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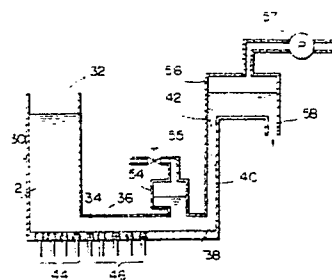
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(54) Method for cleaning molten metal and apparatus therefor.

(57) A method for cleaning molten metal comprises a bubbling process, wherein the gas soluble in molten metal is bubbled in the molten metal under increased pressure, the inclusions in the molten metal are trapped by the gas bubbles produced by bubbling, and the gas is dissolved in the molten metal; a pressure reduction process, wherein fine gas bubbles are produced in the molten metal by reducing a pressure on the molten metal in which gas is dissolved, and the inclusions suspended in the molten metal are trapped by the fine gas bubbles produced by reduction of the pressure; and an inclusions removing process, wherein inclusions having risen to the surface of the molten metal are removed. An apparatus comprises a first vessel (30) which has an inlet (32) for charging molten metal at the top end thereof and outlet (34) for charging molten metal at the bottom thereof; a second vessel (40) which has an inflow port (38) for pressurized molten metal at the bottom thereof and an outflow port (42) for the pressurized molten metal and in which the pressurized molten metal goes upwardly; a communicating tube (36) connecting the first vessel to the second vessel; and a first bubbling device (44) positioned at the bottom of the first vessel for bubbling the gas soluble in molten metal.

FIG. 9



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METHOD FOR CLEANING MOLTEN METAL AND APPARATUS THEREFOR

The present invention relates to a method for cleaning molten metal by removing inclusions suspended in molten metal and an apparatus therefor.

There have been proposed various methods for decreasing or removing inclusions suspended in molten metal since those inclusions can be a cause of defects in quality of a product. Four methods as those methods are shown below:

(a) A first method, wherein inclusions in molten metal are trapped by gas bubbles produced by bubbling inert gas in molten metal at atmospheric pressure from the bottom of a vessel having molten metal therein. The inclusions are removed from the molten metal after the inclusions have risen to the surface of the molten metal.

(b) A second method, wherein inclusions in molten metal are removed by a filter made from calcium oxide which is put in a flow of the molten metal.

(c) A third method, wherein inclusions in molten metal are removed by throwing a solid such as calcium oxide capable of adsorbing the inclusions into the molten metal.

(d) A fourth method, wherein inclusions in molten metal are removed by having the inclusions risen to the surface of the molten metal or gone down by use of differences in densities of the inclusions.

However, in case of having an object of manufacturing quality material, a total amount of oxygen in molten metal needs to be limited to 15 ppm or less. When molten metal is cleaned by use of said methods, there can occur the following problems:

In the first method, a zone of the bubbling only spreads upwardly from a gas blowing-in inlet positioned at the bottom of a vessel. Moreover, there is a problem that it is difficult to bubble the molten metal from the whole vessel. When the bubbles produced by bubbling are large, the molten metal flows, bypassing the bubbles, during the bubbles' rising to the surface of the molten metal. In this case, micro-inclusions in the molten metal are hard to be trapped by the bubbles since the micro-inclusions also move together with the flow of the molten metal, bypassing the bubbles.

In the second method, when a filter capable of removing micro-inclusions is used, the filter often is choked and unable to be used soon after it has begun to be used.

In the third method, when the effectiveness of removing inclusions in molten metal by use of a solid such as calcium oxide lowers, there occurs a necessity for withdrawing the solid out of the molten metal. In this case, there is a problem that the withdrawal of the solid requires a troublesome work and, moreover, the efficiency of the withdrawal of the solid is low.

In the fourth method, due to small particles of the micro-inclusions, the rising or the going-down of the micro-inclusions takes a lot of time. This leads to a decrease of the efficiency of removing the micro-inclusions.

It is an object of the present invention to provide a method for cleaning molten metal, wherein not only inclusions of an ordinary size, but also micro-inclusions can be removed from molten metal.

To accomplish said object, the present invention provides a method for cleaning molten metal, which comprises:

a bubbling process, wherein the gas soluble in molten metal is bubbled in said molten metal under increased pressure, inclusions suspended in said molten metal are trapped by the gas bubbles produced by bubbling, and said gas is dissolved in said molten metal;

a pressure reduction process, wherein fine gas bubbles are produced in the molten metal by reducing a pressure on the molten metal in which gas is dissolved, and the inclusions suspended in the molten metal are trapped by the fine gas bubbles produced by reduction of the pressure; and

an inclusions removing process, wherein inclusions having risen to the surface of the molten metal are removed.

Further, the present invention provides an apparatus for cleaning molten metal, which comprises:

a first vessel which has an inlet for charging molten metal at the top end thereof and an outlet for discharging molten metal at the bottom thereof and in which the molten metal is pressurized by its static pressure;

a second vessel which has an inflow port for pressurized molten metal at the bottom thereof and an outflow port for the pressurized molten metal and in which the pressurized molten metal goes upwardly and a pressure on the molten metal is reduced;

a communicating tube connecting the first vessel to the second vessel; and

a first bubbling device positioned at the bottom of the first vessel for bubbling the gas soluble in molten metal.

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

5 Fig.1 is a cross sectional view showing schematically an apparatus for cleaning molten metal by means of a batch process of the present invention;

Fig.2 is a cross sectional view illustrating another apparatus for cleaning molten metal by means of a batch process of the present invention;

10 Fig.3 is a cross sectional view showing schematically an apparatus for continuously cleaning molten metal with the use of a U-shaped vessel of the present invention;

Fig.4 is a graphic representation of a change in time of a total amount of oxygen in molten metal during processing the molten metal in example-1 and control-1;

Fig.5 is a cross-sectional view showing schematically an outline of an apparatus used for a method of Preferred Embodiment-2;

15 Fig.6 is a graphic representation of the change of the flutter of the surface of the molten metal, which was produced by applying static magnetic field to the molten metal, relative to magnetic flux density of static magnetic field in the abscissa;

Fig.7 is a cross sectional view illustrating an apparatus used for a method in Preferred Embodiment 3.

20 Fig.8 is a graphic representation of a change in time of a total amount of oxygen in molten metal during processing the molten metal in Example-4 of the present invention; and

Fig.9 is a cross sectional view illustrating an apparatus for continuously cleaning molten metal which is used in Example-5.

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Preferred Embodiment-1

30 The gas soluble in molten metal is bubbled in said molten metal under increased pressure. Inclusions of large particle size in the molten metal are trapped by the bubbles produced by a first bubbling, go upwardly to the surface of the molten metal and are removed. Since the molten metal under increased pressure is bubbled, a large amount of gas is uniformly dissolved in the molten metal by stirring the molten metal by means of bubbling. Thereafter, the gas dissolved in the molten metal is converted to fine gas bubbles under the pressure rapidly reduced. The fine gas bubbles are produced from the whole area of the

35 molten metal. Micro-inclusions are trapped by the fine gas bubbles, rise to the surface of the molten metal and are removed.

Nitrogen gas and hydrogen gas are preferred as the gas soluble in molten metal. Hydrogen gas is more desirable if the later removal of the gas having remained in the molten metal is taken into consideration. A pressure of from 1 to 10 atm is preferred to the atmospheric pressure for applying a pressure on the molten metal. When the molten metal is pressurized at a pressure of less than 1 atm, it is less effective to pressurize the molten metal. When the molten metal is pressurized at a pressure of more than 10 atm, the apparatus becomes too expensive. The pressure on the molten metal is desired to be reduced in several stages from a pressure applied to the molten metal because fine bubbles are produced at every stage of the pressure reduction. For example, the pressure on the molten metal is reduced in such a manner as; 10 atm → 7 atm → 4 atm → 1 atm. The method of the present invention as mentioned above can be carried out by means of a batch process wherein a pressure vessel is used or a continuous process wherein a U-shaped vessel is used.

Fig.1 is a cross sectional view showing schematically an apparatus for cleaning molten metal by means of a batch process. A method for cleaning molten metal by means of the batch process will now be explained with specific reference to Fig. 1. Firstly, molten metal is poured into pressure vessel 10. Thereafter, pressure vessel 10 is closed with cover 14 and molten metal 12 is pressurized by controlling pressure valve 16 mounted on a duct connected to cover 14. Gas 20 soluble in the molten metal is blown in the molten metal under pressure from bubbling device 18 positioned at the bottom of vessel 10. After a bubbling has finished, a pressure applied to molten metal 12 is rapidly reduced by controlling pressure valve 16. Finally, the inclusions which have risen to the surface of the molten metal are removed.

55 Fig.2 is a cross sectional view illustrating another apparatus for cleaning molten metal by means of a batch process. With the use of this apparatus, a pressure applied to molten metal 12 can be rapidly reduced by transferring the molten metal being kept under pressure to vessel 24 opened for the air through

communicating tube 22.

Fig.3 is a cross sectional view showing schematically a method for continuously cleaning molten metal with the use of a U-shaped vessel. Molten metal is continuously charged into a vessel through inlet 32 positioned at the top end of first vessel 30. Molten metal 12 goes down inside first vessel 30 and is gradually pressurized by its static pressure. Molten metal 12 which has reached the bottom of vessel 30 is sufficiently pressurized by its static pressure. There is output port 34 at the bottom of vessel 30. The molten metal flows to communicating tube 36 through outflow port 34. the molten metal is bubbled by bubbling device 44 positioned at the bottom of first vessel 30 and by bubbling device 46 positioned at the bottom of communicating tube 36 connected to the first vessel. The molten metal, which has passed through communicating tube 36, enters second vessel 40 through inflow port 38 positioned at the bottom of second vessel 40. There is output port 42 for discharging molten metal at the top end of second vessel 40. The molten metal rises toward outlet 42 for discharging molten metal inside second vessel 40. With the rise of the molten metal, a pressure on the molten metal is rapidly reduced, and gas dissolved in the molten metal appears in the molten metal as fine gas bubbles. The fine gas bubbles rise to the surface of the molten metal, trapping inclusions in the molten metal. The molten metal, which has gone out of outlet 42 for discharging molten metal of second vessel 40, enters receptor 48. The inclusions floating on the surface of the molten metal inside receptor 48 are continuously removed.

20 Preferred Embodiment-2

A method of Preferred Embodiment-1 is highly effective in removing inclusions in molten metal. It was understood that, in order to further decrease the inclusions in the molten metal, it is good to decrease the flutter of the molten metal surface which is produced when the gas bubbles produced by bubbling and the innumerable bubbles produced by a pressure reduction rise to the surface of the molten metal and to take measures so that the inclusions which had risen to the surface of the molten metal could not mix again with the molten metal. Therefore, in a method of Preferred Embodiment-2, static magnetic field is applied to the surface of the molten metal when the inclusions trapped by the bubbles produced by bubbling and by innumerable bubbles produced by the pressure reduction rise to the surface of the molten metal.

Fig.5 is a cross sectional view showing schematically an outline of an apparatus used for a method of Preferred Embodiment-2. When static magnetic field is applied to molten metal in a direction at right angles to a flow of the molten metal, a braking force against the flow of the molten metal takes place. A flutter of the molten metal surface just corresponds to an up-and-down flow of the molten metal bath. A force suppressing the up-and-down flow of the molten metal is produced by applying the static magnetic field to the surface of the molten metal with the use of electromagnet 50. Thereby, the width of the flutter is decreased, and this can prevent the occurrence of waves on the surface of the molten metal. Force F suppressing the flutter of the molten metal surface is represented by the following formula:

$$F = \sigma \times B^2 \times V$$

σ : electric conductivity of molten metal bath

40 B: magnetic induction

V: velocity of up-and-down movement of molten metal surface

The magnetic induction of the static magnetic field is preferred to be of from 1000 to 5000 gaussses. When said magnetic induction is less than 1000 gaussses, a force suppressing the flutter of the molten metal surface is small. When the magnetic induction exceeds 5000 gaussses, there is no change in the effectiveness of the force suppressing the flutter of the molten metal surface.

Preferred Embodiment-3

The present inventor conducted various tests for the purpose of increasing a processing capability of the apparatus and understood that, when time for leaving the molten metal as it was shortened, micro-inclusions in the molten metal were not removed as expected. In consequence, it was thought to further increase the efficiency in the removal of ordinary inclusions by the bubbling carried out before the pressure reduction process. As a result of the tests conducted later, it was understood that the efficiency in the removal of inclusions by bubbling was increased by applying a low frequency electromagnetic force to molten metal during bubbling and actively stirring the molten metal. It is thought that the reason why the efficiency in the removal of the inclusions is increased is that the inclusions in the molten metal increasingly strike against one another by stirring and the inclusions having grown comparatively larger rise to the

surface of the molten metal during bubbling. In addition, since the amount of bubbling gas dissolved in the molten metal was expected to be increased by stirring, the amount of fine gas bubbles was increased by the pressure reduction and the efficiency in the removal of the micro-inclusions was expected to be increased.

5 On the other hand, the temperature of the molten metal was decreased by the bubbling. In this connection, the amount of the bubbling gas dissolved in the molten metal was decreased. Fluidity of the molten metal also was decreased. In consequence, the effectiveness of the stirring by the bubbling decreased.

10 In order to overcome those difficulties, the molten metal could be actively heated by Joule's heat produced by induced current generated by applying an electromagnetic force to the molten metal during bubbling.

The reason why it was only during bubbling when the electromagnetic force was applied to the molten metal was consideration so that the inclusions having once risen to the surface of the molten metal after the pressure reduction could not be mixed again with the molten metal by an electromagnetic stirring.

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Example-1

20 The cleaning of molten metal in Preferred Embodiment-1 was carried out by means of a batch process with the use of a pressure vessel of 2 m in inside diameter and 3 m in height as shown in Fig. 1.

Firstly, 50 tons of molten steel were poured into pressure vessel 10. Subsequently, pressure vessel 10 was closed with cover 14 and sealed. Atmospheric gas inside pressure vessel 10 was substituted for argon gas. Thereafter, a mixed gas consisting of 70% Ar gas and H₂ gas was bubbled in the molten steel for 20 minutes at a rate of 200 l/min from bubbling device 18 positioned at the bottom of pressure vessel 10. A
25 gas pressure inside pressure vessel was adjusted to 3 atm by means of pressure valve 16. After the bubbling had finished, the gas pressure inside pressure vessel 10 was reduced to the atmospheric pressure by means of pressure valve 16. The molten steel was left as it was for 20 minutes until the gas bubbles produced by the pressure reduction rose to the surface of the molten steel. Finally, the molten steel was transferred to the next process.

30 The cleaning of molten steel was carried out as control-1 by use of a prior art gas bubbling method. That is, argon gas was blown in 50 tons of the molten steel under the atmospheric pressure at a rate of 400 l/min or 40 minutes.

Fig.4 is a graphic representation of a change in time of a total amount of oxygen in the molten steel during processing the molten steel in Example-1 and Control-1. The change of the total amount of oxygen in the molten steel in Example-1 is shown with a solid line and that in Control-1 with a dashed line. The total
35 amount of oxygen before processing the molten steel was 80 ppm, but the amount of oxygen was decreased to 15 ppm in Example-1 while the amount of oxygen was decreased only to 30 ppm in Control-1. It was understood that the case of Example-1 of the present invention was superior to the case of Control-1 in the effectiveness of cleaning the molten steel. A total amount of bubbling gas was 16000 l in Control-1. A total amount of the bubbling gas was 4000 l (2800 l of Ar gas and 1200 l of H₂ gas) in Example-1. In
40 Example-1 of the present invention, the amount of gas used for the bubbling could be decreased and this could lead to a decrease of running cost.

Example-2

A method of the present invention in Preferred Embodiment-1 was carried out by means of a continuous process with the use of a U-shaped vessel as shown in Fig.3. The dimensions of each portion of the vessel were as follows:

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Height of a first vessel:	4 m
Inside diameter of the first vessel:	1 m
Length of a communicating tube:	2 m
Inside diameter of the communicating tube:	30 cm
Bubbling device (zones of 44 and 46)	2 m
Diameter of a second vessel:	10 cm

Molten steel was continuously charged into the vessel from inlet 32 positioned at the top end of first vessel 30 at a rate of 250 t/hr. A mixed gas consisting of 60% Ar gas and 40% H₂ gas was bubbled in the molten steel from bubbling devices 44 and 46 at a rate of 200 l/min. In consequence, the total amount of oxygen, which was 80 ppm before the molten steel was processed, was decreased to 12 ppm in the molten steel at the bottom of receptor 48. It was understood that the effectiveness in oxidation of the molten steel became higher.

Example-3

The cleaning of molten metal in Preferred Embodiment-2 was carried out by means of a batch process with the use of a pressure vessel of 2 m in inside diameter and 3 m in height as shown in Fig.5.

Molten metal was poured into pressure vessel 10 so that the level of the molten steel could rise to 2 m in height in pressure vessel 10. The atmosphere inside pressure vessel 10 was substituted for argon gas. Thereafter, a mixed gas consisting of 70% Ar gas and 30% H₂ gas was blown in the molten steel from bubbling device 18 positioned at the bottom of pressure vessel 10 at a rate of 300 l/min to bubble the molten steel. A gas pressure inside pressure vessel 10 was increased to 10 atm during bubbling. Subsequently, static magnetic field was applied to the surface of the molten steel bath by use of electromagnet 50. Thereby, a force suppressing a flutter of the molten steel surface was produced. Thereafter, the bubbling was stopped. The gas pressure inside pressure vessel 10 was rapidly reduced by means of pressure valve 16, and fine gas bubbles were produced from the whole area of the molten steel. In Example-3, static magnetic field was applied to the surface of the molten steel even when the gas pressure was reduced. Fig.6 is a graphic representation of the change of the flutter of the molten steel surface, which was produced by applying static magnetic field to the molten steel, relative to magnetic flux density of static magnetic field in the abscissa. In this schematic representation when the magnetic flux was over 1000 gauss, there appeared an effect of suppressing a flutter on the surface of the molten steel, and, when the magnetic flux exceeded 5000 gauss, there was no change in the effectiveness of the force suppressing the flutter of the molten steel.

Example-4

The cleaning of molten metal in Preferred Embodiment was carried out by means of a batch process with the use of a pressure vessel of 2 m in inside diameter and 3 m in height as shown in Fig.7.

Firstly, 50 tons of molten steel were poured into pressure vessel 10. Subsequently, pressure vessel 10 was closed with cover 14 and sealed. Atmospheric gas inside pressure vessel 10 was substituted for argon gas. Thereafter, mixed gas consisting of 70% Ar gas and 30% H₂ gas was blown in the molten steel from bubbling device 18 positioned at the bottom of pressure vessel 10 at a rate of 200 l/min and the molten steel was bubbled for 20 minutes. A gas pressure inside pressure vessel 10 was adjusted to 3 atm by means of pressure valve 16. An electromagnetic force was applied to the molten steel with the use of electromagnetic coils 52 arranged around pressure vessel 10 during bubbling, and the molten steel was subjected to electromagnetic stirring. Subsequently, the gas bubbling and the electromagnetic stirring were stopped, and the gas pressure inside pressure vessel 10 was reduced to the atmospheric pressure by means of pressure valve 16. The molten steel was left as it was until the gas bubbles produced by the pressure reduction rose to the surface of the molten steel.

Fig.8 is a graphic representation of a change in time of a total amount of oxygen in the molten steel during processing the molten steel in Example-4. In Example-4, the total amount of oxygen in the molten steel was already fairly decreased by an electromagnetic stirring during bubbling a mixed gas. It is thought that inclusions in the molten steel increasingly stroke against one another, that the inclusions having had grown comparatively larger rose to the surface of the molten steel, and that the total amount of oxygen in the molten steel was decreased. Moreover, the total amount of oxygen after the completion of all the processes also was decreased to 10 ppm, which were less than in Example-1. The decrease of the total amount of oxygen can be explained by the following two reasons: Firstly, comparatively small inclusions in the molten steel grew larger by striking against one another, being stirred during bubbling, and were easily trapped by gas bubbles; and, subsequently, the amount of gas dissolved in the molten steel became large and this increased the amount of fine gas bubbles produced during a pressure reduction. Accordingly, it is necessary to take a little bit more time to leave the molten steel as it is after the pressure reduction so as to make the total amount of oxygen in the molten steel processed in Example-1 equal to the total amount of

oxygen in the molten steel processed in Example-4.

Examples-5

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Preferred Embodiment of the apparatus for cleaning molten metal of the present invention will now be explained with specific reference to Fig.9. The apparatus for cleaning molten metal was composed of first vessel 30, communicating tube 36, second vessel 40 and vacuum storage vessel 56. First vessel was of 1 m in inside diameter and of 5 m in height. An opening at the top end of said first vessel was inlet 32 for charging molten metal. Outlet 34 for discharging molten metal was arranged at the bottom of first vessel 30. The molten metal flows through outlet 34 to communicating tube 36. Communicating tube 36 was of 50 cm in inside diameter and of 6 m in length. First bubbling device 44 was positioned at the bottom of first vessel 30 and second bubbling device 46 at the bottom of communicating tube 36 connected to first vessel 30 so that the molten metal could be bubbled from said bubbling devices 44 and 46. Gas storage chamber 54 was arranged at the position located a little bit beyond bubbling device 46 positioned at the bottom of communicating tube 36. Measures were taken by discharging a part of the bubbled gas to storage chamber 54 so that the gas bubbles rising to the surface of the molten metal inside second vessel 40 which would be described later could not grow too large. The gas inside gas storage chamber 54 was discharged by means of pressure valve 55. The molten metal, which had passed through communicating tube 36, entered second vessel 40 through inflow port 38 positioned at the bottom of second vessel 40. Second vessel 40 was of 30 cm in inside diameter and of 5 m in height. The inside diameter of second vessel 40 was made small so that the pressure on the molten metal could be rapidly reduced by having the molten metal more rapidly flowed inside second vessel 40. Outlet 42 for discharging molten metal was positioned at the top end of second vessel 40. Vacuum storage vessel 56 of 2 m in inside diameter connected to outlet 42 for discharging molten metal was arranged, and the molten metal stored in vacuum storage vessel 56 was degassed. Vacuum storage vessel 56 was arranged for the purpose of removing the gas bubbles produced by the bubbling and the pressure reduction, removing the inclusions rising to the surface of the molten metal, being trapped by the gas bubbles and discharging the gas dissolved in the molten metal even under atmospheric pressure. Gas in vacuum storage vessel 56 was exhausted by means of vacuum pump 57. Tube 58 of 30 cm in inside diameter for bringing out the molten metal having been cleaned to the next process was connected to the bottom of vacuum storage vessel 56. In said apparatus, molten metal is continuously charged into a vessel through inlet 32 and the molten metal taken out through outlet 42 to vacuum storage vessel 56 can be the molten metal very well cleaned by bubbling the gas soluble in the molten metal from bubbling devices 44 and 46. That is, molten metal 12 discharged through inlet 32 is gradually pressurized by its static pressure, going down inside first vessel 30. A large amount of the gas bubbled from bubbling devices 44 and 46 dissolves in the molten metal. Simultaneously, inclusions of ordinary size are trapped by bubbling gas and flow through communicating tube 36. A part of the bubbling gas enters gas storage chamber 54 and is taken out of gas storage chamber 54 outwardly by means of pressure valve 55. The molten metal having passed through communicating tube 36 enters second vessel 40 through inflow port 38 positioned at the bottom of second vessel 40. The pressure on the molten metal is rapidly reduced when the molten metal goes upwardly inside second vessel 40. Then, the gas dissolved in the molten metal appears as fine gas bubbles. Those fine gas bubbles rise to the surface of the molten steel, trapping inclusions in the molten metal. The molten metal enters vacuum storage chamber 56 through outlet 42. In vacuum storage vessel 56, the inclusions are trapped by the gas bubbles and the fine gas bubbles produced by the bubbling and the pressure reduction respectively and rise to the surface of the molten metal. To remove the gas soluble in the molten metal, the molten metal is degassed inside vacuum storage vessel 56. The molten metal cleaned by removing the soluble gas is taken out through passage 42.

The present inventor conducted a test of processing molten steel containing a total amount of 80 ppm of oxygen by use of the present apparatus. The molten metal was continuously charged into a vessel through inlet 32 at a rate of 250 t/hr. The molten metal was bubbled by a mixed gas consisting of 60% Ar gas and 40% H₂ gas blown in from bubbling devices 44 and 46 at a rate of 200 l/min for 20 minutes. The molten metal containing a total amount of 12 ppm of oxygen was taken out in vacuum storage device at a rate of 250 t/hr through passage 42.

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Claims

1. A method for cleaning molten meta comprising:
 an inclusions removing process, wherein the inclusions having risen to the surface of the molten metal are
 5 removed,
 characterized by comprising a process of a bubbling process, wherein the gas soluble in molten metal is
 bubbled in said molten metal under increased pressure, the inclusions suspended in said molten metal are
 trapped by the gas bubbles produced by bubbling, and said gas is dissolved in said molten metal; and
 a pressure reduction process, wherein fine gas bubbles are produced in the molten metal by reducing a
 10 pressure on the molten metal in which gas is dissolved, and the inclusions suspended in the molten metal
 are trapped by the fine gas bubbles produced by reduction of the pressure; and
2. The method of claim 1, characterized in that gas soluble in molten metal includes nitrogen and
 hydrogen.
3. The method of claim 1 or 2, characterized in that said, wherein the molten metal under pressure
 15 includes the molten metal, to which a pressure of from 1 to 10 atm is applied.
4. The method of claim 1, 2 or 3, characterized in that said reduction of the pressure in said pressure
 reduction process includes the reduction of the pressure which is carried out in several stages.
5. The method of any one of claims 1 to 4, characterized by further comprising a process of
 suppressing the flutter of the molten metal surface by applying static magnetic field to the surface of the
 20 molten metal when the inclusions trapped by the gas bubbles produced by bubbling in the bubbling
 process go upwardly.
6. The method of any one of claims 1 to 5, characterized by further comprises a process of
 suppressing the flutter of the molten metal surface by applying static magnetic field to the surface of the
 molten metal when the inclusions trapped by the gas bubbles produced by bubbling in the pressure
 25 reduction process go upwardly.
7. The method of claim 5, characterized in that said static magnetic field includes the static magnetic
 field of magnetic flux of from 1000 to 5000 gaussses.
8. The method of claim 6, characterized in that said static magnetic field includes the static magnetic
 field of magnetic flux of from 1000 to 5000 gaussses.
9. The method of any one of claims 1 to 8, further comprising a process of stirring the molten metal
 30 during bubbling in said bubbling process.
10. The method of claim 9, characterized in that said stirring includes the stirring by an electromagnetic
 force of low frequency.
11. The method of any one of claims 1 to 10, characterized by further comprising a process of heating
 35 the molten metal during bubbling in said bubbling process.
12. The method of claim 11, characterized in that said heating includes heating by an electromagnetic
 force of high frequency.
13. The method of any one of claim 1 to 12, characterized further comprising a process of degassing
 the molten metal processed in said pressure reduction process in vacuum.
14. An apparatus for cleaning molten metal, characterized by comprising a process of
 40 a first vessel (30) which has an inlet(32) for charging molten metal at the top end thereof and an outlet(34)
 for discharging molten metal at the bottom thereof and in which the molten metal is pressurized by its static
 pressure;
 a second vessel (40) which has an inflow port(38) for the pressurized molten metal at the bottom thereof
 45 and an outflow port (42) for the molten metal and in which the pressurized molten metal goes upwardly and
 a pressure on the molten metal is reduced;
 a communicating tube (36) connecting the first vessel to the second vessel; and
 a first bubbling device (44) positioned at the bottom of the first vessel for bubbling the gas soluble in molten
 metal.
15. The apparatus of claim 14, characterized by further comprising a second bubbling device (46) in
 50 said communicating tube.
16. The apparatus of claim 14 or 15, characterized by further comprising a vacuum storage vessel (56)
 connected to the outlet for discharging molten metal which is arranged in said second vessel.
17. The apparatus of claim 14, 15 or 16, characterized by further comprising a gas storage chamber (54),
 55 by use of which a part of the bubbled gas is discharged.
18. The apparatus of any one of claims 14 to 17, characterized in that said first vessel has
 electromagnetic coils for stirring molten metal in said first vessel around said first vessel.

FIG. 1

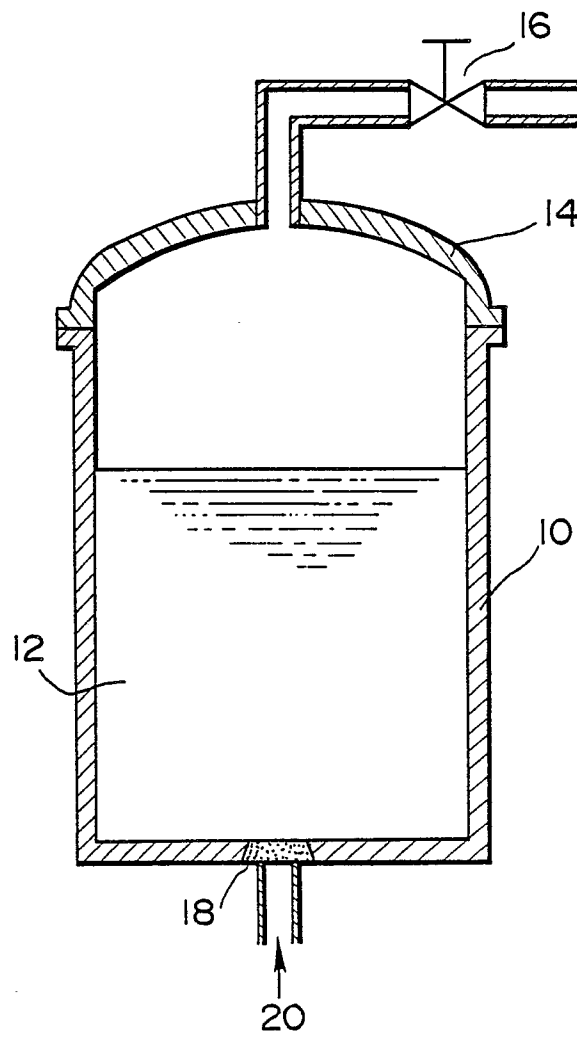


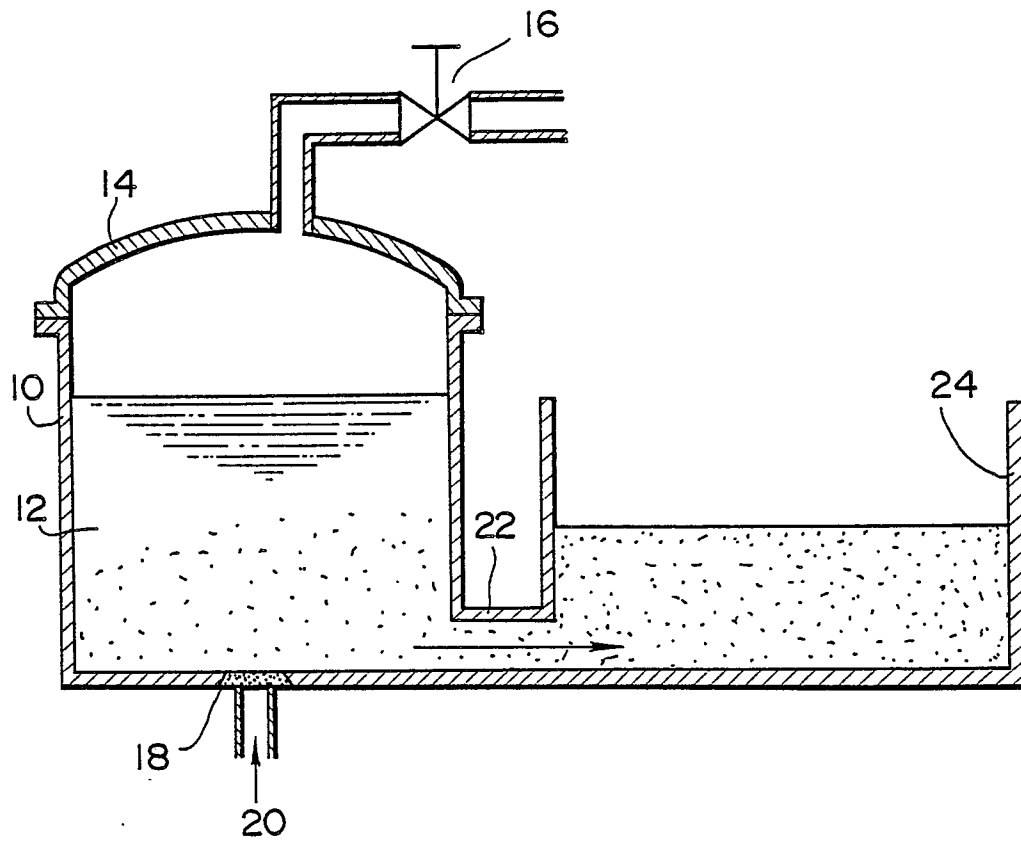
FIG. 2

FIG. 3

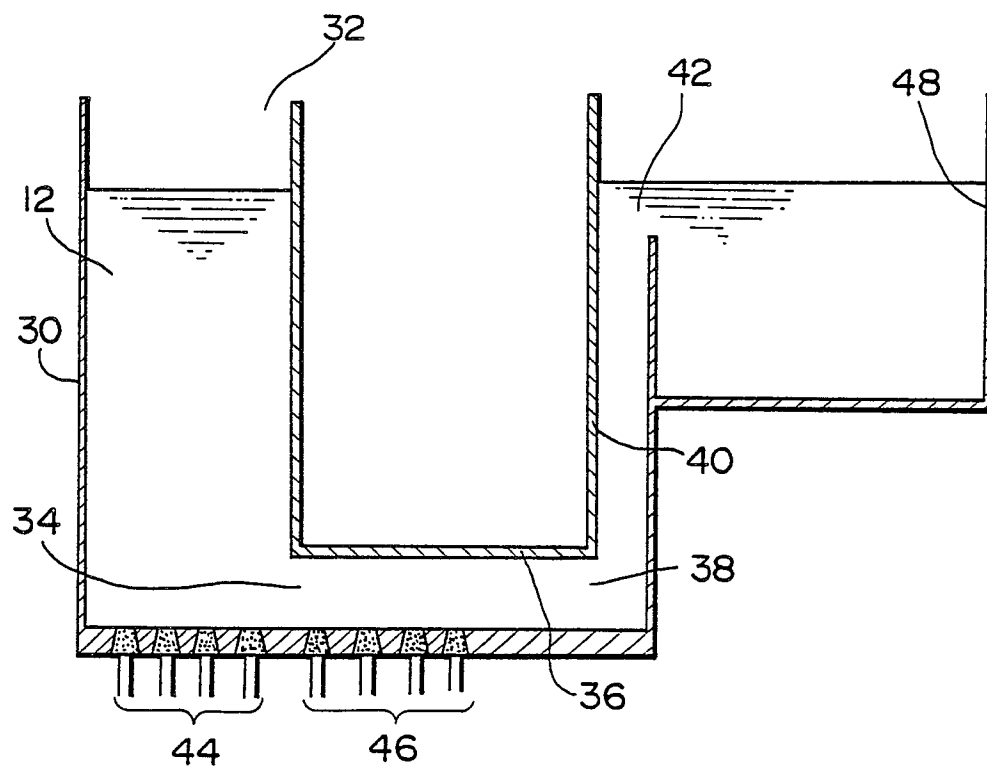


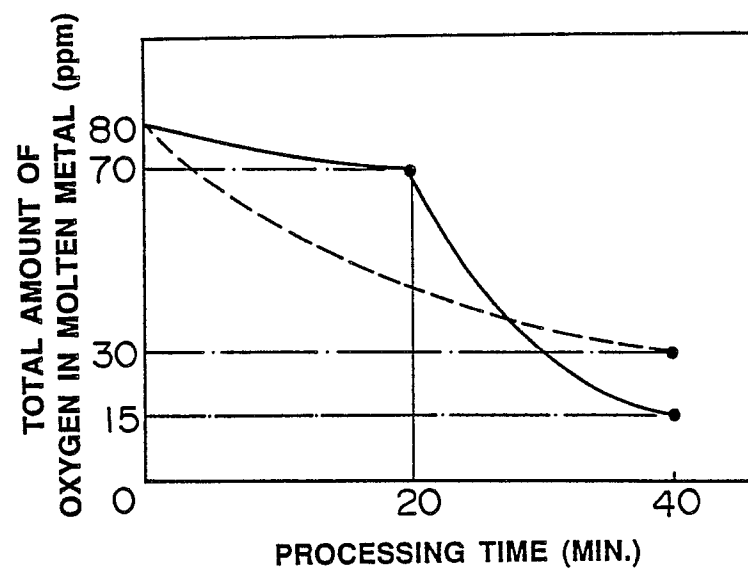
FIG. 4

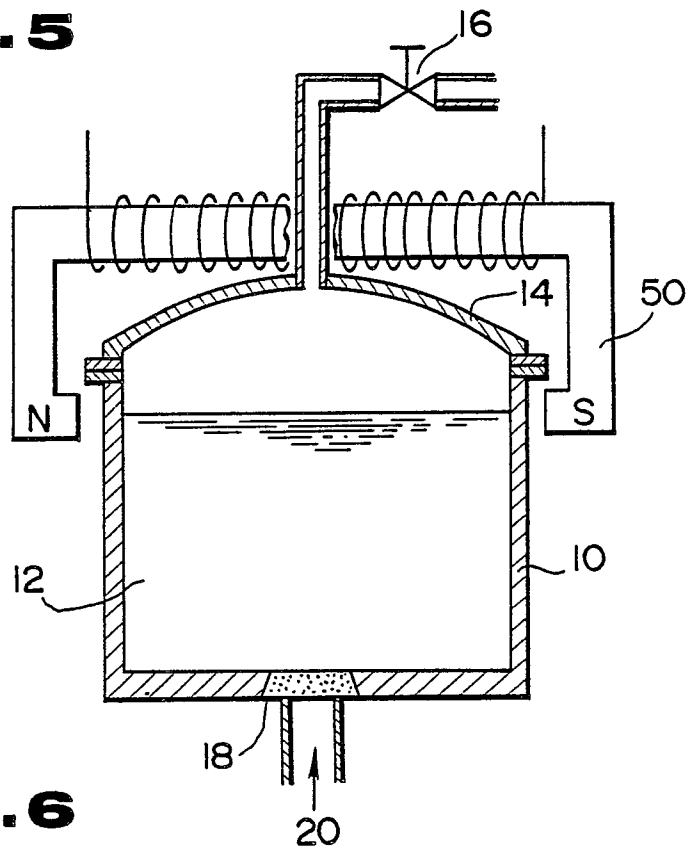
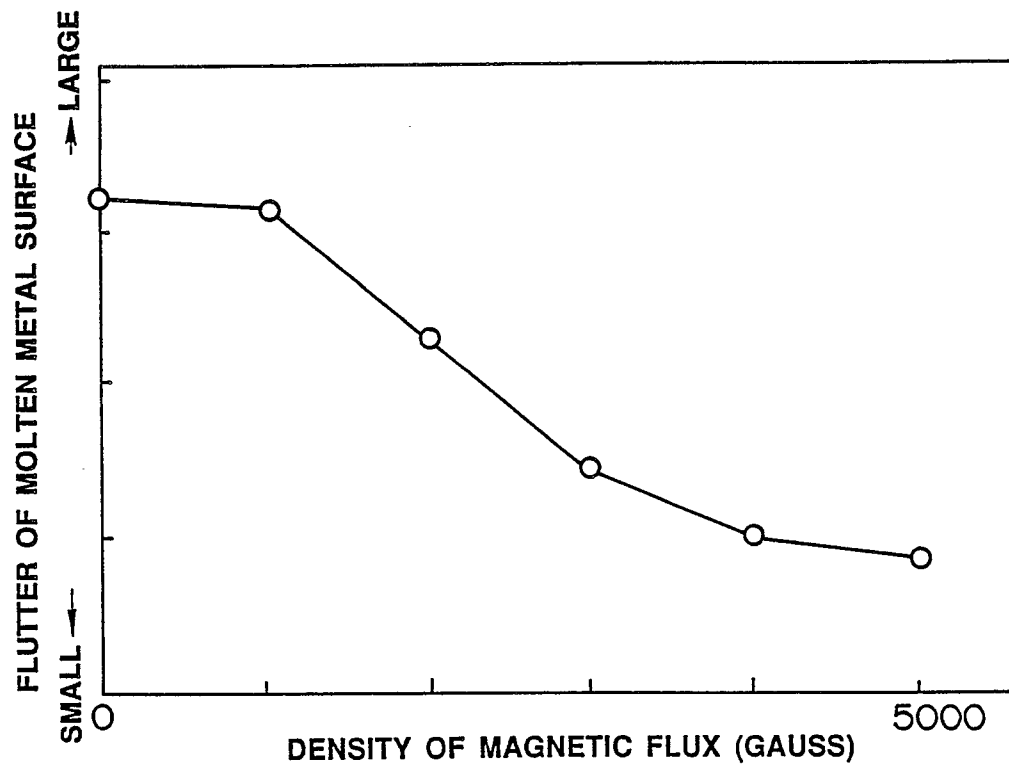
FIG. 5**FIG. 6**

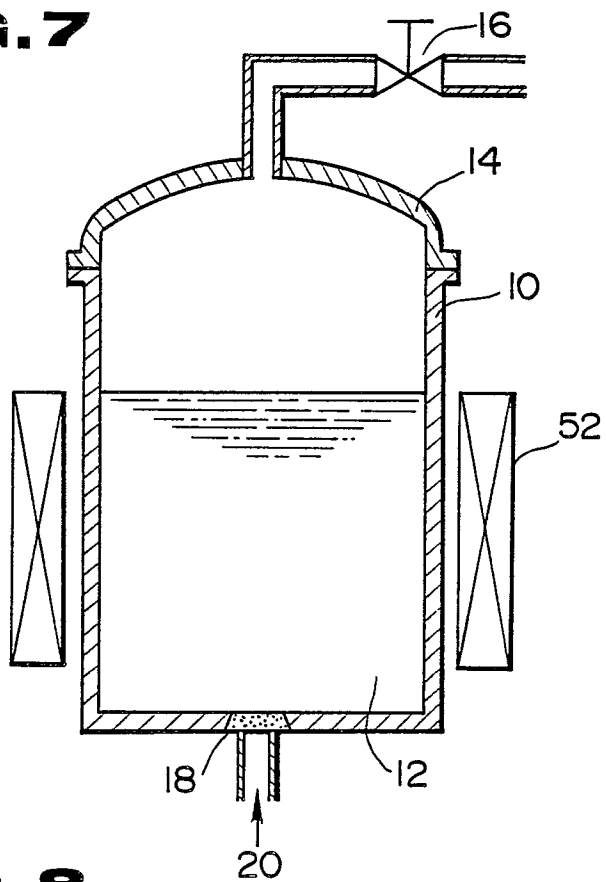
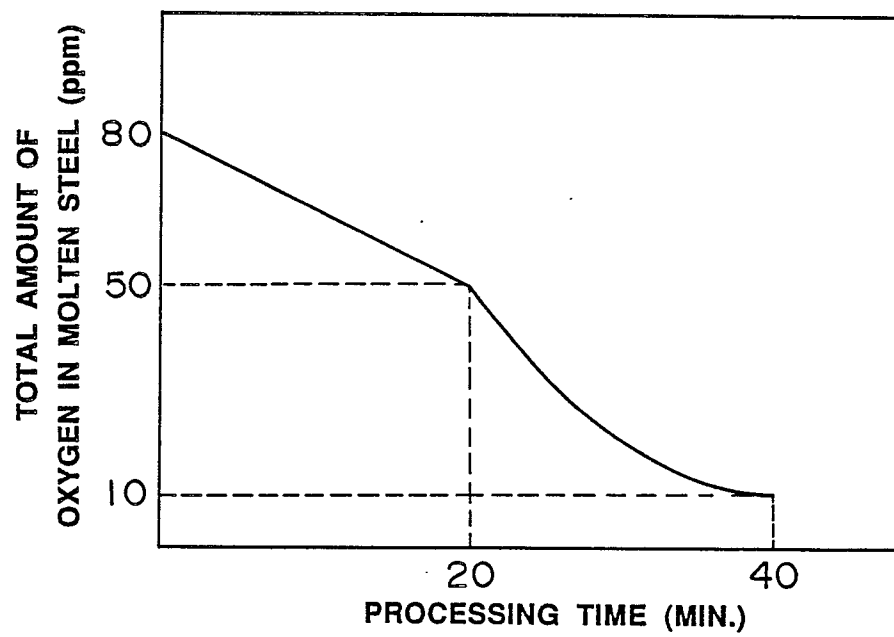
FIG. 7**FIG. 8**

FIG. 9