following detailed description given solely by way of non limitative example, with reference to the appended figures in which:

- Figure 1 represents a section view of a continuous casting equipment as previously referred as hollow jet nozzle according to the prior art.
- Figure 2 represents a section view of the dome according to a first embodiment of the invention. Figure 2 also represents a section view A-A of the injection tube.
- Figure 3 represents a section view of the dome according to a second embodiment of the invention.
- Figure 4 represents a section view of the dome according to a third embodiment of the invention.
- Figure 5 represents a section view of the dome according to a fourth embodiment of the invention.

Legend:

(1) Tundish
(2) Refractory dome
(3) Copper tube
(4) Water cooling jacket
(5) Refractory ring
(6) Hole
(7) Support arm
(8) Submerged entry nozzle
(9) Mould
(10) Powder container
(11) Powder feeder
(12) Hollow body
(13) Double wall
(14) Insulating layer
(15) Vibration means

[0011] The invention relates to a continuous casting process in which a flow of liquid metal is poured from a tundish into a ingot mould through the hollow jet nozzle (HJN). A hole is made through the dome 2 of the HJN, and in particular through one of the support arm 7 of the dome 2, to allow the injection of powder in the melt, as already known from the prior art.

[0012] During the injection, the metallic powder flowing through the hole is in direct contact with the refractory dome that is at a very high temperature (up to 1200°C). Inventors have discovered that despite the very short contact time between the particles and the refractory material, it is sufficient to gradually stick the particles together and to sinter them. A cluster of sintered powder is then formed after some minutes of casting and can lead to the

full plugging of the powder injector. For example, an injection hole of 20 mm diameter is fully plugged after about 10 minutes of casting when using an iron powder with a size range between 100 and 180 µm.

[0013] With particles powder of a size superior to 200 µm, said problem does not occur, as particles do not stick together in the lapse of time during which they are in direct contact with the refractory dome.

[0014] According to the invention, first means are provided to prevent a direct contact between the dome 2 at high temperature (approximately between 1000 and 1300°C) and the powder during injection. Said first means comprise a hollow body 12 extending inside the hole 6 of the dome 2, the powder being injected inside the hollow body 12 during casting. This hollow body 12 may have any suitable shape as long as it creates a physical barrier between the dome 2 and the powder. For example, as illustrated in figure 2 to 5 for different embodiments of the invention, the hollow body may be a tube with a circular section; it can be made of a refractory material or metal such as low carbon steel. The inner diameter of said tube depends on the powder flow rate to be injected and can, for example, range from 8 to 30 mm for a powder flow rate between 1 and 7 kg/min.

[0015] In addition to said first means, second means are provided for preventing the sticking and sintering of the powder inside the hollow body. They are described in figures 2 to 5 in different embodiments. These second means according to the different embodiments allow reducing the surface temperature of the inner wall of the hollow body 12 and thereby reducing the heating of the powder.

[0016] In a first embodiment of the invention as illustrated in figure 2, said hollow body 12 has a double wall 13 cooled by gas. The gas inlet and outlet in the double wall 13 are respectively illustrated by dashed arrows in figure 2. The external and internal walls can have, for example, a thickness of 2 mm and the thickness of the gas film in the double wall can be of about 1.5 mm. The gas can be nitrogen or any other suitable gas and circulates usually in the double wall with a flow rate ranging from 10 to 30 m^3/h. In a preferred embodiment said gas circulates in closed loop in order to avoid any gas injection inside the nozzle which could disturb the liquid steel flow and the good working of the casting equipment. In addition to this gas cooling, the hollow body 12 can also be wrapped in an insulating layer 14 to create a thermal barrier between the hollow body 12 and the refractory dome 2. The continuous casting equipment can also be provided with means for measuring the temperature and the gas flow rate at the inlet and outlet of the cooling device.

[0017] In figure 2, the powder feeder 11, which is preferably a screw feeder, is disposed above the dome 2. In another embodiment the hollow body 12 has the shape of a bent tube and the powder feeder 11 is partly located into said hollow body 12 inside the dome 2. As illustrated in figure 3 the hollow body 12 with a shape of the bent tube can also goes through a support arm 7 of the dome 2 and the powder feeder 11 is partly located into said hollow body 12 and goes through said support arm 7. This configuration allows gaining space to reduce the size of the equipment.

[0018] Trials performed with a casting equipment according to this first embodiment of the invention and with

injection of powder having particles size ranging between 100 and 200 µm have shown a drastic improvement of the duration of the injection without any plugging problem.

[0019] In another embodiment of the invention as illustrated in figure 4, the hollow body 12 is rotary mounted about the longitudinal axis of the hole. The rotation of the hollow body 12 allows creating shear stresses on the particles in order to avoid their possible sintering or sticking on the hollow body 12 and to obtain a cooling of the hollow body 12 by the heat exchange between this latter and the powder. The hollow body 12, as illustrated in figure 4, is a double wall hollow body as previously described, but in another embodiment, not illustrated, it could be a single tube without gas circulation. As in the previous embodiments, said hollow body 12 can be isolated from the refractory dome 2 by an insulating layer 14.

[0020] In another embodiment of the invention as illustrated in figure 5, the hollow body 12 is mounted in such a way that it may vibrate in the hole. The vibration applied to the hollow body 12 allows avoiding the formation of powder clusters inside the hollow body. The vibration can be generated by a mechanical vibrator, by ultrasounds or by other adequate means 15 creating high frequency vibrations, between 50 and 500HZ. The hollow body 12 can also be wrapped with an insulating layer 14 to reduce the inner surface temperature of the hollow body 12.

[0021] In this embodiment the powder feeder 11 is located above the dome 2 but in another embodiment, not illustrated, it could be located into the hollow body 12 having a shape of a bent tube.

[0022] For all embodiments, the insulating layers can be made up of ceramic fibres which are resistant to high temperatures, such as 1300°C.

[0023] The powder used for injection can be of any type, i.e. metallic or ceramic, or a mixture of different powder types.

CLAIMS

1. Continuous casting process of a steel semi-product comprising:

- a step of casting using a hollow jet nozzle located between a tundish and a continuous casting mould, said nozzle comprising, in its upper part, a dome for deflecting a liquid metal arriving at an inlet of said nozzle towards an internal wall of the nozzle, thus defining an internal volume with no liquid metal,

- a simultaneous step of injection of powder through a hole of the dome, said powder having a particle size inferior to 200 µm and said dome comprising first means to inject said powder without any contact with said dome, said first means comprising a hollow body, and second means to avoid sticking or sintering of said powder onto said first means.

2. Continuous casting process according to claim 1 wherein second means are able to apply mechanical stresses to the powder particles in contact with said hollow body.

3. Continuous casting process according to any one of claims 1 to 2 in which said hollow body comprises a double wall in which gas is circulating.

4. Continuous casting process according to claim 3 in which said gas is nitrogen.

5. Continuous casting process according to any one of claims 1 to 4, wherein a powder feeder is partly disposed in the hollow body.

6. Continuous casting process according to claim 5, wherein the powder feeder goes through a support arm of the dome.

7. Continuous casting process according to any one of claims 1 to 6 in which said second means comprise means for rotating the hollow body about its longitudinal axis.

8. Continuous casting process according to any one of claims 1 to 7 in which said second means comprise means for vibrating the hollow body inside the hole.

9. Continuous casting process according to claim 8 in which said means for vibrating the hollow body comprise a mechanical vibrator or an ultrasound vibrator.

10. Continuous casting process according to any one of claims 1 to 9 in which an insulating layer is disposed inside the hole between the dome and the hollow body to create a thermal barrier.

11. Continuous casting process according to claim 10, wherein said insulating layer comprises ceramic fibers.

12. Continuous casting process according to any one of claims 1 to 11, wherein said hollow body is a tube with a circular section.

13. Continuous casting process according to claim 12, wherein the inner diameter of said tube ranges from 8 to 30 mm.

14. Continuous casting apparatus for continuously casting a steel semi-product, the continuous casting apparatus comprising a hollow jet nozzle located between a tundish and a continuous casting mould, said nozzle comprising, in its upper part, a dome for deflecting a liquid metal arriving at an inlet of said nozzle towards an internal wall of the nozzle, the dome comprising a hole for injecting a powder in the liquid metal deflected by the dome, the dome further comprising first means to inject said powder without any contact with said dome, said first means comprising a hollow body, and second means to avoid sticking or sintering of said powder onto said first means.

PRIOR ART

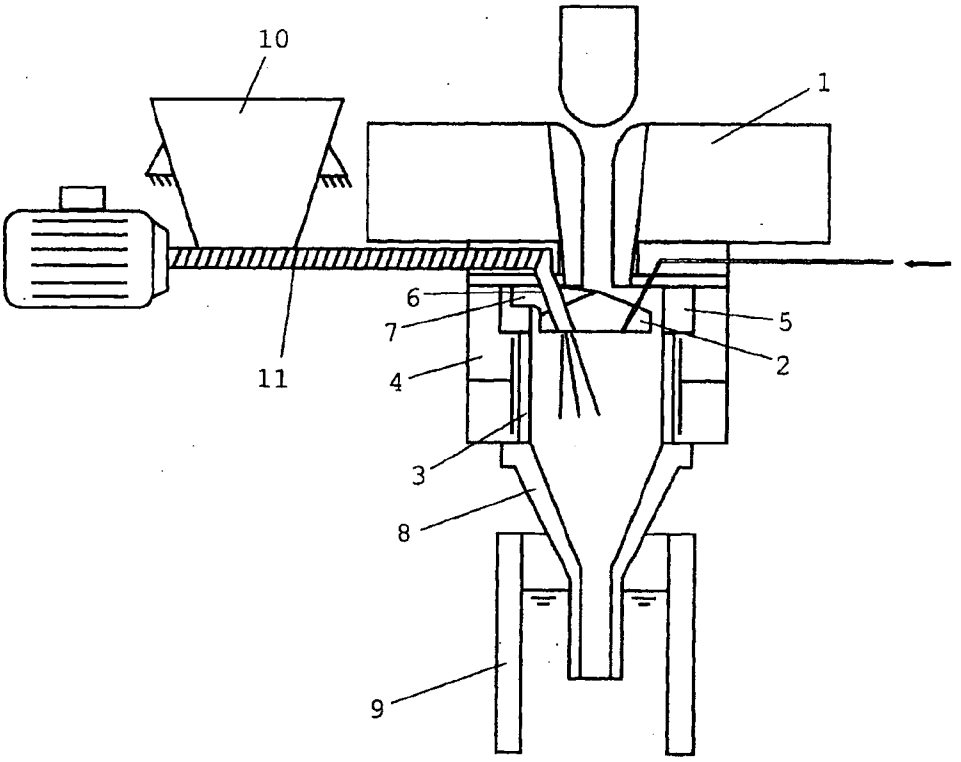


FIG.1

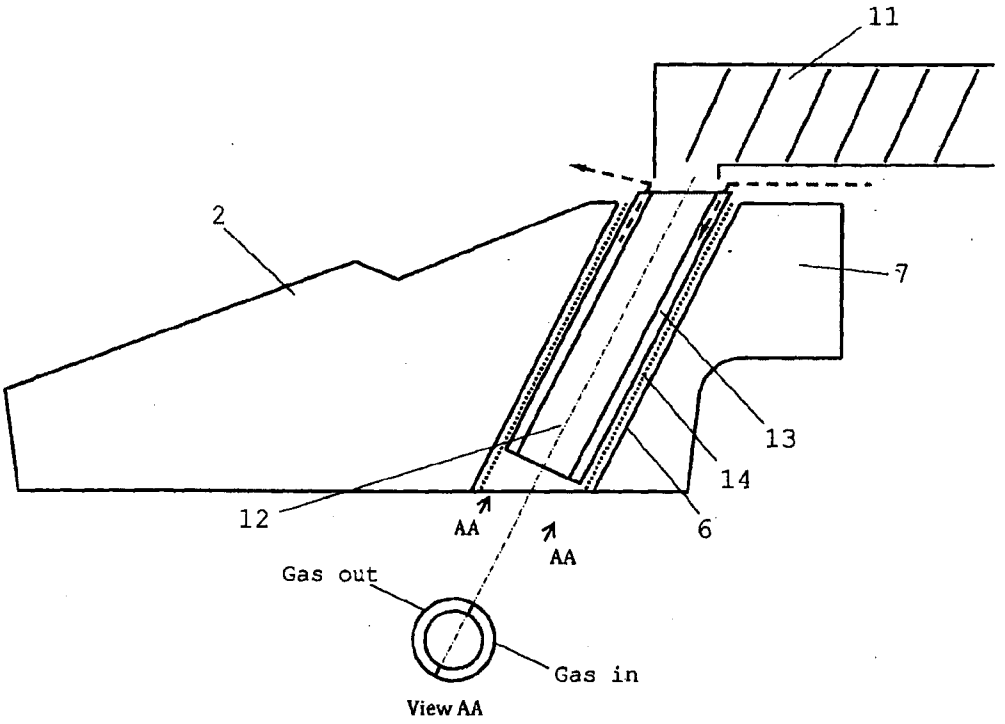

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FIG.2

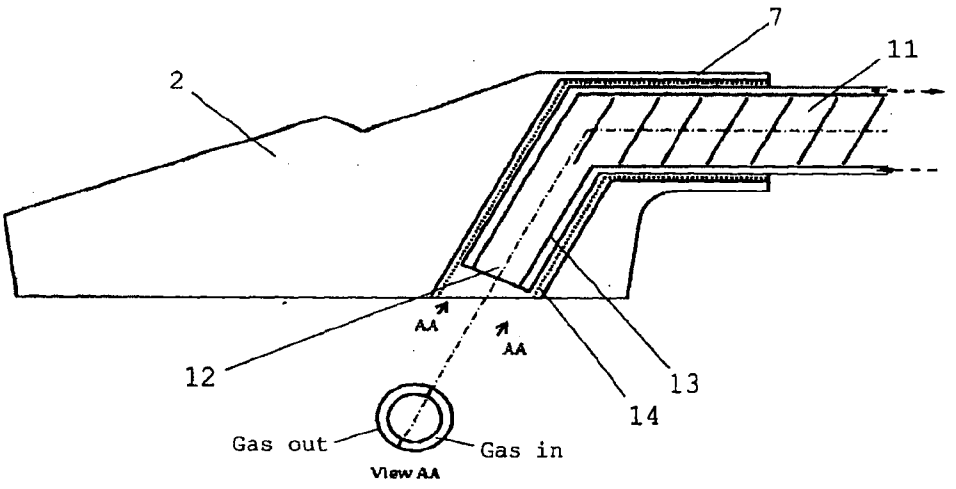
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FIG.3

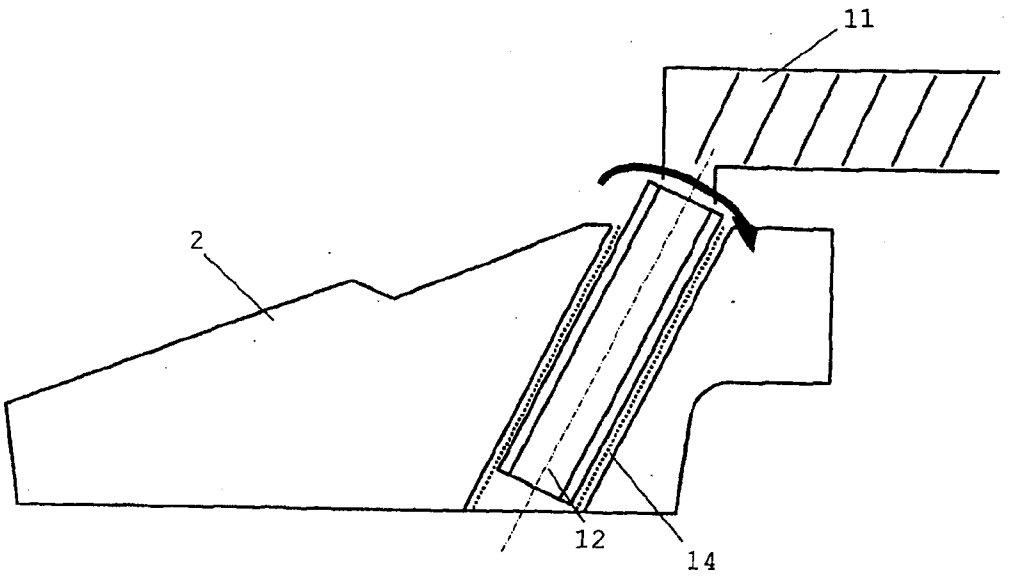


FIG.4

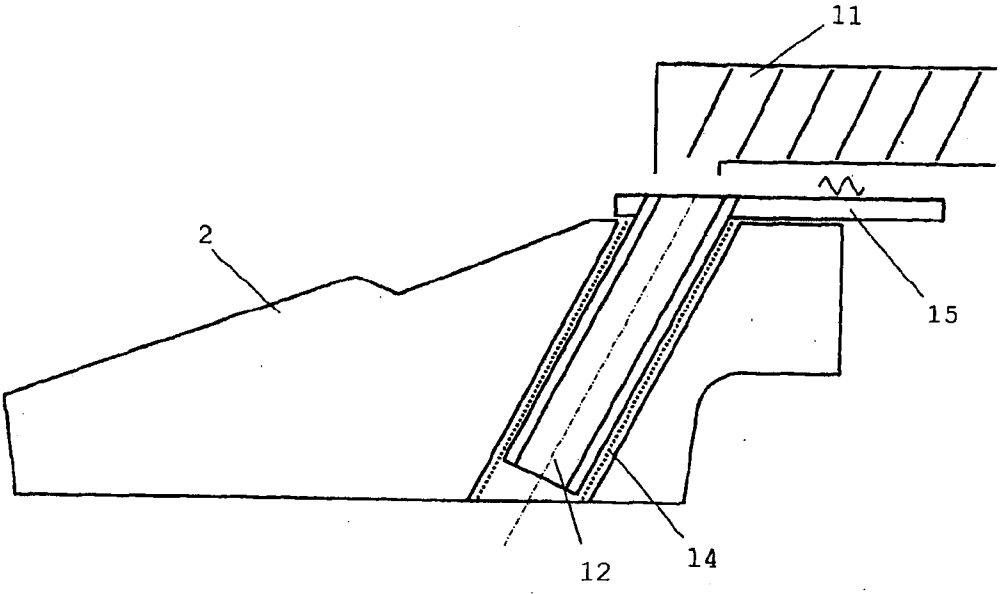
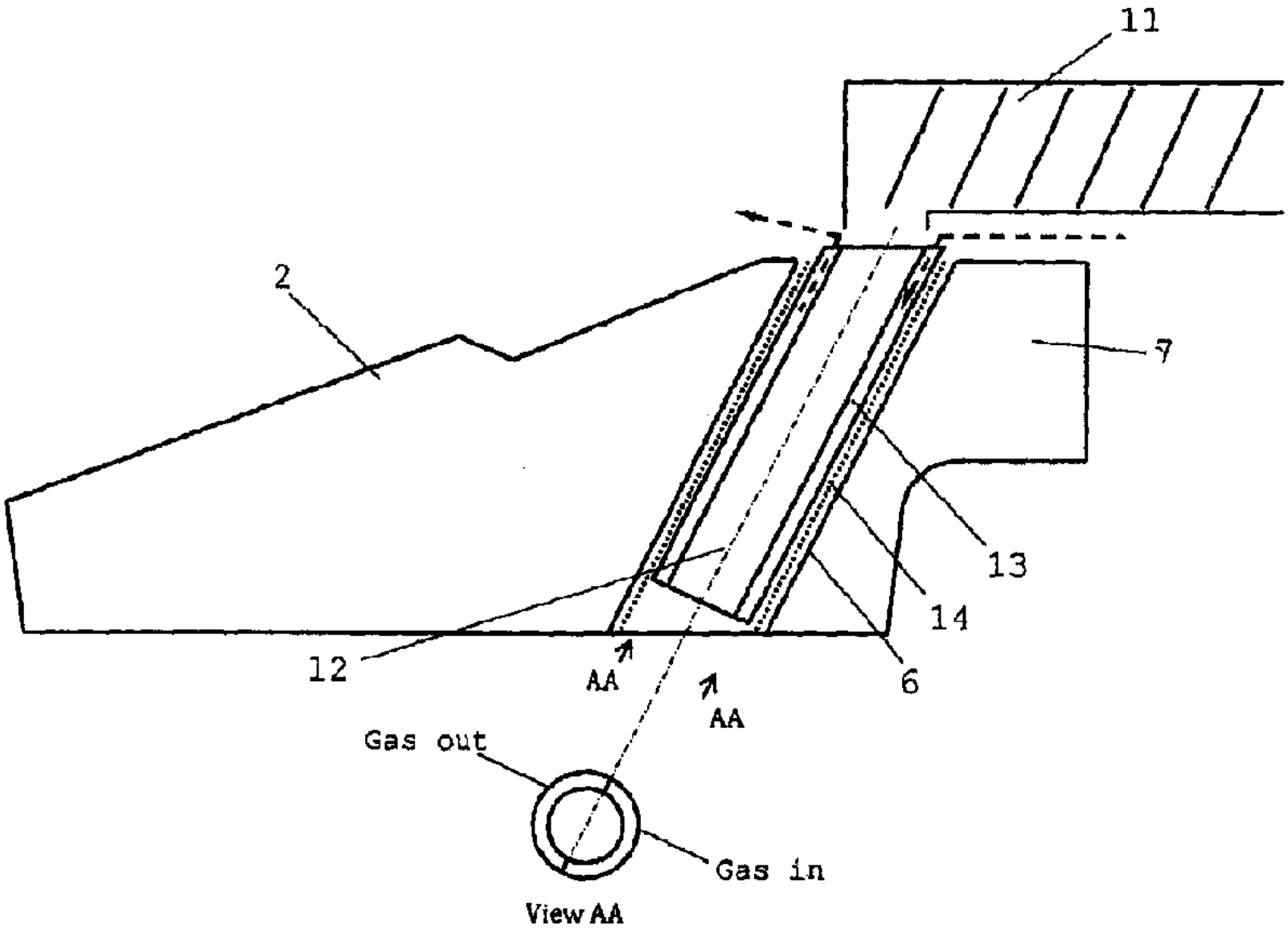


FIG.5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