United States Patent

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[33] **Australia**
[31] **33751/68**

[54] **METHOD FOR REFINING METALS**
8 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **75/46,**
75/52, 75/60, 75/75, 75/93, 266/34
[51] **Int. Cl.** **C21b13/14,**
C21c 5/00
[50] **Field of Search** 75/60, 51,
52, 46, 45, 43, 75, 93

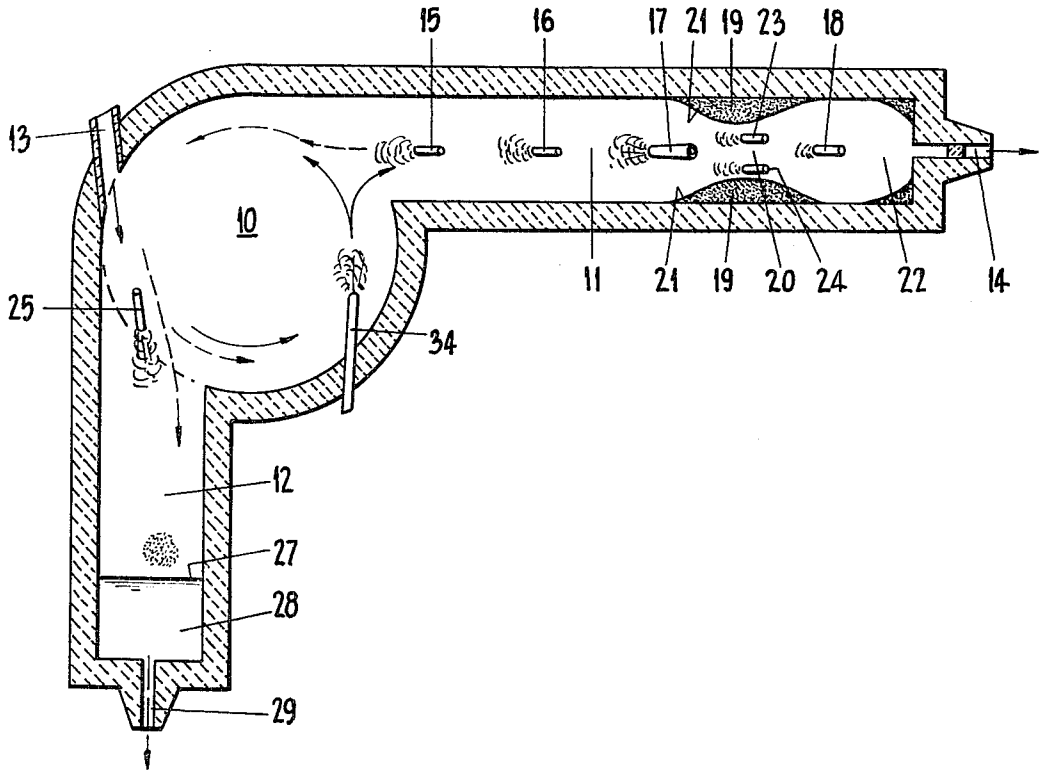
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ABSTRACT: A procedure for the continuous refining of metals makes use of a furnace which is characterized by certain novel features, viz, it possesses an elongated refining zone in which the slag is caused to flow substantially countercurrent to metal, a substantially circular refining zone in which slag is caused to circulate substantially concurrently with metal, and a slag conditioning and settling zone, into which the slag flows from the two refining zones. The three furnace zones are substantially separate compartments in communication with each other in substantially one horizontal plane. The slag separation zone is preferably connected with the circular refining zone at some distance from the junction between the latter and the elongated refining zone.



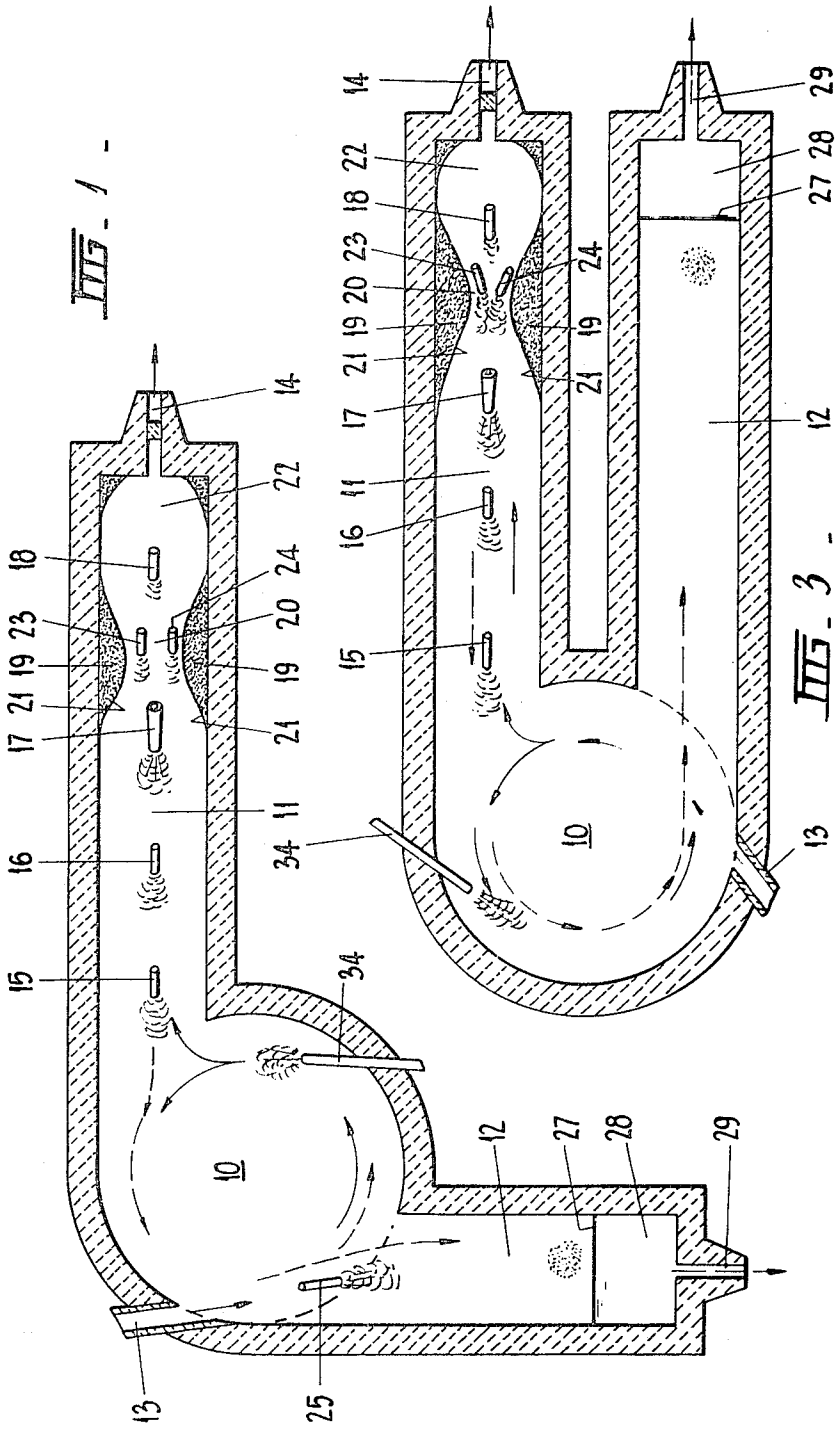


FIG. 1

FIG. 3

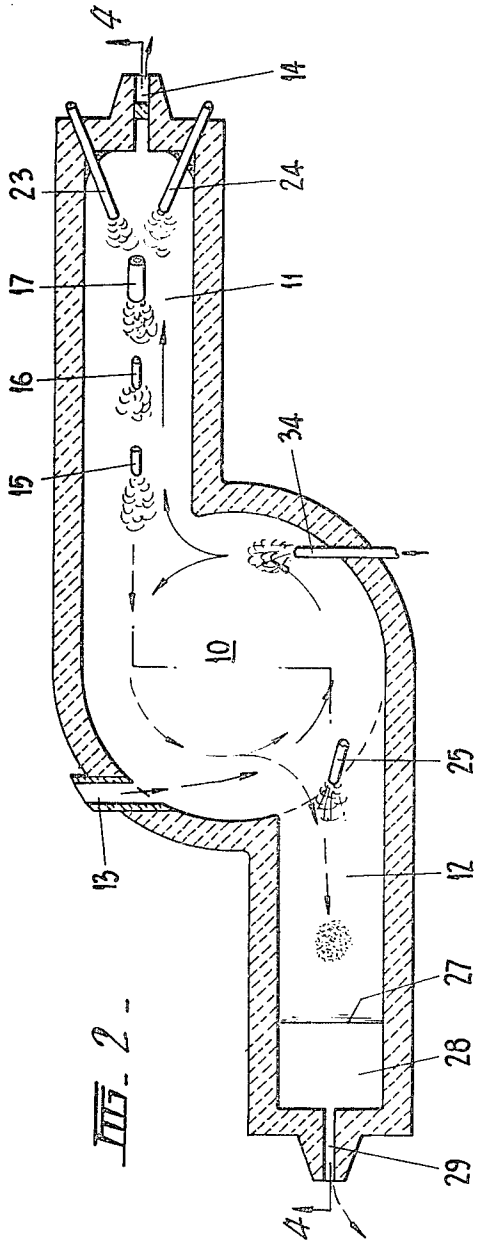

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FIG. 2

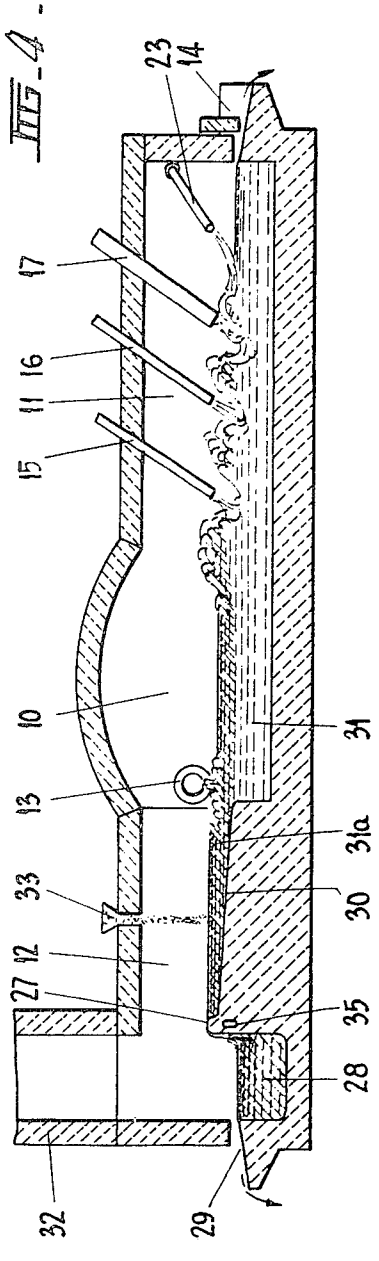

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FIG. 4

METHOD FOR REFINING METALS

This invention relates to improvements in the continuous furnace refining of crude metals or alloys or mattes by lancing of the molten flowing stream with an oxygen-containing gas and if desired, other oxidants, such as the oxide(s) of the metal being produced. The invention refers to improvements in the methods and apparatus referred to in Australian Pat. applications Nos. 48138/64 and 3170/66. It applies particularly to the continuous refining of molten pig iron to steel, but is also suitable for the continuous refining of other crude metals, for example tin-iron alloy ("hard head").

In this specification the term "metal" includes crude metals, alloys and mattes.

The invention is concerned particularly with the continuous refining of metals using furnaces which are characterized by certain novel features, viz, they possess, preferably, an elongated substantially rectangular launderlike refining zone (hereinafter termed the elongated refining zone) in which the slag is caused to flow substantially countercurrent to metal, a substantially or approximately circular refining zone (hereinafter termed the circular refining zone) in which slag is caused to circulate substantially concurrently with metal, and a slag conditioning and settling zone, (hereinafter termed the slag separation zone) into which the slag flows from the two refining zones. The three furnace zones are substantially separate compartments in communication with each other in substantially one horizontal plane. The slag separation zone is preferably connected with the circular refining zone at some distance from the junction between the latter and the elongated refining zone.

A process for the refining of metals which comprises introducing molten unrefined metal and oxygen-containing gas into a substantially circular refining zone of a refining furnace, causing the slag formed in the circular refining zone to circulate concurrently with the molten metal in the circular refining zone, causing the partially refined metal to flow from the circular refining zone into an elongated second refining zone connected to the circular refining zone, introducing oxygen-containing gas into the molten material in the second refining zone, causing the slag in the second refining zone to flow mainly countercurrent to the molten metal in said zone and to flow into the circular refining zone, causing slag to flow from the circular-refining zone into a substantially quiescent slag separation zone connected to the circular-refining zone, withdrawing refined metal from the second refining zone, and withdrawing slag from the slag separation zone.

Molten unrefined metal is introduced preferably tangentially to the walls of the circular refining zone and refined metal is withdrawn from at or near the end of the elongated refining zone remote from the circular refining zone.

It has been found that while furnaces of T-shape, L-shape or U-shape are often convenient to use, furnaces in which one refining zone is substantially of circular shape and the other refining zone is substantially of elongated rectangular shape, together with an elongated slag separation branch, have certain advantages. Among these are increased contact time between slag and metal in the circular refining zone due to the greater path of flow of the two liquid phases in this zone consequent upon the shape and the circulation flow patterns.

The circular-refining zone also acts as a reservoir ahead of the elongated refining zone and eliminates minor (short term) fluctuations in composition in the ingoing crude metal or matte so that a more uniform liquid flows into the elongated refining zone. In order to ensure adequate residence time of the molten metal in the circular-refining zone, the capacity of said zone should be at least as great as that of the elongated refining zone, and is preferably at least twice as great as that of the latter zone.

The countercurrent and concurrent flows of the two slag streams, and their final flow into the slag separation zone, are aided by the furnace design itself, and may also be assisted by the use of appropriately angled jets of oxygen-containing gas impinging onto the slag in such a manner as to force the

streams in the desired direction. The oxygen from such jets also assists the combustion of any carbon monoxide or other combustible gases emerging from the bath and so both heat and momentum are conveyed to the slag.

In the refining of molten pig iron by the method and apparatus of this invention a little of the basic fluxing material may be added in the circular refining zone near to the entry of the molten pig iron. However, the greater proportion of the basic flux is preferably added nearer to the steel outlet end of the elongated refining zone and the slag formed near that end is caused to flow countercurrent to the metal because of a wall or baffle which prevents it flowing out with the metal.

The circular-refining zone serves primarily to achieve continuous desiliconization and the beginning of the removal of the carbon. Titanium and other readily oxidizable elements are also removed in this zone.

In the elongated-refining zone where the larger quantity of basic fluxing material is preferably added towards the steel tapping end, the slag formed will be both highly basic and well oxidized, containing possibly over 25 percent FeO and the balance mainly CaO. This slag, being well oxidized reacts vigorously with the carbon-containing metal and generates considerable quantities of carbon monoxide thereby causing vigorously boiling of the bath. This is a beneficial phenomenon in steel making and ensures adequate mixing of the highly basic refining slag with the steel from which it is extracting sulphur and phosphorus.

When it is desired to make low-carbon steels, as for example rimming steels, it is advantageous to provide a means for preventing the flow of large volumes of slag into the very low-carbon zone, towards the steel outflow end, preferably by the use of low-angle jets or alternatively by a slag bridge. By such means the refining chamber is divided into three refining zones, the circular concurrent slag flow refining zone, the countercurrent slag flow refining zone and a final refining zone with little or no slag flow. This third refining zone, receiving metal with low-carbon content and already defined with respect to sulphur and phosphorus, does not require the formation of much slag for only carbon remains to be removed and this leaves the bath as bubbles of carbon monoxide. However, a thin film of slag usually forms in the said third refining zone by reaction of iron oxide and basic fluxes and possibly also minor reactions with refractories; and this film helps to reduce the quantity of heat reflected from the hot metal surface to the roof of the refining chamber.

Means such as low-angle jets or a slag bridge may be provided to prevent, or minimize, the flow of slag from the second refining zone into the third refining zone where pickup of iron oxides in the slag would otherwise be appreciable.

Some foaming in the backward flowing slag is beneficial but excessive frothing in one or other of the refining zones may be controlled by sprinkling or injecting (through lances, or by other means) appropriate finely particulate solids, for example lime, limestone or fluorospar, onto the slag surface.

Various features of the present invention will be better understood by reference to the accompanying annotated drawings of typical furnace configurations in which the circular refining zone is designated as **10**, the elongated refining zone as **11** and the slag separation zone as **12**.

FIG. **1** is a sectional plan view of a furnace constructed in accordance with the invention in which the circular refining zone **10** is located at the center of a right angle formed by the elongated refining zone **11** and the slag separation zone **12**.

FIG. **2** is a sectional plan view of a furnace in which the elongated refining zone **11** and the slag separation zone **12** are parallel to each other and arranged duotangentially with respect to the circular refining zone **10**.

FIG. **3** is a sectional plan view of a U-shaped furnace in which the elongated refining zone **11** and the slag separation zone **12** form the sides, and the circular refining zone **10** forms the bottom, of the U.

FIG. **4** is a view in sectional elevation on line **4—4** of FIG. **2**.

The corresponding numerals in the different FIGS. have the same connotations. In FIGS. 1 to 3, the flow of metal is indicated by full lines and the flow of slag is indicated by dotted lines.

The furnaces in FIGS. 1, 2, 3 all comprise a circular refining zone 10, in which slag flows substantially concurrent with the metal, and an elongated second refining zone 11, in which slag flows substantially countercurrent to metal, and a slag separation zone 12. In these FIGS., zones 11 and 12 are always connected with zone 10. The disposition of zones 11 and 12 with respect to each other and to zone 10 are essentially illustrative and nonlimitative. The selection of particular furnace designs will be governed by factors peculiar to individual plants such as the availability of space, handling equipment, transport facilities and the specific refining operations undertaken. In FIG. 1, for instance, zones 11 and 12 are disposed at right angles to each other. The open configurations shown in FIGS. 1 and 2 have the advantage of easy access to various parts of the furnaces for maintenance and repair, whereas the furnace represented by FIG. 3 has a basic compactness which may be well suited to sites of limited size.

The molten metal to be refined is admitted tangentially to the furnaces through a launder 13 and refined metal is withdrawn from taphole 14. Positions other than those shown for the entry of the metal to be refined may be employed.

Jets of oxygen or oxygen-containing gas are injected into the slowly flowing molten metal in the refining zones 10 and 11 by means of a plurality of lances, e.g., 34, 15, 16, 17 and 18. The lance 34 is preferably disposed approximately tangentially to the refining zone 10. These lances may be suitably inclined so as to aid the flow of the countercurrent and concurrent slag streams in the direction of the slag separation zone 12. As an alternative to inclining the complete lances the end portions of the gas-carrying bores of the lances may be angled in such a way as to promote the flow of slag in the directions desired.

While a little of the basic fluxing materials may be added in the circular refining zone 10 (the location of entry of such materials is not critical and is therefore not shown), the greater proportion of these materials will preferably be injected through lance 17 or through auxiliary pipes adjacent to this lance.

In the embodiments of the invention shown in FIGS. 1 and 3 refractory peninsulas 19 are formed at an appropriate position along the walls of refining zone 11 (usually about ⅝ to ¾ of the distance along the length of the elongated zone 11). The restricted passage 20 between such peninsulas is a convenient location for one or or more low-angle jets 23, 24 of oxygen-containing gas playing on the liquid surface in such a manner as to restrict the flow of slag into the final or third refining zone 22. The peninsulas 19 may be fluid cooled by metal tubes or blocks (not shown) and are appropriately curved with smooth surfaces 21.

The said refractory peninsulas 19 may be constructed as part of the furnaces' refractory linings or alternatively may be banks built up from refractories, e.g., dolomite, which are dropped or otherwise introduced into the furnaces through appropriate ports.

A slag weir 27 (see FIG. 4) may be formed in the slag separation zone 12 and a final slag well 28 thus provided between slag weir 27 and slag outlet 29. The slag weir 27 may be fluid cooled by metal tubes or blocks 35.

The conditions in the slag separation zone 12 are relatively quiescent. The floor 30 of zone 12 (see FIG. 4) is arranged to slope generally downwards from the slag weir 27 to the junction of the zone 12 with the refining section 10 of the furnace, at which point the floor 30 is approximately level with the surface of the metal 31 in the refining zone 10. By this means, metal which separates out from the slag 31*a* in the zone 12 is caused to flow back along the floor 30 into the circular refining section 10 of the furnace and the flow of metal from the refining zones 10 and 11 into the slag separation zone 12 is substantially prevented.

The slag well 28, being preferably of much greater depth and total volume than that of the relatively shallow sloping section of the zone 12, effectively increases the residence time of the slag flowing slowly towards the slag taphole 29 and thereby gives greater opportunity for gravitational settlement of fine shot or prills of metal from the slag. The metal which slowly accumulates in the bottom of the well 28 can be tapped at appropriate (infrequent) intervals and returned by ladle to the main refining zone 10. Alternatively it may be pumped back over weir 27 to flow back under gravity into the refining zone 10.

The slag separation branch 12 is a convenient region where additions can be made to the slag, (e.g., via port 33). In pig iron refining these additions can be made to assist in the elimination of iron from the slag (e.g. by the addition of ferro silicon, calcium carbide, char, coke or other reducing material) or to make the slag suitable for other uses (e.g., silica, soda etc. to convert the slag to a glass), subsequent to tapping.

A gas offtake 32 is provided at a convenient position. In the embodiment shown in FIG. 4 it is above the slag well 28.

Jets produced by lances 25 and 34 of oxygen or oxygen-containing gas serve to burn some at least of the appreciable percentage of carbon monoxide present in the furnace gases emerging from the boiling bath. The lances 34 also assist the circulation of the liquids in circular zone 10. Lances 25 help to direct slag from the circular refining zone 10 into the slag separation zone 12.

EXAMPLE

The process of this invention has been under development at the works of Sulphide Corporation, Cockle Creek, New South Wales, for 3 years, in which time over 25 refining trials were conducted.

A typical 6-hour trial is described below:

Molten pig iron was fed to a furnace of the type shown in FIG. 1 at the rate of 4 tons/hour. The pig iron was of the following composition.

	%
C	3.75
Si	1.15
Mn	0.8
P	0.09
S	0.06
Fe	Remainder

Flux in the form of high quality burnt lime (−1/16-inch diameter particle size) supplemented by finely ground fluorspar was injected via lance 17 at the rate of 120 lbs. of lime and 5 lbs. of fluorspar per ton of steel produced. Vigorously foaming slag was generated in the elongated refining zone. The slag having initially an almost infinite $CaO:SiO_2$ ratio flowed freely back to and through the circular refining zone 10 and was tapped with a final basicity ($CaO:SiO_2$) ratio of 2.2 at 27 into a granulating launder (not shown).

For the first 2 hours of the run oxygen injection rates were adjusted to produce a high-carbon steel (0.9–1.0 percent C) and while producing such high carbon material the levels of other elements were as follows:

	%
Si	0.06
Mn	0.30
P	0.008
S	0.008
Fe	Remainder

Thus over 90 percent of phosphorus and over 85 percent of sulphur were removed at a lime addition rate lower than in conventional batch steel making. The oxygen efficiency was high with only 1,300 cu. ft. of oxygen being used per net ton of steel produced.

In the remaining hours of the trial the same pig iron was used to produce low-carbon steel of the following composition:

	%
C	0.15
Si	0.02
Mn	0.03
P	0.004
S	0.006
Fe	Remainder

In this case over 95 percent of the phosphorus and 90 percent of the sulphur were removed.

Because of the beneficial effects due to countercurrent slag refining, iron losses in the slag were rarely greater than 0.6 percent of the tonnage of steel produced, and while making high-carbon steel these losses were less than 0.5 percent. Sufficient heat was generated to enable the addition of 12–15 percent of coolant in the form of cold shredded scrap. Indications are that in commercial scale refining according to this invention the scrap consumption will be well over 35 percent and thus be higher than in conventional batch oxygen steelmaking.

I claim:

1. A process for the continuous refining of metals which comprises introducing molten unrefined metal and oxygen-containing gas tangentially into a substantially circular refining zone of a refining furnace in the direction of flow of the molten metal therein; causing the slag formed in the circular refining zone to circulate concurrently with the molten metal in the circular refining zone, causing the partially refined metal to flow from the circular refining zone into an elongated second refining zone connected to the circular refining zone, the circular refining zone having a capacity at least twice as great as that of the elongated refining zone whereby the circular refining zone acts as a reservoir ahead of the elongated refining zone and the residence time of the molten metal in the said reservoir is at least twice as great as that of the metal in the elongated refining zone whereby composition variations in the metal are controlled in the said reservoir before the metal passes to the elongated refining zone; introducing oxygen-containing gas into the molten material in the elongated refining zone, causing the slag in the elongated refining zone to flow mainly countercurrent to the molten metal in said zone and thence to flow into the circular refining zone substantially tangentially thereto and in the direction of flow of the molten metal therein, causing slag to flow from the circular refining zone into a substantially quiescent slag separation zone connected to the circular refining zone, withdrawing refined metal from the elongated refining zone; and withdrawing slag from the slag separation zone.

2. A process according to claim 1 wherein the partially refined metal from the circular refining zone enters the elongated second refining zone at one end thereof and the refined metal is withdrawn from the second refining zone at or near the opposite end thereof.

3. A process according to claim 1 wherein slag from the circular refining zone enters the slag separation zone at one end thereof and slag is withdrawn from the slag separation zone at or near the opposite end thereof.

4. A process according to claim 1 wherein the metal flows from the second refining zone through a restricted passage to a third refining zone where the metal is further refined, and refined metal is withdrawn from the third refining zone.

5. A process according to claim 4, wherein the flow of slag from the second refining zone into the third refining zone is restricted.

6. A process according to claim 1 wherein the flow of metal from the circular refining zone into the slag separation zone is substantially prevented.

7. A process according to claim 6 wherein metal which separates out from the slag in the slag separation zone flows back into the circular refining zone.

8. A process according to claim 1 wherein the slag in the slag separation zone flows into a slag pool in which further slag settling and separation of metal from the slag is effected, slag being withdrawn from the slag pool.

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