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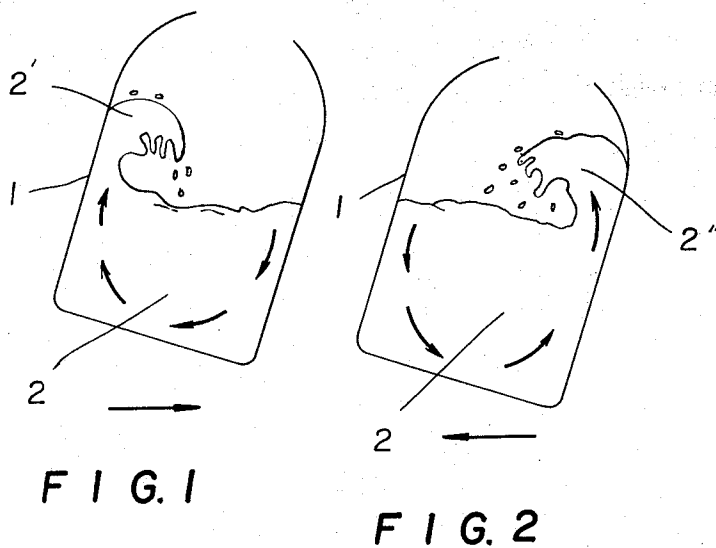
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3,334,993

METHOD OF AND APPARATUS FOR REFINING MOLTEN METALS

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2 Sheets-Sheet 1



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2 Sheets-Sheet 2

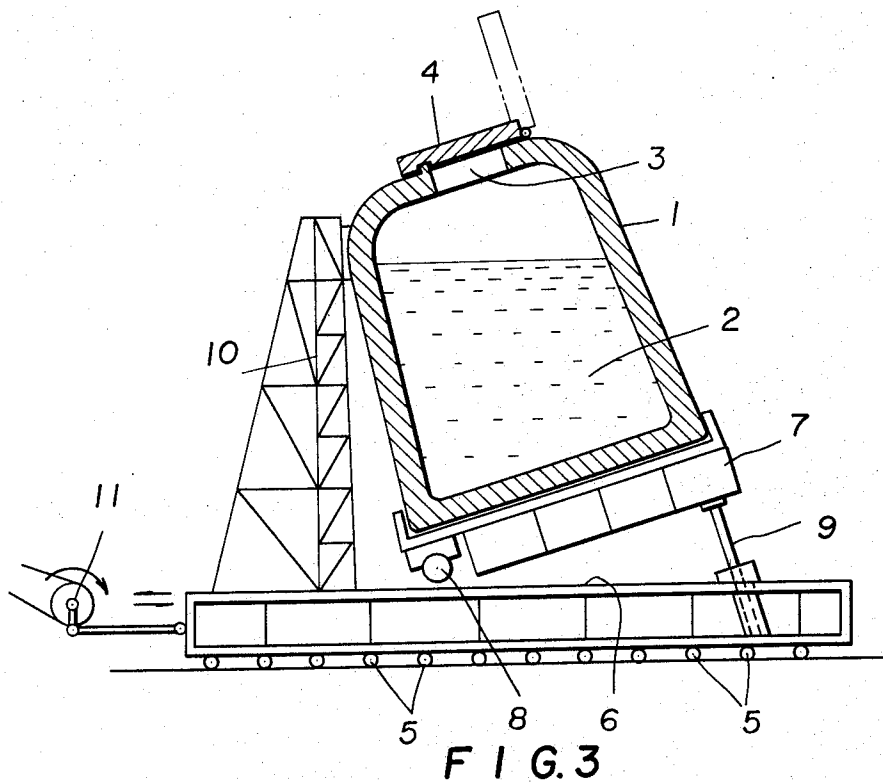


FIG. 3

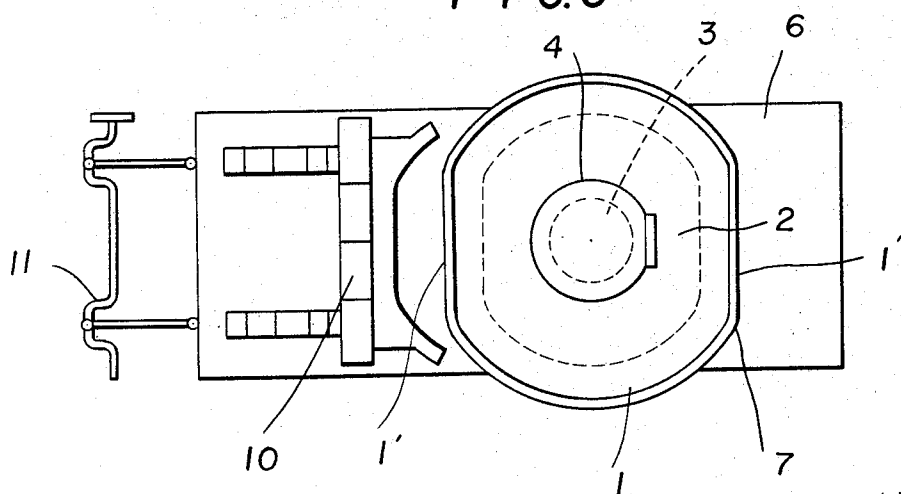


FIG. 4

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METHOD OF AND APPARATUS FOR REFINING MOLTEN METALS

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This invention relates to a method of and apparatus for further refining crude molten metals obtained from a blast furnace or other type of smelting furnaces, and more particularly to an improved method of and apparatus for improving contact between the crude molten metal contained in a reaction vessel and refining additives incorporated thereto, whereby to improve the efficiencies of desulfurization, dephosphorization, decarbonization, degassing of the metal or addition of certain elements to the metal.

To refine metals by removing impurities which consist of undesirable elements, included gases and non-metallic inclusions, from the crude molten metal, the practical method has comprised pouring the crude molten metal in such a metallurgical reaction vessel as a converter or a ladle, floating any suitable slag forming agents or other reagents upon the molten metal, and thus combining, physically or chemically, said addition agents and undesirable elements. In order to perform such a refining process at a high efficiency, it is necessary to increase the contact area between the molten metal and the addition agents, or to thoroughly agitate the whole mass, as is well understood by those skilled in the art.

The following four methods of agitation have been recently developed, and are presently used in research works or commercial production:

- (1) A method wherein an acting gas is blown into the reaction vessel.
- (2) An electromagnetic stirring method or an ultra-sonic vibrating method.
- (3) A method wherein the reaction vessel is rotated.
- (4) A method wherein the content of a reaction vessel is transferred by pouring to another vessel.

The method of blowing pure oxygen gas into a converter is widely used throughout the world on a large production scale as a revolutionary excellent method of making steel. Moreover, where it is desired to remove phosphorous, sulfur, carbon and the like which are contained in small quantities in pig iron or steel, the purifying method of using rotary drum type vessel or eccentrically moving type vessel has become the object of keen interest of modern refining art. However, with these apparatus the stirring action is not sufficiently effective notwithstanding complicated construction and vigorous motion, and further there are many problems to be solved from the standpoint of their construction and efficiency. In a relatively small scale refining installation the fourth method, wherein the content is transferred to another vessel, is after adopted, but as this method accompanies a rapid temperature fall, it is not an effective refining method. Electromagnetic and super-sonic stirring methods are still in the experimental stage.

An object of this invention is to provide a novel method of refining which can refine metals more rapidly and effectively than the prior art methods mentioned above.

A further object of this invention is to improve the conventional mechanically moving method utilizing a rotating vessel or an eccentrically revolving vessel whereby to provide a novel apparatus of simple construction and yet can be operated readily at a high efficiency.

These objects can be attained in accordance with this invention by putting crude molten metal and addition agents into a metallurgical reaction vessel, which is mounted on a platform provided with wheels at an in-

clined position with respect to a vertical line, and reciprocating the platform together with the reaction vessel in the horizontal direction and in the direction of inclination for a predetermined time.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which I regard as my invention, it is believed that the invention will be better understood from the following description taken in connection with the accompanying drawings, in which:

FIGS. 1 and 2 illustrate the states of stirring the content in a reaction vessel shaken in accordance with this invention;

FIG. 3 is an elevational view, partly in longitudinal section of a refining apparatus of this invention, with the reaction vessel in an inclined position; and

FIG. 4 is a plan view of the apparatus shown in FIG. 3, with the reaction vessel in the vertical position.

By the conventional rotary or eccentric type of method of refining molten metals, the content is shaken, but not substantially stirred in the reaction vessel notwithstanding its large motion. Due to the rolling motion of the content in the reaction vessel the contact area between the molten metal and the addition agents is increased than the prior method using a stationary vessel, so that the former method is more effective than the latter. However, large contact area does not always assure good refining action. This is because that since the molten metal at the bottom of the vessel is difficult to circulate toward the upper layer, it requires substantially long time until all of the molten metal is brought into contact with the additive agents floating on the molten metal. If it is possible to easily stir the content in the reaction vessel it would be readily expected that it is not only possible to increase the contact area but also to improve the circulation of the molten metal and the addition agents, thus greatly reducing the refining time. Even when the above mentioned reaction vessel of the rotary or eccentric type is used, a certain degree of agitation could be expected when their speed of rotation is increased. However, too fast revolution will result in the complication of the construction of the refining apparatus and also in damage to the inner side wall of the brick lining. Thus it will be clear that there is a certain limit for the speed of revolution.

According to this invention, a vertical type vessel containing the molten metal and the additive agents is fixedly supported at a slightly inclined position on a platform provided with wheels, and the vessel is merely reciprocated in the horizontal direction and in the direction of inclination without imparting any revolving motion. By this method it was found that contact by agitation between the molten metal and the addition agents could be exceptionally improved thus completing the refining operation in very short time without accompanying undue lowering of the temperature of the content.

The principle of stirring of this invention will now be considered by referring to FIGS. 1 and 2 of the accompanying drawing. More particularly, when an inclined reaction vessel 1 is reciprocated in the horizontal direction as shown by horizontal arrows, the content 2 will be impacted upon the inclined side and bottom walls of the vessel due to its inertia to rise upwardly along the side wall which is on the side opposite to the direction of movement, and will then fall down like a billow, as indicated by reference numerals 2' and 2''. As a result the content will be caused to circulate as shown by arrows to be thoroughly stirred in a short time.

The angle of inclination of the reaction vessel with respect to the vertical axis is preferably to be selected within a range of from 10° to 30° depending upon the type of the molten metal and the configuration of the

reaction vessel. However, angle of from about 15° to 20° was found generally most effective. While the stroke of horizontal reciprocating motion may be about 10 cm., it may be selected to be in a range of from 5 to 20 cm. depending upon the specific gravity of the molten metal and the capacity of the reaction vessel. Too large stroke will cause vigorous agitation to incur overflow of the content beyond the upper edge of the vessel, whereas too small stroke will result in mere rolling of the content, thus not causing stirring by billow like motion. The condition of stirring is also dependent upon the number of reciprocating motions per unit time. The more the number of reciprocating motions the severer is the agitation. However, too large number of reciprocating motion not only causes the content to overflow but also necessitates structural reinforcement as well as excessive operating power, which are uneconomical. Usually, 30 reciprocations per minute is preferable, but it is preferable to select the number of reciprocations per minute in a range of from approximately 10 to 50.

The configuration of the reaction vessel utilized in this invention may be of any desired form, but the results of experiment showed that vessels having flat surfaces at the sides perpendicular to the direction of reciprocating motion could provide more effective stirring action than those having a circular or elliptical cross section as in the conventional vessels. It was also found that reaction vessels having a trapezoidal vertical cross section could be more stably supported at an inclined angle on the platform and could provide larger stirring action than cylindrical vessels. It is preferable to close the charging mouth at the upper end of the reaction vessel by means of a removable cover or lid in order to prevent splash or overflow of the molten metal as well as the addition agents. The cover also serves to prevent heat loss due to radiation through the charging mouth.

FIGS. 3 and 4 show a preferred construction of a refining apparatus embodying this invention. As shown the upper end of a trapezoidal reaction vessel 1 having slightly larger bottom surface is closed by a curved ceiling having a perforation or charging mouth 3, which is normally closed by a lid 4. The configuration of the reaction vessel is not frusto-conical but, as shown in FIG. 4, left and right sides 1' and 1'' are flat. The reaction vessel is mounted on a platform 6 provided with a plurality of wheels 5 through a box like support 7. One end of the support 7 is hinged to the platform 6 by means of a transversal pivot pin 8, while the opposite end is supported by an adjustable means such as an oil jack 9 mounted on the platform 6. An upright support 10 is provided to prevent the reaction vessel from falling down during reciprocating motion when it is inclined by the operation of the oil jack 9. To the fore end of the platform 6 is connected a suitable crank mechanism 11 which is driven by an electric motor (not shown), thus imparting reciprocating motion to the inclined reaction vessel. As already pointed out the reaction vessel is mounted on the platform in such a manner that its flat sides 1' and 1'' cross at right angles the direction of reciprocation.

While it is preferable to construct the reaction vessel to have trapezoid shape from the standpoints of stable mounting and improved stirring action, a barrel type configuration having the largest diameter at the central portion is also preferred for stronger stirring action, in which case a more rigid supporting structure should be used against inclination, falling down and instability during reciprocation.

When the inclined reaction vessel is reciprocated according to this invention, the motion of the reaction vessel is more quiet and smooth than the conventional reaction vessel of the rotary drum type or eccentric type, thus decreasing damage of the vessel and the required driving power. Further the stirring action for the contents of the reaction vessel is far stronger, which is the feature of this invention.

Following examples show the results of this invention carried out in a laboratory.

Example 1

Two tons of molten pig iron were charged in a refining vessel having an average diameter of 0.8 m., a height of 2 m. and a configuration as shown in FIGS. 3 and 4. This is subjected to desulfurization under conditions of the inclination angle 15°, the stroke 12 cm., the number of reciprocations per minute 30 and the temperature 1330° C. of the molten pig iron at the commencement of operation. As the addition agents, 7 kg. of calcined lime and 14 kg. of calcium carbide were used. After treatment of 8 minutes the sulfur content of the molten pig iron was decreased to 0.012% from the initial value of 0.056%, which corresponds to 79% desulfurization. With conventional method of desulfurization utilizing a rotary vessel the treating time of about 15 to 20 minutes are required to attain the same percentage of desulfurization. Thus it will be clear that by the inventive method and apparatus it is possible to reduce the treating time to less than about one half to simplify the construction and to make more smooth the motion of the reactive vessel, thus permitting very economical refining.

The relation between treating time and decrease in the percentage of sulfur is shown in the Table 1.

TABLE 1—PROCEEDINGS OF DESULFURIZATION

	Time elapsed (min.)						
	0	2	4	6	8	10	12
Sulfur content in the molten pig iron (percent $\times 10^{-3}$)	56	45	31	17	12	11	10
Percentage of desulfurization	0	20	45	69	79	81	82

Example 2

This example shows the results of addition of Si into molten pig iron using the same apparatus and under the same conditions as in Example 1. While metallic ferro-silicon is usually employed as the additive for adding silicon, as the specific gravity of ferro-silicon is smaller than that of the molten pig iron, the added ferro-silicon floats on the surface of the molten pig iron. Accordingly, without proper stirring, only the surface portion of the molten pig iron will increase silicon content, and it would be difficult to uniformly increase the silicon content throughout the molten pig iron. By this reason, addition of silicon is usually performed by transfer pouring method of the molten metal, but this method is not effective to provide uniform distribution of silicon because of temperature fall. However, according to the process of this invention substantially uniform addition was realized by the reciprocation motion of only 5 minutes.

Example 3

In this example non-metallic inclusions in molten steel were removed by using the same apparatus as in Example 1. The composition of the molten steel was:

	Percent
C	0.032
Si	3.15
Mn	0.08
P	0.012
S	0.016

Two tons of molten steel of 1580° C. temperature were put in a reaction vessel, and as the flux 30 kg. of pig iron smelting slag and 20 kg. of fluorspar were added thereto. Thereafter the molten steel was stirred for 10 minutes under the same conditions as in Example 1. As a result the non-metallic inclusions in the molten steel were adhered to the flux and removed together therewith. The non-metallic inclusion contents of 0.0252% SiO₂ and 0.0076% Al₂O₃ before treatment were reduced respec-

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tively to 0.0127% SiO_2 and 0.0037% of Al_2O_3 after treatment. This means that the contents of the non-metallic inclusions were reduced to about one half, thus greatly improving the purity of the molten steel. Especially, it has been quite difficult to remove Al_2O_3 by any known technique because it does not readily float on the molten metal. Thus it is particularly to be noted that Al_2O_3 can be easily reduced to one half by the novel method of this invention.

While the invention has been explained by describing particular embodiments thereof, it will be apparent that improvements and modifications may be made without departing from the scope of the invention as defined in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A method of refining molten metals comprising the steps of pouring crude molten metal and additive agents into a metallurgical reaction vessel which is mounted at an inclined angle with respect to a vertical line on a platform provided with wheels, and reciprocating said platform together with said vessel in the horizontal direction and in the direction of inclination for a predetermined time.

2. The method of refining molten metals according to claim 1 wherein said angle of inclination is from 10° to 30° .

3. The method of refining molten metals according to claim 1 wherein the stroke of said horizontal reciprocating motion is from 5 to 20 cm.

4. The method of refining molten metals according to claim 1 wherein the number of reciprocating motions is from 10 to 50 per minute.

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5. An apparatus for refining molten metals comprising a metallurgical reaction vessel provided with a removable lid, a platform provided with wheels, means to support said reaction vessel on said platform at an inclined position, said means including a box adapted to support said reaction vessel, a transversal pivot at one end of said box pivotally connected to said platform, adjustable means provided at the other end of said box to adjust the inclination thereof, and means to reciprocate said platform together with said reaction vessel in the horizontal direction.

6. The apparatus for refining molten metals according to claim 5 wherein the configuration of said reaction vessel is trapezoidal having slightly larger bottom surface.

7. The apparatus for refining molten metals according to claim 5 wherein said reaction vessel is of barrel shape.

8. The apparatus for refining molten metals according to claim 5 wherein both sides of said reaction vessel are flat, and said reaction vessel is so mounted on said platform that said flat sides are to the direction of reciprocation of said platform.

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