

June 27, 1972

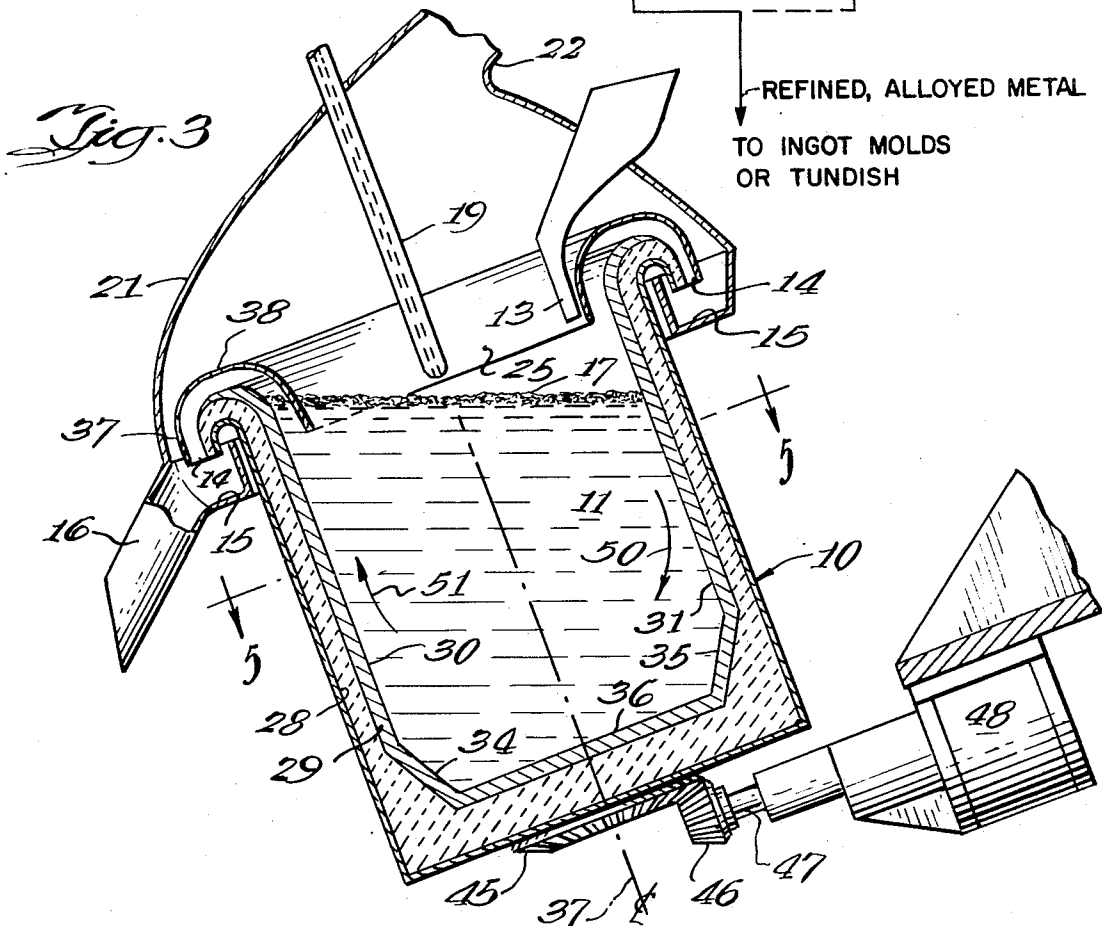
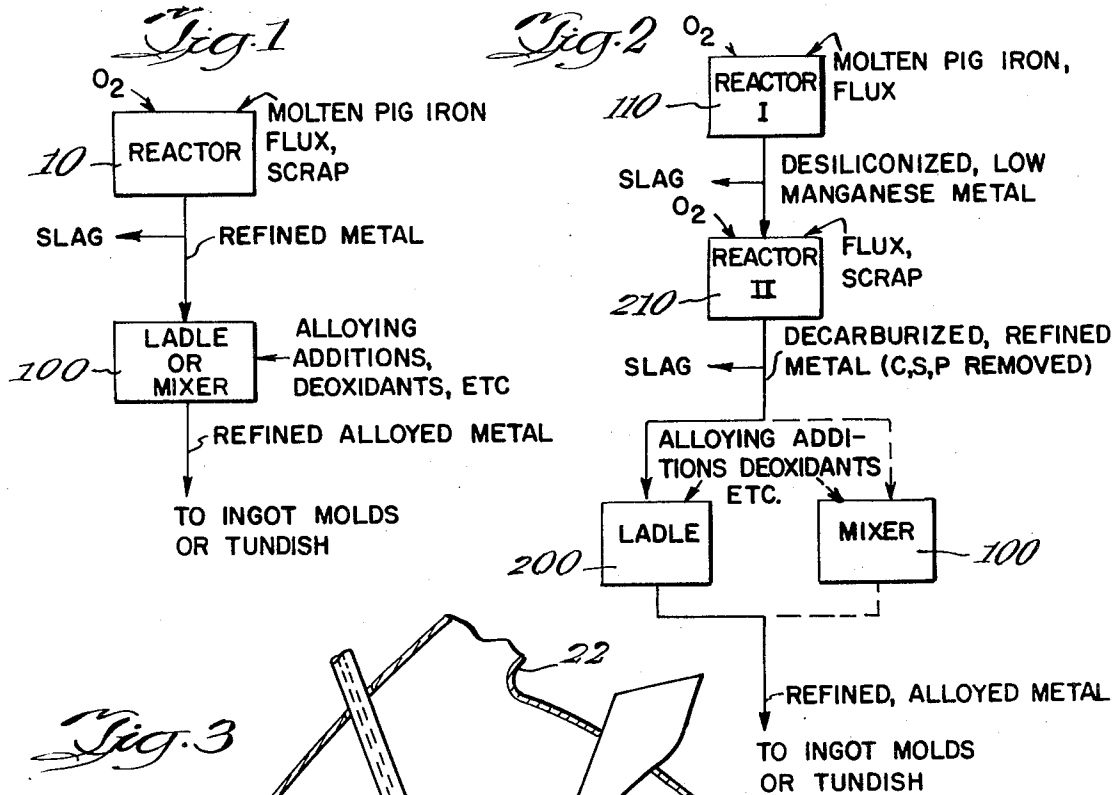
C. F. NIEHAUS

3,672,869

CONTINUOUS METALLURGICAL PROCESS

Filed April 13, 1970

3 Sheets-Sheet 1



INVENTOR

Conrad J. Niehaus

BY Merrison, Marshall, Shapiro & Klose
ATTORNEYS

June 27, 1972

C. F. NIEHAUS

3,672,869

CONTINUOUS METALLURGICAL PROCESS

Filed April 13, 1970

3 Sheets-Sheet 2

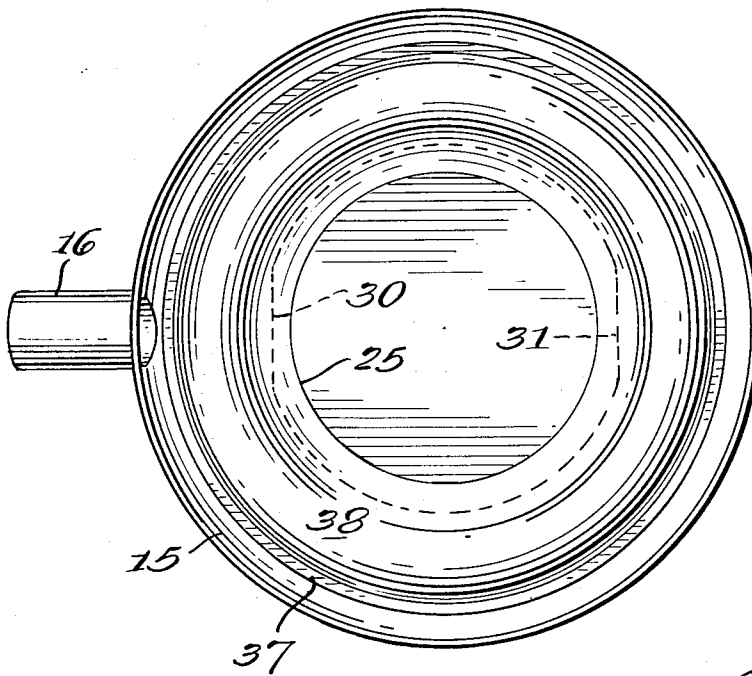
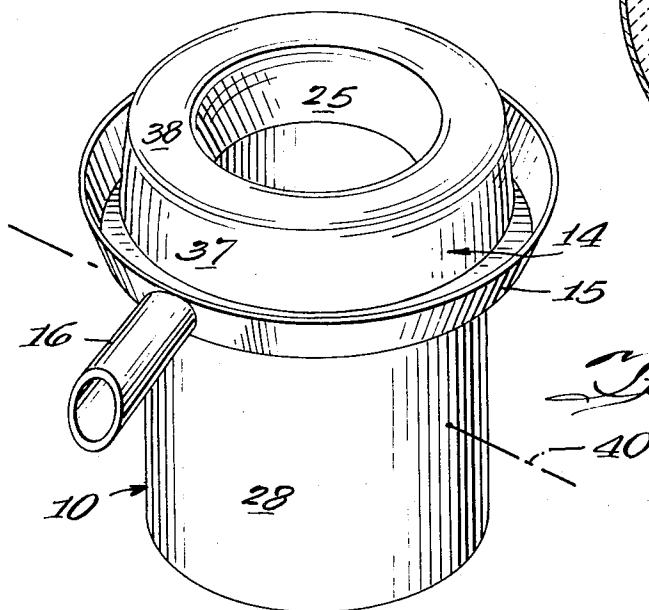
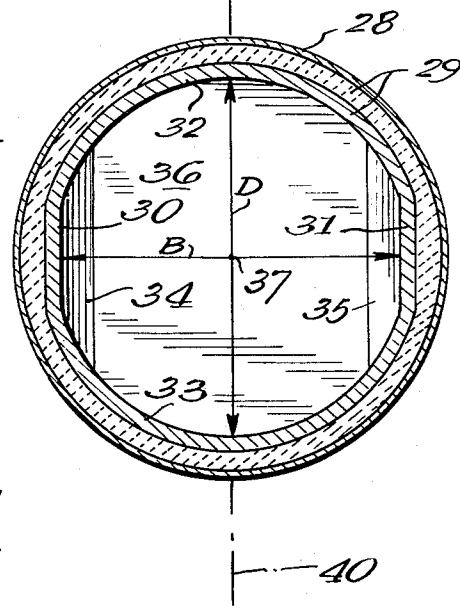


Fig. 5



INVENTOR

Conrad F. Niehaus

BY Merriam, Marshall, Shapiro & Kline
ATTORNEYS

June 27, 1972

C. F. NIEHAUS

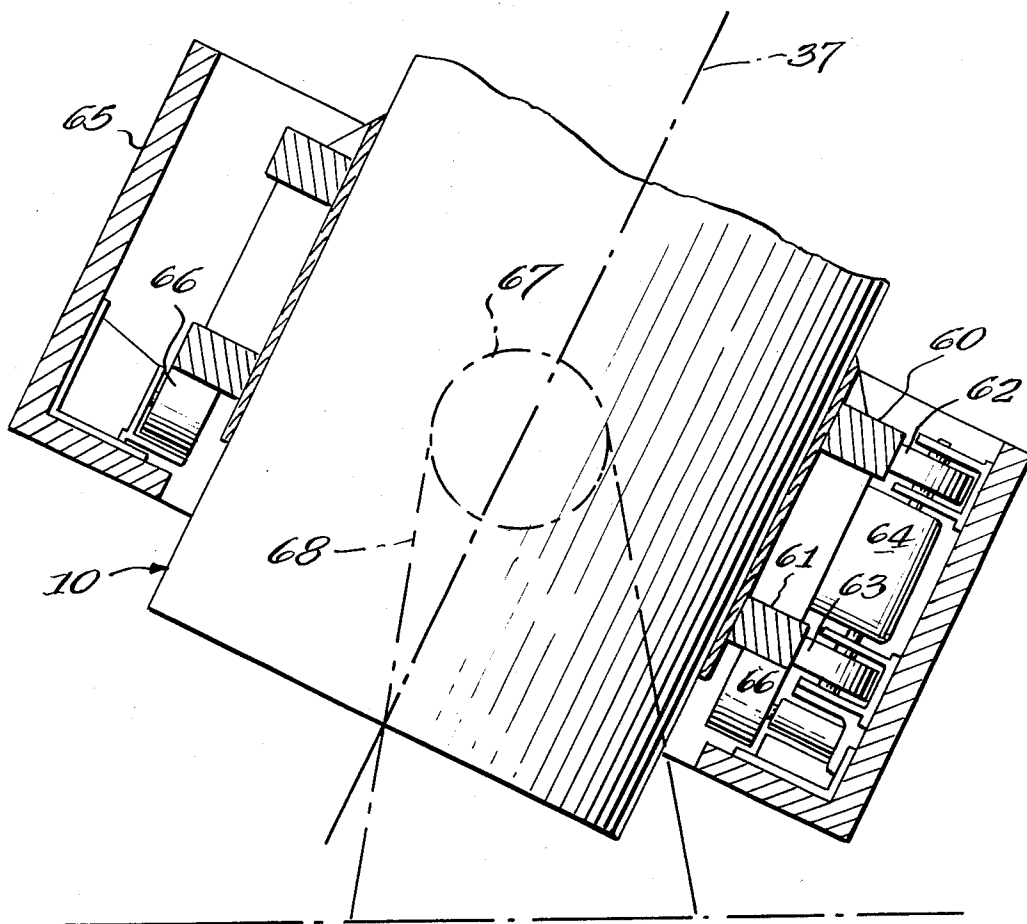
3,672,869

CONTINUOUS METALLURGICAL PROCESS

Filed April 13, 1970

3 Sheets-Sheet 3

Fig. 7



INVENTOR

Conrad J. Niehaus

BY Merriam, Marshall, Shepard & Klose

ATTORNEYS

1

3,672,869

CONTINUOUS METALLURGICAL PROCESS
 Conrad F. Niehaus, 2 Muirfield Road, Emmarentia,
 Johannesburg, Transvaal, Republic of South Africa
 Filed Apr. 13, 1970, Ser. No. 27,695
 Int. Cl. C21c 1/00, 7/00

U.S. Cl. 75—45

18 Claims

ABSTRACT OF THE DISCLOSURE

Relatively unrefined or untreated molten metal and one or more treating or refining ingredients (e.g., oxygen, flux, alloying addition) are continuously introduced onto the top of a bath of relatively refined or treated molten metal contained in a predominantly vertically tilted vessel, rotated about its longitudinal axis. Surface and sub-surface bath currents, resulting from rotation of the tilted vessel, enhance and speed up the refining or treating action. Relatively refined or treated molten metal is continuously withdrawn from the top portion of the bath, at the front of the vessel, at a location spaced from the location at which the unrefined or untreated molten metal is introduced.

BACKGROUND OF THE INVENTION

The present invention relates generally to metallurgical refining processes, such as steel-making processes, and more particularly to converting a relatively unrefined molten metal, such as molten pig iron, into a refined molten metal, such as steel, using a continuous process. Herein, the term "metal" includes alloys.

Conventionally, commercially practicable metallurgical refining processes are batch-type operations. For example, commercially practicable steel-making processes, whether utilizing a Bessemer furnace, an open-hearth furnace, an electric arc furnace or an oxygen converter, are batch-type operations.

A continuous metallurgical refining process has readily apparent advantages over a batch-type operation. To economically produce large quantities of refined molten metal, such as steel, use of the oxygen converter is desirable; but conventional techniques accompanying the use of oxygen converters do not lend themselves to a continuous process.

SUMMARY OF THE INVENTION

The present invention provides a continuous metallurgical refining process utilizing an oxygen converter, thereby combining the advantages of both.

A method in accordance with the present invention comprises containing a bath of relatively refined molten metal in a cup-shaped reactor vessel tilted to a predominantly vertical angular position and rotated about its longitudinal axis. This causes both a surface and a sub-surface mixing action within the bath. At the same time, the bath is maintained as a continuous mass. The surface mixing action is produced by surface waves. The sub-surface mixing action includes downwardly moving bath currents adjacent the downwardly facing inner wall surface at the back of the tilted reactor vessel and upwardly moving bath currents at the upwardly facing inner wall surface at the front of the tilted reactor vessel.

Relatively unrefined molten metal is continuously introduced into the top portion of the bath, preferably adjacent the downwardly facing inner wall surface at the back of the vessel.

One or more refining ingredients (e.g., oxygen, flux) are continuously introduced onto the top of the bath undergoing the aforementioned mixing action, to remove impurities in the molten metal and thereby refine the

2

latter. A flux is a material which combines with oxidized or unoxidized impurities in the molten metal to form a slag which floats as a separate layer atop the molten metal. Many impurities will not readily enter the slag until they have been oxidized. Impurities may be oxidized by blowing a stream of oxygen onto the top of the bath.

The oxygen is introduced by a conventional oxygen lance, but the pressure of the oxygen is preferably controlled to avoid significant interference with the subsurface bath currents produced by the movement imparted to the tilted reactor vessel.

Fluxes may be introduced at approximately the same location as is the relatively unrefined molten metal, for example.

The angle of tilt and the volume of molten metal in the vessel are controlled to permit overflow withdrawal of molten metal from the top portion of the bath adjacent the upwardly facing inner wall at the front of the tilted vessel. Relatively refined molten metal (with some slag) is continuously withdrawn from the top portion of the bath at a location spaced from the location at which the relatively unrefined molten metal is introduced.

The refining ingredients (e.g. oxygen, flux) are supplied at a rate sufficient to quantitatively reduce the impurities, in the continuously introduced unrefined molten metal, to the desired level of refinement. The relatively refined molten metal is withdrawn at substantially the same rate as the relatively unrefined molten metal is introduced; and the volume of unrefined molten metal in the reactor vessel, at any given time, is relatively small compared to the volume of refined molten metal in the reactor vessel.

The process may utilize one or more vessels, in series. Such a series of reactor vessels is desirable where the unrefined molten metal contains at least two impurities one of which requires refining conditions, for optimum removal, different than those conditions desirable for removal of the other impurity. The first tilted, rotated reactor vessel is used to remove a first impurity under conditions which favor its removal, thereby partially refining the molten metal; and the second tilted, rotated reactor vessel is used to remove the second impurity under conditions which favor its removal, thereby completing the refinement.

A tilted, rotated reactor vessel may also be used, without the addition of oxygen or other refining ingredients, to mix continuously added refined molten metal from a preceding reactor vessel with continuously added alloying ingredients. All reactor vessels are tilted and rotated about their longitudinal axes to produce the bath mixing currents described above.

Other features and advantages are inherent in the process claimed and disclosed or will become apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow diagram of an embodiment of a continuous metallurgical refining process in accordance with the present invention;

FIG. 2 is a flow diagram of another embodiment of the continuous process;

FIG. 3 is a vertical sectional view illustrating an embodiment of apparatus utilized in the process;

FIG. 4 is a top plan view of a portion of the apparatus;

FIG. 5 is a sectional view taken along line 5—5 in FIG. 3;

FIG. 6 is a perspective of a portion of the apparatus; and

FIG. 7 is a vertical sectional view illustrating another embodiment of apparatus utilized in the process.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring initially to FIGS. 3-6, illustrated generally at 10 is a reactor vessel having a steel outer shell 28 lined on the interior with refractory 29. Contained within vessel 10 is a bath 11 of relatively refined molten metal atop which floats a layer of slag 17. Reactor vessel 10 is mounted for tilting about a horizontal axis 40 (FIGS. 5 and 6) with conventional tilting structure such as that shown in Murer U.S. Pat. No. 3,219,322. In its operative position, vessel 10 is tilted to a predominantly vertical angular position, as illustrated in FIG. 3.

As used herein, the term "rear" or "back" is used to identify the right side of the vessel (as viewed in FIG. 3) and the term "front" is used to identify the left side of the vessel (as viewed in FIG. 3).

Covering reactor vessel 10 is a hood 21 through which extends an inlet spout 13 for introducing relatively unrefined molten metal into the top portion of the bath, preferably adjacent the downwardly facing inner wall at the back of the tilted reactor vessel.

The angle to which vessel 10 is tilted and the volume of molten metal in the vessel are controlled to permit overflow withdrawal of molten metal from the top portion of the bath, adjacent the upwardly facing inner wall at the front of the reactor vessel, through a peripheral withdrawal spout 14 attached to the top of vessel 10. Spout 14 extends around the entire outside of the vessel, and comprises an outer wall 37 integral with a top portion 38 from which depends an internal peripheral lip 25 extending downwardly within the interior of vessel 10 adjacent the top thereof.

Extending through hood 21 is an oxygen lance 19 for directing oxygen onto the top of bath 11. Hood 21 communicates with an exhaust duct 22 for exhausting reaction gases and fumes from the top of reactor vessel 10.

Referring to FIG. 3, vessel 10, spout 14 and internal peripheral lip 25 are mounted for rotation, as a unit, about the longitudinal axis 37 of vessel 10 by structure including a gear 45 attached to the bottom of vessel 10 on the outside thereof and engaged by a pinion 46 driven by a shaft 47 driven by a motor 48 attached to a cradle (not shown) also mounting vessel 10. A detailed description of such a cradle is contained in Murer U.S. Pat. No. 3,219,322.

FIG. 7 illustrates a preferred embodiment utilizing a side-mounted drive for rotating vessel 10 about its longitudinal axis 37. Attached to the outside of vessel 10 are upper and lower circumferential rings 60, 61, respectively, each engaged by a respective driving wheel 62, 63, driven by a motor 64. Driving wheels 62, 63 and motor 64 are mounted on an annular cradle 65 encircling vessel 10. Also mounted on cradle 65 are supporting rollers 66 atop which rests lower ring 61. Cradle 65 is mounted for tilting about the axis of trunnion pins (phantom lines 67) mounted on stanchions (phantom lines 68). Vessel 10 tilts with cradle 65.

In the illustrated embodiment, vessel 10 has a pair of diametrically opposed substantially planar inner wall portions 30, 31 connected by a pair of curved inner wall portions 32, 33. A pair of opposed inwardly inclined lower wall portions 34, 35 each extend between a respective one of planar inner wall portions 30, 31 and a vessel bottom 36.

For convenience of reference, the distance between planar inner walls 30, 31, along a line passing through longitudinal axis 37 of vessel 10, is given the designation B; and the distance between curved inner walls 32, 33 along a line also passing through longitudinal axis 37 is given the designation D. In a typical embodiment of reactor vessel 10, the ratio of D to B is 1.15. Because the inner walls of vessel 10 are composed of refractory material, during continued use of the vessel the walls will be eroded away; but the interior of the vessel will retain

substantially the cross sectional shape shown in FIGS. 3 and 5.

The angle of inclined walls 34, 35 is typically about 45°.

The angle to which vessel 10 is tilted is predominantly vertical, i.e., an angle at which the vessel's longitudinal axis 37 is less than 45° from the vertical. Typically, the angle of tilt is about 20-30° from the vertical and it should be at least about 10° from the vertical. A typical speed of rotation for vessel 10 is about 15-20 revolutions per minute. In some embodiments a minimum of about 5-10 revolutions per minute is necessary to obtain the desired mixing action. Once the desired mixing action is underway, it can be maintained with a slower speed of rotation. The larger the vessel, the slower the speed required. In some embodiments, the speed of rotation generally should not exceed about 30 revolutions per minute. Permissible minimum and maximum speeds for particular vessels can be readily determined by those skilled in the art.

When a reactor vessel, having an interior constructed as described above, is tilted and rotated, as described above, the movement imparted to the tilted reactor vessel 10 produces downwardly moving bath currents adjacent the downwardly facing inner wall at the back of the tilted reactor vessel and upwardly moving bath currents adjacent the upwardly facing inner wall at the front of the tilted reactor vessel, as indicated by the arrows 50, 51. Between these two walls there are other sub-surface bath currents having radial directional components. All of these bath currents produce sub-surface mixing within bath 11. Rotation of the tilted reactor vessel also produces mixing at the surface of bath 11 due to the formation of surface waves.

The downward movement of bath current 50 is at a maximum when one of the planar inner wall portions 30, 31 is at the back of the tilted reactor vessel, during rotation thereof; and the upward movement of bath current 51 is at a maximum when one of the planar inner wall portions is at the front of the tilted reactor vessel, during rotation thereof.

In operation, tilted reactor vessel 10 is continuously rotated about its longitudinal axis 37 thereby continuously producing the aforementioned surface and sub-surface bath currents. Relatively unrefined molten metal and flux are continuously introduced through inlet spout 13 into the top portion of bath 11, adjacent the rear of vessel 10.

In one embodiment wherein unrefined molten metal is introduced into the bath at the rear of the vessel, introduction is restricted substantially to those times when a planar inner wall portion 30, 31 is also at the rear of vessel 10, during rotation thereof (to the right in FIG. 3), these being the times when downward movement of bath current 50, at the location of introduction of the unrefined molten metal, is at a maximum. In such an embodiment, continuous introduction of unrefined molten metal would be as a continuous succession of spurts rather than as a continuous flow.

Oxygen is continuously introduced through lance 19 onto the top of bath 11 to oxidize the impurities in the molten metal and thereby refine the latter. Preferably, the pressure of the oxygen is controlled to avoid significant interference with the sub-surface bath currents produced by rotating the tilted reactor vessel 10. Because the oxygen is not needed to start and maintain turbulence, the resulting lower usable oxygen pressure reduces the amount of iron lost by fuming.

Oxygen is supplied through lance 19 at a rate sufficient to quantitatively reduce the impurities, in the continuously introduced unrefined molten metal, to the desired level of refinement. Flux is added at a rate sufficient to form slag with the impurities introduced with the unrefined molten metal.

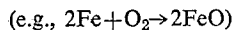
Relatively refined molten metal (with some slag) is withdrawn through withdrawal spout 14, by overflow, at

5

substantially the same rate as the relatively unrefined molten metal is introduced. The volume of unrefined molten metal in reactor 10, at any given time, is relatively small compared to the volume of refined molten metal in the reactor vessel.

Relatively unrefined molten metal and refining ingredients (flux) introduced into the top portion of the bath adjacent the rear of the reactor vessel, are carried downwardly, by downwardly moving bath current 50 at the back of the reactor vessel, below the surface of the bath where they are mixed with the relatively refined molten metal and subjected to a refining action.

Oxygen introduced onto the top of the bath initially oxidizes at least some of the molten metal



which in turn oxidizes the oxidizable ingredients in the unrefined molten metal (e.g., $2FeO + Si \rightarrow SiO_2 + 2Fe$). The surface and sub-surface mixing action carries oxidizing agent (e.g., FeO) below the surface of the bath to promote the refining action.

Upwardly moving bath current 51 adjacent the front of the reactor vessel carries relatively refined molten metal upwardly, toward withdrawal spout 14. Lip 25 maintains a separation between that part of the top portion of the bath at which refined molten metal is withdrawn and that part of the top portion of the bath into which the relatively unrefined molten metal is introduced. Refined molten metal which has undergone the sub-surface mixing action is withdrawn at spout 14.

Relatively refined molten metal withdrawn through spout 14 flows into a gutter 15 from which it flows through a runner 16 to a deslagger (not shown). The deslagger is similar to a conventional slag skimmer used on iron-making furnaces or on front slagging cupolas, but is covered to reduce heat loss from radiation (e.g., see p. 237 of *The Making, Shaping and Treating of Steel*, United States Steel Corporation, Pittsburgh, Pa., 1957). From the deslagger the refined molten metal, free of slag, is further processed in a manner to be described in greater detail below.

Referring to FIG. 1, one embodiment of the method, useful in refining molten pig iron, will now be described. Tilted, rotated reactor vessel 10 contains a bath of relatively refined iron from which silicon, manganese, carbon, phosphorous and sulfur have been removed or quantitatively reduced to the extent desired, utilizing conventional oxygen converter reactions, and from which most of the slag on the top of the bath has been removed. Relatively unrefined molten pig iron and the conventional fluxes used in conventional oxygen converter practice (e.g., lime, fluorspar) are introduced into the top portion of the bath, and oxygen is blown onto the top of the bath.

The usual reactions occurring in conventional oxygen converter practice take place to oxidize the silicon, manganese, carbon and phosphorous in the unrefined molten pig iron, and the oxidized silicon and phosphorous combine with the flux and the oxidized manganese to form slag on the top of the bath.

The acidic oxidized silicon (SiO_2) is neutralized by the basic flux (CaO) to prevent the former from attacking the basic refractory with which the reactor vessel is lined. The sulfur in the unrefined molten pig iron is absorbed by the flux and also becomes part of the slag on the top of the bath.

The carbon is oxidized into a gas, generally carbon monoxide, which passes off at the top of the bath where at least some of it reacts with the oxygen from lance 19 to form carbon dioxide.

Oxygen is introduced at a rate sufficient to quantitatively reduce the oxidizable ingredients (silicon, manganese, carbon, phosphorous) in the unrefined molten pig iron to the desired level. Flux is introduced at a rate sufficient to neutralize the oxidized silicon and absorb the oxidized phosphorous and the sulfur in the unrefined molten pig iron.

6

The mixing action resulting from the rotation of the tilted reactor vessel enhances and speeds up the refining operation, compared to conventional oxygen converter practice. Removal of oxidized impurities (e.g., phosphorous) and of sulfur are enhanced by the mixing action which carries CaO (lime) below the surface of the bath to there absorb sulfur and oxidized phosphorous.

The angle of tilt of the vessel and the volume of molten metal within the vessel are sufficient to cause continuous withdrawal of relatively refined iron, by overflow, as unrefined molten pig iron is continuously added to the vessel. The rate of withdrawal of relatively refined molten iron is substantially the same as the rate of introduction of relatively unrefined molten pig iron.

Some of the slag is continuously withdrawn with the relatively refined molten metal. Continuous withdrawal of slag enhances the absorption of oxidized newly introduced impurities (e.g., Si, P) and of sulfur by newly introduced flux (CaO) to form new slag. This is because the sulfur and oxidized silicon and phosphorous in the withdrawn slag cannot dilute the neutralizing power (for SiO_2) and absorbing power (for P_2O_5 and S) of the newly added CaO.

From the reactor vessel, the withdrawn molten material is passed through a deslagger, in which the slag is removed from the relatively refined molten metal.

The relatively refined molten metal, minus the slag, is continuously introduced into a mixer 100, which may be similar to reactor vessel 10 but without an oxygen lance, or into a conventional ladle.

Mixer 100 is tilted and rotated in the same manner as vessel 10 and alloying additions (e.g., manganese, aluminum, titanium, vanadium) are added to mixer 100 (e.g., through inlet spout 13). The mixing action induced by the rotation of tilted mixer 100 effectively mixes the additions with the refined molten iron to produce the desired composition of steel; and the desired composition of steel is continuously withdrawn from rotated, tilted mixer 100 at substantially the same rate as the relatively refined, deslagged, molten iron is introduced. The refined, alloyed metal (steel) withdrawn from vessel 100 is flowed into the tundish of a continuous casting machine or into a ladle used for filling ingot molds.

Alternatively, the alloying additions may be mixed with the refined molten iron in a conventional ladle without tilting or rotation thereof. In such an embodiment, the continuous part of the process would all be upstream of the ladle in which the alloying additions are made.

FIG. 2 illustrates another embodiment of the method used in conjunction with the refining of molten pig iron. In the embodiment of FIG. 2, the refining process is performed in two tilted, rotated reactor vessels, 110 and 210, rather than one. Each of the two reactor vessels are constructed and operated essentially as shown in FIG. 3. Continuous introduction and withdrawal of molten metal in each of the two vessels 110 and 210 is essentially as described in conjunction with reactor vessel 10 in the embodiment illustrated in FIG. 1.

First reactor vessel 110 contains a bath from which silicon has been removed and manganese partially quantitatively reduced. Carbon, phosphorous and sulfur are substantially unremoved. Unrefined molten pig iron is continuously introduced into first reactor vessel 110, together with flux; and oxygen is blown onto the top portion of the bath. The rate of oxygen introduction is controlled so as to substantially remove the silicon and partially quantitatively reduce the manganese, but not to reduce the carbon content to the desired level, nor are phosphorous or sulfur substantially removed in vessel 110. Flux is added to neutralize the oxidized silicon in the slag. The molten metal withdrawn from first reactor vessel 110 is relatively refined, compared to the molten metal introduced, but still contains a relatively large amount of manganese, an undesirably high carbon content and undesirably large amounts of phosphorous and sulfur.

In second reactor vessel 210, the bath contained therein is substantially free of manganese, carbon, sulfur, and phosphorous, as well as silicon. The partially refined molten metal withdrawn from vessel 110 is continuously introduced into vessel 210. Oxygen is introduced into vessel 210 at a rate sufficient to remove the rest of the manganese, quantitatively reduce the carbon content to the desired low level, and oxidize the phosphorous. Flux is introduced into the second reactor vessel at a rate sufficient to combine with the oxidized phosphorous and with the sulfur to form slag which accumulates on the top of the bath of the second reactor vessel. Oxidized manganese is also in the slag. The molten metal withdrawn from second reactor vessel 210 is essentially completely refined molten iron from which manganese, silicon, carbon, phosphorous and sulfur have been removed.

The flux added to first reactor vessel 110 is one (e.g., CaO) which will combine with and neutralize the oxidized silicon to form a slag therewith. The flux added to second reactor vessel 210 is one (e.g., CaO, CaF₂) which will combine with the oxidized phosphorous and with the sulfur to form slag therewith.

Using two stages (vessels 110 and 210) to remove impurities, as in the embodiment of FIG. 2, allows the removal of more sulfur and phosphorous, more efficiently than in an embodiment having one refining stage (FIG. 1). This is because there is virtually no SiO₂ in second reactor vessel 210 to react with the CaO added to absorb the sulfur and oxidized phosphorous. The slag in second reactor vessel 210 is more basic (alkaline) than a slag containing SiO₂, and a more basic slag favors the removal of sulfur and phosphorous.

Because the silicon has been eliminated in the first vessel and because the manganese has been partially quantitatively reduced in the first vessel, a relatively greater part of the oxygen introduced into the second vessel is available to form oxides with carbon. This, together with the reduced oxygen pressure resulting from not having to start and maintain turbulence with the oxygen, permits a greater percentage of CO to be burned to CO₂ in the second vessel above the bath surface. At least a major part of the carbon undergoing oxidation may be oxidized to carbon dioxide within the second vessel; and this generates large quantities of surplus heat which permits the addition of substantial quantities of scrap metal to second reactor vessel 210. At least the major portion of the scrap steel consumed in the process of FIG. 2 is added to the second reactor vessel.

Scrap may be continuously added to the second vessel, and the scrap is preferably in relatively small chunks (e.g., no bigger than fist-sized) and relatively uniformly sized. Commercially available shredded auto bodies is a suitable example.

The defined molten iron withdrawn from the second reactor vessel is then continuously deslagged and introduced into either a ladle 200 or a mixer 100 for the addition of alloying ingredients, in the manner described previously in connection with the method illustrated in FIG. 1.

Embodiments using other than one or two refining vessels are also included within the present invention. For example, if an extremely low sulfur content is desired, molten metal withdrawn from second reactor vessel 210 may be continuously introduced into a third tilted, rotated reactor vessel along with a highly basic flux such as soda ash (Na₂CO₃), without the introduction of oxygen. The mixing action of the predominantly vertically tilted, rotated third reactor vessel would speed up and enhance the reaction between the flux and the sulfur resulting in the latter ending up in a surface layer of slag.

The continuous process described above is not limited to steel-making or even to the refinement or mixing of iron base alloys. Other metals and alloys may also be continuously refined or mixed in accordance with the method of the present invention. Examples include: continuous desulfurizing of molten pig iron outside the blast

furnace, thereby reducing the desulfurizing requirements of the blast furnace and decreasing the volume of flux required, thus increasing production in the blast furnace; continuous desulfurizing, recarburizing, etc. of molten foundry iron (for castings) produced in a cupola; continuous refining of copper matte to copper; continuous production of ferro-nickel; and continuous refining and mixing of copper base alloys.

What is claimed is:

1. A process for continuously refining molten metal in a reactor vessel having a closed bottom end and closed side walls extending upwardly from the bottom end, said process comprising the steps of:

containing a bath of relatively refined molten metal in said reactor vessel;

tilting said reactor vessel to a predominantly vertical angular position so that there is a downwardly facing inner wall at the back of the reactor vessel and an upwardly facing inner wall at the front of the reactor vessel;

imparting movement, to the tilted vessel, which produces surface and sub-surface mixing in said bath while maintaining the bath as a continuous mass; continuously introducing relatively unrefined molten metal into the top portion of said bath;

continuously adding a refining ingredient onto the top of said bath undergoing said mixing to remove impurities in said molten metal and thereby refine the latter;

controlling the angle of tilt and the volume of molten metal in the vessel to permit withdrawal of molten metal from the top portion of said bath, adjacent said upwardly facing inner wall at the front of the reactor vessel;

and continuously withdrawing relatively refined molten metal from the top portion of said bath, adjacent the upwardly facing inner wall at the front of the tilted reactor vessel, at a location spaced from the location at which said relatively unrefined molten metal is introduced.

2. A process as recited in claim 1 wherein:

said refining ingredient is supplied at a rate sufficient to quantitatively reduce the impurities, in the continuously introduced unrefined molten metal, to the desired level of refinement;

said relatively refined molten metal is withdrawn at substantially the same rate as said relatively unrefined molten metal is introduced;

and the volume of unrefined molten metal in said reactor vessel, at any given time, is relatively small compared to the volume of refined molten metal in the reactor vessel.

3. A process as recited in claim 1 and comprising:

imparting movement to said tilted reactor vessel which continuously produces downwardly moving bath currents adjacent the downwardly facing inner wall at the back of the tilted reactor vessel;

said introduction of the relatively unrefined molten metal into the top portion of said bath being confined to a location adjacent the downwardly facing inner wall at the back of the tilted reactor vessel.

4. A process as recited in claim 1 and comprising: imparting movement to said tilted reactor vessel which continuously produces downwardly moving bath currents adjacent the downwardly facing inner wall at the back of the tilted reactor vessel and upwardly moving bath currents adjacent the upwardly facing inner wall at the front of the tilted reactor vessel.

5. A process as recited in claim 4 wherein:

said movement-imparting step comprises rotating said reactor vessel about its longitudinal axis;

said reactor vessel has a pair of diametrically opposed substantially planar inner wall portions, connected by a pair of curved inner wall portions, and a pair of opposed inwardly inclined lower wall portions

9

each extending between a respective one of said planar inner wall portions and the vessel bottom; the downward movement of said bath current is at a maximum when one of said planar inner wall portions is at the back of the tilted reactor vessel, during rotation thereof;

and the upward movement of said bath current is at a maximum when one of said planar inner wall portions is at the front of the tilted reactor vessel, during rotation thereof.

6. A process as recited in claim 5 wherein: said step of introducing said relatively unrefined molten metal into the top portion of said bath is restricted substantially to those times, during rotation of the tilted reactor vessel, when the downward movement of the bath current is at said maximum.

7. A process as recited in claim 1 and comprising: imparting movement to said tilted reactor vessel which continuously produces upwardly moving bath currents adjacent the upwardly facing inner wall at the front of the tilted reactor vessel;

and said withdrawal of the relatively refined molten metal is confined to a location adjacent the upwardly facing inner wall at the front of the tilted reactor vessel.

8. A process as recited in claim 1 wherein said refining step comprises:

continuously blowing oxygen onto the top of said bath to oxidize impurities in said molten metal and thereby refine the latter;

continuously introducing flux onto the top portion of said bath to form slag with said oxidized impurities; and continuously withdrawing slag from the top portion of said bath, adjacent said upwardly facing inner wall at the front of the reactor vessel.

9. A process as recited in claim 1 wherein:

said movement-imparting step comprises rotating said reactor vessel about its longitudinal axis to continuously produce downwardly moving bath currents adjacent the downwardly facing inner wall at the back of the tilted reactor vessel and upwardly moving bath currents adjacent the upwardly facing inner wall at the front of the tilted reactor vessel; said refining step comprises continuously blowing oxygen onto the top of said bath to oxidize impurities in said molten metal and thereby refine the latter; and the pressure of said oxygen is controlled to avoid significant interference with the sub-surface bath currents produced by said movement imparted to said tilted reactor vessel.

10. A process as recited in claim 1 wherein:

said relatively unrefined molten metal is unrefined molten pig iron; said relatively refined molten metal is refined pig iron in which silicon, manganese and carbon have been substantially reduced to desired levels; and said refining step comprises blowing oxygen onto the top of said bath to oxidize the silicon, manganese and carbon and quantitatively reduce the amounts of these elements in the molten metal to desired levels.

11. A process as recited in claim 1 wherein:

said relatively refined molten metal is partially refined molten pig iron from which silicon has been substantially removed and manganese substantially quantitatively reduced by oxidation but which still contains an undesirably high level of carbon; said relatively refined molten metal is unrefined molten pig iron; and said refining step comprises blowing oxygen onto the top of said bath to oxidize silicon and manganese in said molten pig iron and substantially remove the silicon and substantially quantitatively reduce the manganese.

10

12. A process as recited in claim 11 and comprising: containing a second bath of further refined molten pig iron in a second reactor vessel;

tilting said second reactor vessel and imparting movement, to the tilted second reactor vessel, which causes surface and sub-surface mixing in said second bath;

continuously introducing partially refined molten pig iron from said first recited reactor vessel into the top portion of said second bath;

continuously blowing oxygen onto the top of said second bath undergoing said mixing to oxidize impurities in the partially refined molten pig iron and quantitatively reduce carbon to the desired level and thereby further refine said molten pig iron;

controlling the angle of tilt and the volume of molten metal in the second reactor vessel to permit withdrawal of molten metal from the top portion of said second bath, at the front of the second reactor vessel;

and continuously withdrawing further refined molten pig iron which has undergone said sub-surface mixing from the top portion of said second bath, adjacent the upwardly facing inner wall at the front of the second reactor vessel.

13. A process as recited in claim 12 and comprising: oxidizing the phosphorous in said molten pig iron during the course of oxidizing the impurities in the second reactor vessel;

and adding, to said second reactor vessel, a basic flux which will form a slag with the sulfur and with the oxidized phosphorous in said molten pig iron; the major portion of sulfur removed in said process being removed in said second reactor vessel.

14. A process as recited in claim 13 and comprising: oxidizing carbon to CO and oxidizing at least a major part of said CO to CO₂ in said second reactor vessel; and adding scrap steel to said second reactor vessel; at least the major portion of the scrap steel consumed in said process being added to said second reactor vessel.

15. A process as recited in claim 1 wherein said refined molten metal is withdrawn by overflow.

16. A process as recited in claim 1 and comprising: maintaining a separation between that part of the top portion of the bath at which said refined molten metal is withdrawn and that part of the top portion of the bath into which said relatively unrefined molten metal is introduced.

17. A process for continuously treating molten metal in a reactor vessel having a closed bottom end and closed said walls extending upwardly from the bottom end, said process comprising the steps of:

containing a bath of relatively treated molten metal in said reactor vessel;

tilting said reactor vessel to a predominantly vertical angular position so that there is a downwardly facing inner wall at the back of the reactor vessel and an upwardly facing inner wall at the front of the reactor vessel;

imparting movement, to the tilted vessel, which produces surface and sub-surface mixing in said bath while maintaining the bath as a continuous mass; continuously introducing relatively untreated molten metal into the top portion of said bath;

continuously adding a treating ingredient onto the top of said bath undergoing said mixing to thereby treat said molten metal;

controlling the angle of tilt and the volume of molten metal in the vessel to permit withdrawal of molten metal from the top portion of said bath, adjacent said upwardly facing inner wall at the front of the reactor vessel;

and continuously withdrawing relatively treated molten metal from the top portion of said bath, adjacent

11

the upwardly facing inner wall at the front of the tilted reactor vessel, at a location spaced from the location at which said relatively untreated molten metal is introduced.

18. A process as recited in claim 17 wherein said treating ingredient is an alloying addition.

References Cited

UNITED STATES PATENTS

3,393,997	7/1968	Faste	75—61	X	10
3,427,150	2/1969	Niehavs	75—52	X	
2,574,764	11/1951	Smalley	75—51		

12

3,034,885	5/1962	Hardt	75—52
3,259,485	7/1966	Kootz et al.	75—61 X
2,622,977	12/1952	Kalling et al.	75—61 X
3,098,739	7/1963	Graef et al.	75—60 X
3,169,055	2/1965	Josefsson et al.	75—62 X

L. DEWAYNE RUTLEDGE, Primary Examiner

G. K. WHITE, Assistant Examiner

U.S. Cl. X.R.

75—46, 52, 60, 61, 93

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,672,869

Dated June 27, 1972

Inventor(s) Conrad F. Niehaus

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 53, cancel "cup-shaped";

Column 1, line 53, after "vessel" insert

--having a closed bottom end and closed side walls extending upwardly from the bottom end. The reactor vessel being--;

Column 9, line 69, "refined" should be --unrefined--;

Column 10, line 36, "cabon" should be --carbon--;

Column 10, line 52, "said" should be --side--;

Column 11, line 12, "51" should be --61--;

Column 12, line 5, "62X" should be --52X--.

Signed and sealed this 2nd day of January 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents