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(54) **Method for refining molten steel in a vacuum.**

(57) A method for refining molten steel in a vacuum comprises an immersion process, wherein two immersion nozzles (5) (6) arranged at the lower portion of a vacuum vessel (4) are immersed in molten steel (2) in a ladle (1); a dissolving process, wherein gases are dissolved in molten steel by blowing gases containing at least gas soluble in the molten steel from a gas blow-in opening (3) arranged in a ladle in the molten steel; a first degassing process, wherein the molten steel is degassed by keeping the the vacuum vessel evacuated, having the molten steel circulated between the ladle and the vacuum vessel by injecting gases containing at least an inert gas, from the middle of the rising tube and blowing gases containing at least gas soluble in the molen steel from a gas blow-in opening arranged in the ladle; and a second degassing process, wherein the molten steel is degassed by keeping the vacuum vessel evacuated, stopping a gas blow-in from the gas blow-in opening arranged in the ladle and having the molten steel circulated between the ladle and the vacuum vessel by injecting gases containing at least an inert gas from the middle of the rising tube in the molten steel.

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METHOD OF REFINING MOLTEN STEEL IN A VACUUM

The present invention relates to a method for refining molten steel in a vacuum, and more particularly to a method for degassing molten steel.

A large amount of gas components is contained in molten steel produced in a steel-making furnace such as converter and the like which smelts and refines steel. To remove the gas components, there are carried out various vacuum processing methods wherein molten steel is degassed in a vacuum. Out of those methods, for example, RH vacuum degassing method is known. In this RH vacuum degassing method, molten steel is degassed in such a manner as described below. A ladle is filled up with molten steel to be processed. Two immersion nozzles arranged at the lower portion of a vacuum vessel are immersed in the molten steel from the upper side of the ladle. Inert gas is blown from the middle of one immersion nozzle to have the molten steel in the ladle circulated through the immersion nozzles inside the vacuum vessel. In this way, the molten steel is degassed in the vacuum vessel.

Requirements for components of steel for a special use, however, are more severe than those of molten steel processed with RH vacuum degassing method. Therefore, it is necessary to use other methods so as to process molten steel for a special use. To remove alumina inclusions in molten steel, for example, a total amount of oxygen in the molten steel needs to be decreased. The total amount of oxygen in the molten steel can barely be decreased to approximately 10 ppm by use of RH vacuum degassing method. Therefore, the RH vacuum degassing method cannot be applied to steel which requires a total amount of oxygen of less than 10 ppm.

It is an object of the present invention to provide a method for refining molten steel in a vacuum which effectively removes inclusions in molten steel. To accomplish said object, the present invention provides a method for refining molten steel in a vacuum comprising: an immersion process, wherein two immersion nozzles arranged at the lower portion of a vacuum vessel are immersed in molten steel in a ladle, said two immersion nozzles are a rising tube and a sinking tube; a first degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, having said molten steel circulated between said ladle and said vacuum vessel being kept evacuated by injecting gases containing at least an inert gas from the middle of said rising tube; and blowing in said molten steel gases containing at least gas soluble in said molten steel.

A further method comprising: an immersion process, wherein two immersion nozzles are immersed in molten steel in a ladle, said immersion nozzles are a rising tube and a sinking tube; a dissolving process, wherein gases are dissolved in said molten steel by blowing in said molten steel gases containing at least gas soluble in said molten steel from a gas blow-in opening arranged in said ladle; a first degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, having said molten steel circulated between said ladle and said vacuum vessel by injecting gases containing at least an inert gas from the middle of said rising tube in said molten steel, and blowing gases containing at least gas soluble in said molten steel from a gas blow-in opening arranged in said ladle; and a second degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, stopping a gas blowing-in from said gas blow-in opening arranged in said ladle and having said molten steel circulated between said ladle and said vacuum vessel being kept evacuated by injecting gases containing at least an inert gas from the middle of said rising tube in said molten steel.

The above objects and other objects and advantages of the present invention will become apparent from the detailed description to follow, taken in connection with the appended drawings.

Fig. 1 is a sectional view schematically showing a dissolving process, wherein gases are dissolved in molten steel, according to the present invention;

Fig. 2 is a sectional view schematically showing a first degassing process of the present invention;

Fig. 3 is a sectional view schematically showing a second degassing process of the present invention; and

Fig. 4 is a graphical representation indicating the relation between a processing time in a vacuum refining and a total amount of oxygen in molten steel in Example-1 of the present invention.

Preferred Embodiment

A method for refining molten steel in a vacuum of the present invention comprises an immersion process, wherein immersion nozzles are immersed in molten steel, a dissolving process, wherein gases are dissolved in said molten steel, a first degassing process and a second degassing process.

Immersion process

Two immersion nozzles arranged at the lower portion of vacuum vessel 4 are immersed in molten steel in a ladle. One of the two immersion nozzles is rising tube 5 and the other sinking tube 6.

Dissolving process

Fig. 1 is a sectional view schematically showing a dissolving process, wherein gases are dissolved in molten steel, according to the present invention. Molten steel 2 inside ladle 1 is pressurized by its static pressure. Gases containing at least gas soluble in molten steel are blown in molten steel 2 through gas blow-in opening 3 arranged at the bottom of ladle 1. It is, of course, possible to blow a mixed gas consisting of gas soluble in said molten steel and an inert gas in said molten steel. Molten steel 2 is bubbled by said mixed gas. Together with bubbling of said molten steel, a large amount of gas soluble in said molten steel dissolves in said molten steel. Gases can be simultaneously blown in said molten steel through gas blow-in opening 7 arranged in rising tube 5 of vacuum vessel 4. The amount of gases dissolved in said molten steel is expected to be quickly increased. A part of inclusions in molten steel 2 is trapped by bubbled gas and rises to the surface of said molten steel. When said molten steel rises to the surface of said molten steel, a pressure to said molten steel is decreased. As a result, the gases having been dissolved in said molten steel convert to fine bubbles. Fine inclusions in said molten steel are trapped by produced gas bubbles and rise to the surface of said molten steel.

Hydrogen gas, nitrogen gas and hydrocarbon gas as gases soluble in the molten steel are used out of a mixed gas blown in the molten steel. Ar gas and He gas are used as an inert gas. Only gases soluble in the molten steel can be used instead of the mixed gas. In this preferred Embodiment, gases were blown in the molten steel from gas blow-in opening 3 arranged at the bottom of ladle 1, but ways of a gas blow-in are not limited to this. Gases can be blown in the lower portion of the molten steel in ladle 1. Gas blow-in opening 3, however, is desired to be arranged in the bottom wall of ladle 1 just under rising tube. In this process, a large amount of gas can be blown in the molten steel with the use of an immersion lance before an immersion nozzle is immersed in the molten steel. Said immersion lance is immersed from the surface of the molten steel into the molten steel.

First degassing process

Fig. 2 is a sectional view schemtically showing a first degassing process of the present invention. Vacuum vessel 4 is kept evacuated. An inert gas is injected from gas blow-in opening 7 arranged in the middle of rising tube 5. Thereby, molten steel is made to circulate between ladle 1 and vacuum vessel 4. Gases including at least gas soluble in the molten steel are blown in molten steel 2 from gas blow-in opening 3 of ladle 1. Molten steel 2 is bubbled by the gases blown in. Together with bubbling, the gas soluble in the molten steel dissolves in the molten steel. On the other hand, since a pressure of the atmosphere inside the vacuum vessel is reduced to 2 to 3 Torr, the molten steel is degassed. With the rise of the molten steel toward the surface of the molten steel in vacuum vessel 4, the gas dissolved in the molten steel converts to bubbles. The gas components having been dissolved in the molten steel in the dissolving process and having not appeared near the surface of the molten steel also appear in the form of bubbles. Fine inclusions contained in the molten steel are trapped by the produced gas bubbles and rise to the surface of the molten steel in vacuum vessel 4. A part of the inclusions contained in molten steel 2 are trapped by bubbled inert gas and rises to the surface of the molten steel in vacuum vessel 4.

An inert gas was used in this Preferred Embodiment as gas which was injected from the gas blow-in opening arranged in the middle of rising tube 5. The gases to be used, however, are not limited to the inert gas. A mixed gas of an inert gas and gas soluble in the molten steel can be used. In case the mixed gas is used, fine inclusions are expected to be removed because the gas is dissolved in the molten steel and fine gas bubbles are produced under decreased pressure. Ar gas and He gas can be used as an inert gas. As in case of gas blow-in in the dissolving process, the gas blown in molten steel 2 from gas blow-in opening 2 of ladle 1 can be either a mixed gas consisting of gas soluble in the molten steel and an inert gas or only gas soluble in the molten steel.

Out of mixed gases blown in the molten steel, hydrogen gas, nitrogen gas and hydrocarbon gas are used as the gas soluble in the molten steel. Ar gas and He gas are used as an inert gas. In this Preferred Embodiment, the gas was blown in the molten steel from gas blow-in opening 3 arranged at the bottom of ladle 1, but ways of gas blow-in are not confined to this example. It is sufficient to blow the gas in the lower portion of the molten steel in ladle 1. It, however, is desirable to arrange gas blow-in opening 3 in the bottom wall of ladle 1 just under rising tube 5.

Second degassing process

Fig. 3 is a sectional view schematically showing a second degassing process of the present invention. Vacuum vessel 4 is kept evacuated. An inert gas is injected in vacuum vessel 4 from gas blow-in opening 7 arranged in the middle of rising tube 5 tomake molten steel circulate between ladle 1 and vacuum vessel 4. Gas blow-in from gas blow-in opening 3 of ladle 1 is stopped. Since the atmospheric pressure in vacuum vessel 4 is decreased to 2 to 3 Torr, the molten steel is degassed. Gas components, which have been dissolved in the molten steel in the first degassing process and have not been able to be removed, are removed. In this Preferred Embodiment, an inert gas was used. However, dependent on the permissible range of the gas soluble in molten steel, the gases to be used are not confined to the inert gas. In case a permissible concentration of final gas components soluble in molten steel is high, a mixed gas of an inert gas and gas soluble in molten steel can be used.

The method for refining molten steel in a vacuum

(a) comprising an immersion process, wherein immersion nozzles are immersed in molten steel, a dissolving process, wherein gases are dissolved in said molten steel, a first degassing process and a second degassing process were described above, but the method of the present invention is not limited to said processes. Methods as mentioned below can be used.

(b) A method comprising an immersion process, wherein immersion nozzles are immersed in molten steel, a first degassing process and a second degassing process.

(c) A method comprising an immersion process, wherein immersion nozzles are immersed in molten steel, a dissolving process, wherein gases are dissolved in molten steel and a first degassing process.

(d) A method comprising an immersion process, wherein immersion nozzles are immersed in molten steel and a first degassing process.

(e) A method comprising an immersion process, wherein immersion nozzles are immersed in molten steel, a dissolving process, wherein gases are dissolved in molten steel and a second degassing process.

Differences in effects of the methods of from (a) to (e) during the use of N_2 gas as gas soluble in molten steel will be described. When molten steel is processed by use of the mehtod (a), a total amount of oxygen in the molten steel is decreased to the lowest level among the total amounts of oxygen decreased by use of the methods of from (a) to (e). The amount of N in the molten steel becomes low when the second degassing process is carried out longer by use of the method (e). The methods (b) and (d) which do not comprise the dissoloving process are useful because of a simplicity of the processes. The methods (b) and (d), however, are somewhat inferior to the methods (a), (c) and (e), which comprise the dissolving process, in the effects of removing oxygen in the molten steel. In the method (d), the amount of N in the molten steel increases, but the molten steel is easily processed. Therefore, selection of the methods as mentioned above varies dependent on speicies of steel to be used and equipment which is owened.

Example-1

250 tons of molten steel were processed with the use of the method (b). For first 20 minutes, a mixed gas consisting of 40% Ar gas and 60% H_2 gas was blown in said molten steel from gas blow-in opening 7 of rising tube 5 and from gas blow-in opening 3 of ladle 1 respectively at a rate of 180 Nm^3/hr and at a rate of 60 Nm^3/hr. Thereafter, gas blowing-in from gas blow-in opening 3 of ladle 1 was stopped and, at the same time, 100% Ar gas was blown in the molten steel from gas blow-in opening 7 of rising tube 5 at a rate of 180 Nm^3/hr for 15 minutes. A change of a total amount of oxygen in the molten steel relative to a processing time is indicated in Fig. 4. The total amount of oxygen in the molten steel decreased to 5 ppm in processing of the molten steel for 35 minutes. The amount of hydrogen in the molten steel after having been processed could be decreased to 2 ppm or less.

Example-2

250 tons of molten steel were processed with the use of the method (c). Firstly, a top-blow lance was immersed in the molten steel in a ladle and N_2 gas was blown in the molten steel at a rate of 180 Nm^3/hr for 30 minutes. Subsequently, immersion nozzles were immersed in the molten steel. Vacuum vessel 4 was kept evacuated, and a mixed gas consisting of 60% Ar gas and 40% N_2 was blown through gas blow-in opening 7 of rising tube 5 and through gas blow-in opening 3 of ladle 1 respectively at 120 Nm^3/hr and at 60 Nm^3/hr for 35 minutes. The total amount of oxygen in the molten steel was decreased to approximately 5 ppm by 35 minutes processing of the molten steel. The amount of nitrogen in the molten steel after having been processed was decreased to approximately

90 ppm.

Example-3

250 tons of molten steel were processed by use of the method (d). A mixed gas consisting of 40% Ar gas and 60% H_2 gas was blown in the molten steel through gas blow-in opening 7 of rising tube 5 and through gas blow-in opening 3 of ladle 1 respectively at 120 Nm^3/hr and at 60 Nm^3/hr for 35 minutes. The total amount of oxygen in the molten steel was decreased to approximately 8 ppm by 35 minutes processing of the molten steel. The amount of nitrogen in the molten steel after having been processed was decreased to approximately 80 ppm.

Example-4

250 tons of molten steel were processed by use of the method (e). Firstly, a top-blow lance was immersed in the molten steel in a ladle and N_2 was blown in the molten steel at 180 Nm^3/hr for 30 minutes. Subsequently, immersion nozzles were immersed in the molten steel. Vacuum vessel 4 was kept evacuated and Ar gas was blown through gas blow-in opening 7 of rising tube 5 at 120 Nm^3/hr for 35 minutes. The total amount of oxygen in the molten steel was decreased to approximately 6 ppm by 35 minutes processing of the molten steel. The amount of nitrogen in the molten steel after having been processed was decreased to approximately 35 ppm.

Example-5

250 tons of molten steel were processed by use of the method (b). For the first 20 minutes, a mixed gas consisting of 20% Ar gas and 80% N_2 gas was blown in the molten steel through gas blow-in opening 7 of rising tube 5 and N_2 gas through gas blow-in opening 3 of ladle 1 respectively at 120 Nm^3/hr and at 60 Nm^3/hr. Then, blowing-in of N_2 gas through gas blow-in opening 3 of ladle 1 was stopped, and, at the same time, 100% Ar gas blown in the molten steel through gas blow-in opening 7 of rising tube 5 at 120 Nm^3/hr for 15 minutes. The total amount of oxygen in the molten steel was decreased to approximately 6 ppm by 35 minutes processing of the molten steel. The amount of nitrogen in the molten steel was decreased to approximately 40 ppm.

Example-6

250 tons of molten steel was processed by use of the method (a). Firstly, a top-blow lance was immersed in the molten steel in a ladle, and N_2 gas was blown in the molten steel at 180 Nm^3/hr for half an hour. Then, immersion nozzles were immersed in the molten steel. Vacuum vessel 4 was kept evacuated. For the first 20 minutes, a mixed gas consisting of 20% Ar gas and 80% N_2 gas was blown in vacuum vessel 4 through gas blow-in opening 7 of rising tube 5 and N_2 gas through gas blow-in opening 3 of ladle 1 respectively at 120 Nm^3/hr and at 60 Nm^3/hr. Thereafter, blowing-in of N_2 gas through gas blow-in opening of ladel 1 was stopped, and at the same time, 100% Ar gas was blown through gas blow-in opening 7 of rising tube 5 at 120 Nm^3/hr for 15 minutes. The total amount ofoxygen in the molten steel was decreased to approximately 4 ppm by 35 minutes processing of the molten steel. The amount of nitrogen was decreased to approximately 50 ppm.

Control

250 tons of molten steel were processed by use of a prior art RH vacuum degassing method. Two immersion nozzles were immersed in the molten steel in ladle 1. The two immersion nozzles were rising tube 5 and sinking tube 6. Vacuum vessel 4 was kept evacuated. Ar gas was blown in said vacuum vessel 4 from gas blow-in opening 7 arranged in the middle of rising tube 5 at a rate of 180 Nm^3/hr. An amount of the molten steel circulating in vacuum vessel 4 was 100 tons/min. The molten steel was processed for 35 minutes. A change of a total amount of oxygen in the molten steel relative to a processing time is indicated in Fig.4. The total amount of oxygen in the molten steel decreased to approximately 10 ppm in processing of the molten steel for 35 minutes.

Claims

1. A method for refining molten steel in a vacuum comprising:
an immersion process, wherein two immersion nozzles arranged at the lower portion of a vacuum vessel (4) are immersed in molten steel (2) in a ladle(1), said two immersion nozzles are a rising tube(5) and a sinking tube (6);
characterized by a first degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, having said molten steel circulated between said ladle and said vacuum vessel by injecting gases containing at least an

inert gas from the middle of said rising tube and blowing in said molten steel gases containing at least gas soluble in said molten steel.

2. The method of claim 1, characterized in that said gases containing at least gas soluble in said molten steel includes a mixed gas of gas soluble in said molten steel and an inert gas.

3. The method of claim 2, characterized in that said gases containing at least gas soluble in said molten steel include one selected from a group of hydrogen gas, nitrogen gas and hydrogen gas.

4. The method of claim 1, characterized in that said gases containing at least gas soluble in said molten steel include one selected from a group of hydrogen gas, nitrogen gas and hydrocarbon gas.

5. The method of any one of claims 1 to 4, characterized in that said blowing-in of said gases containing at least gas soluble in said molten steel includes blowing-in of said gases through a gas blow-in opening (3) arranged in said ladle.

6. The method of claim 5, characterized in that said gas blow-in opening arranged in said ladle includes a gas blow-in opening arranged just under said rising tube.

7. The method of any one of claims 1 to 6, characterized in that said blowing-in of gases containing at least gas soluble in said molten steel includes blowing-in of said gases through a top-blow lance which is immersed in said molten steel.

8. The method of any one of claims 1 to 7, characterized in that said gases containing at least an inert gas include a mixed gas of the inert gas and gas soluble in said molten steel.

9. The method of any one of claims 1 to 7, characterized in that said containing at least an inert gas include Ar gas and He gas.

10. The method of any one of claims 1 to 9, characterized by further comprising a dissolving process, wherein gases containing at least gas soluble in said molten steel are dissolved in said molten steel by blowing said gases in said molten steel before said first degassing process.

11. The method of claim 10, charaterized in that said gases containing at least gas soluble in said molten steel include a mixed gas of gas soluble in said molten steel and an inert gas.

12. The method of claim 10, characterized in that said gas soluble in said molten steel includes one selected from a group of hydrogen gas, nitrogen gas and hydrocarbon gas.

13. The method of claim 10, characterized in that said gases containing at least gas soluble in said molten steel include one selected from a group of hydrogen gas, nitrogen gas and hydrocarbon gas.

14. The method of any one of claims 10 to 13, characterized in that said blowing-in of gases containing at least gas soluble in said molten steel includes blowing-in of said gases through a gas blow-in opening arranged in said ladle.

15. The method of claim 14, characterized in that said gas blow-in opening arranged in said ladle includes a gas blow-in opening arranged just under said rising tube.

16. The method of any one of claims 10 to 13, characterized in that said blowing-in of gases containing at least gas soluble in said molten steel includes blowing-in of said gases from a top-blow lance which is immersed in said molten steel.

17. The method of any one of claims 1 to 16, characterized by further comprising a second degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, stopping a gas blowing-in from said gas blow-in opening arranged in said ladle and having said molten steel circulated between said ladle and said vacuum vessel by injecting gases containing at least an inert gas from the middle of said rising tube in said molten steel circulated between said ladle and said vacuum vessel.

18. The method of claim 17, characterized in that said gases containing at least inert gas include a mixed gas of an inert gas and gas soluble in said molten steel.

19. The method of claim 18, characterized in that said gases containing at least an inert gas include Ar gas and He gas.

20. A method of refining molten steel in a vacuum comprising:
an immersion process, wherein two immersion nozzles arranged at the lower portion of a vacuum vessel (4) are immersed in molten steel (2) in a ladle(1), said two immersion nozzles are a rising tube(5) and a sinking tube (6);
characterized by a dissolving process, wherein gases are dissolved in said molten steel by blowing in said molten steel gases containing at least gas soluble in said molten steel from a gas blow-in opening (3) arranged in said ladle; and
a first degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, having said molten steel circulated between said ladle and said vacuum vessel by injecting gases containing at least an inert gas from the middle of said rising tube in said molten steel and blowing gases containing at least gas soluble in said molten steel from a gas blow-in opening arranged in said ladle.

21. A method for refining molten steel in a vacuum comprising:
an immersion process, wherein two immersion nozzles arranged at the lower portion of a vacuum vessel (4) are immersed in molten steel in a ladle

(1), said two immersion nozzles are a rising tube(5) and a sinking tube (6);
characterized by a dissolving process, wherein gases are dissolved in said molten steel by blowing in said molten steel gases containing at least gas soluble in said molten steel from a gas blow-in opening (3) arranged in said ladle;
a first degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated; having said molten steel circulated between said ladle and said vacuum vessel by injecting gases containing at least an inert gas from the middle of said rising tube in said molten steel and blowing gases containing at least gas soluble in said molten steel from a gas blow-in opening arranged in said ladle; and
a second degasing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, stopping a gas blowing-in from said gas blow-in opening arranged in said ladle and having said molten steel circulated between said ladle and said vacuum vessel by injecting gases containing at least an inert gas from the middle of said rising tube in said molten steel.

22. A method for refining molten steel in a vacuum comprising:
an immersion process, wherein two immersion nozzles arranged at the lower portion of a vacuum vessel (4) are immersed in molten steel (2) in a ladle (1), said two immersion nozzles are a rising tube (5) and a sinking tube (6);
characterized by a dissolving process, wherein gases are dissolved in said molten steel by blowing in said molten steel gases containing at least gas soluble in said molten steel from a gas blow-in opening (3) arranged in said ladle; and
a second degassing process, wherein said molten steel is degassed by keeping said vacuum vessel evacuated, stopping a gas blowing-in from said gas blow-in opening arranged in said ladle and having said molten steel circulated between said ladle and said vacuum vessel by injecting gases containing at least an inert gas from the middle of said rising tube in said molten steel.

FIG.1

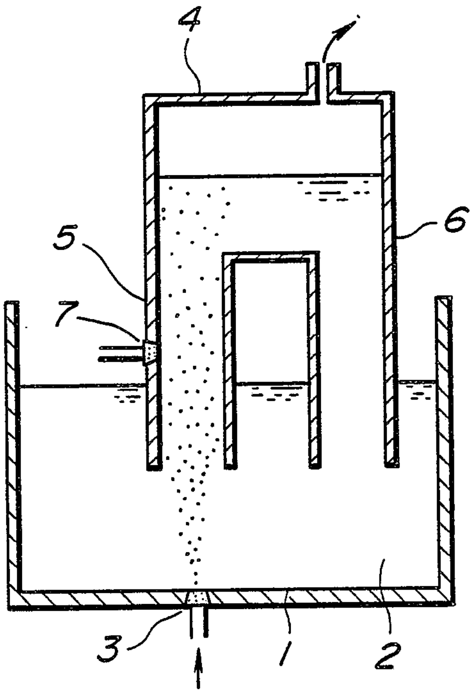


FIG.2

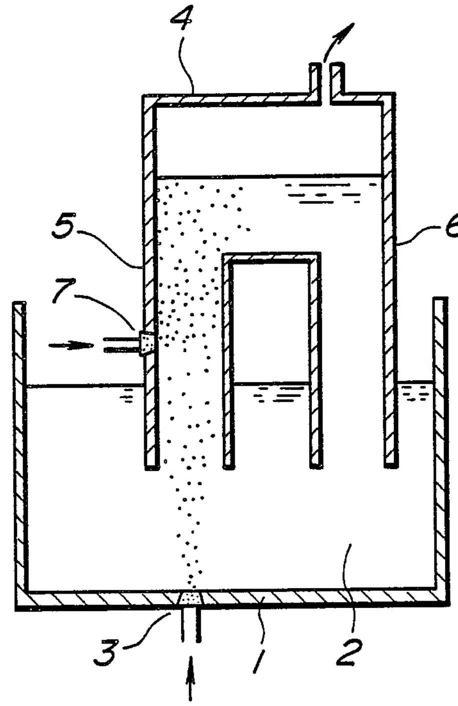


FIG.3

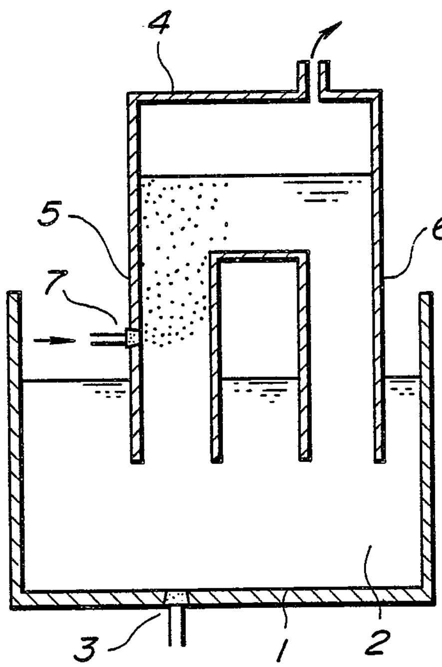
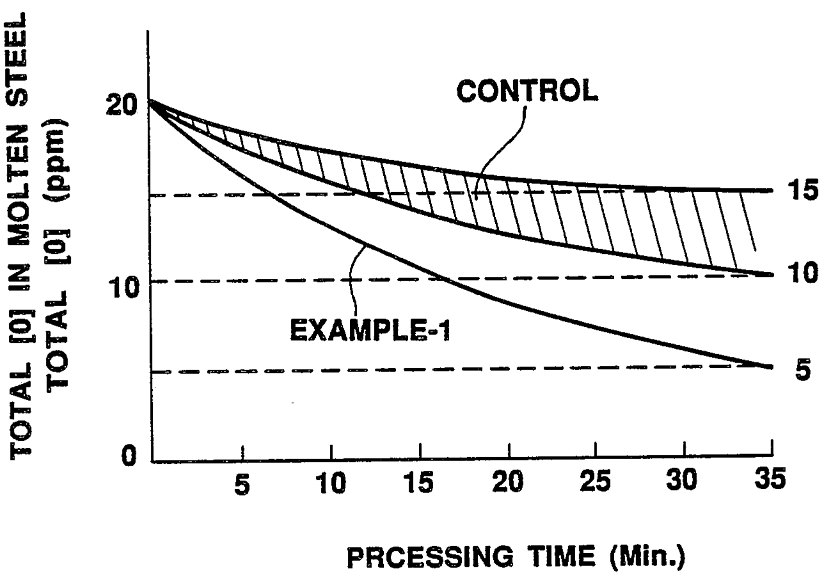


FIG. 4


TOTAL [0] IN MOLTEN STEEL
TOTAL [0] (ppm)
20
10
0
CONTROL
EXAMPLE-1
15
10
5
5
10
15
20
25
30
35
PRCESSING TIME (Min.)