(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 411 000 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
07.08.2024 Bulletin 2024/32

(21) Application number: **22876211.8**

(22) Date of filing: **27.09.2022**

(51) International Patent Classification (IPC):
C21C 7/00 (2006.01) ***C21B 11/10*** (2006.01)
C21C 1/02 (2006.01) ***C21C 5/28*** (2006.01)

(52) Cooperative Patent Classification (CPC):
C21B 11/10; C21C 1/02; C21C 5/28; C21C 7/00

(86) International application number:
PCT/JP2022/035903

(87) International publication number:
WO 2023/054345 (06.04.2023 Gazette 2023/14)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **30.09.2021 JP 2021161078**

(71) Applicant: **NIPPON STEEL CORPORATION**
Chiyoda-ku
Tokyo 100-8071 (JP)

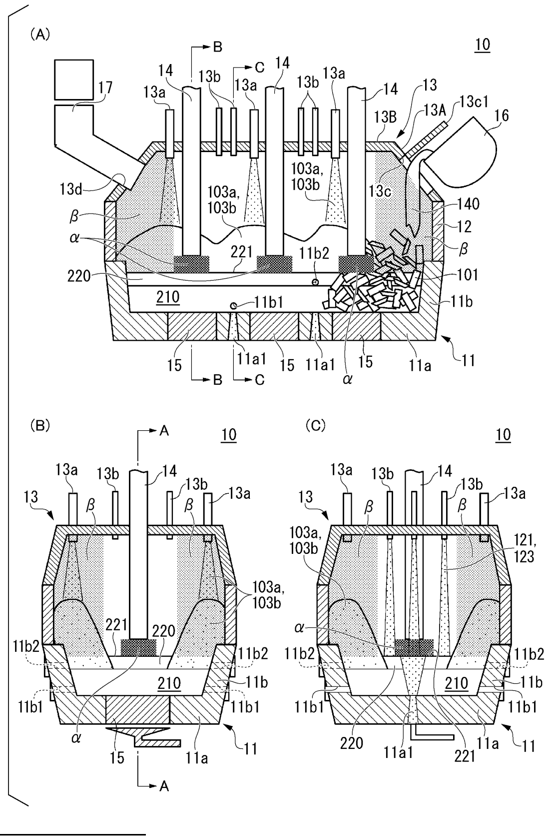
(72) Inventor: **HARADA, Toshiya**
Tokyo 100-8071 (JP)

(74) Representative: **Zimmermann & Partner**
Patentanwälte mbB
Postfach 330 920
80069 München (DE)

(54) MOLTEN IRON PRODUCTION METHOD

(57) In this molten pig iron manufacturing method, using a fixed-type DC electric furnace, an auxiliary raw material is supplied to the fixed-type DC electric furnace and molten pig iron having a C concentration of 2 to 4 mass% at a temperature of 1400°C to 1550°C is tapped from a tap hole in a state in which a solid iron source is present in the furnace inner peripheral wall space and in a state in which the solid iron source is not present in the upper electrode facing space.

FIG. 2



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Description

[Technical Field of the Invention]

[0001] The present invention relates to a molten pig iron manufacturing method.

[0002] The present application claims priority based on Japanese Patent Application No. 2021-161078 filed in Japan on September 30, 2021, the contents of which are incorporated herein by reference.

[Related Art]

[0003] Molten pig iron manufactured by blast furnace method is manufactured by reducing iron ore with coke, and therefore the amount of CO_2 generated is large. As a means for reducing CO_2 emission, there is a method in which a solid iron source such as iron-containing scrap or reduced iron is melted in an electric furnace to manufacture molten pig iron, and then molten steel is manufactured utilizing a steelmaking step mainly using an existing converter. So far, methods for manufacturing molten pig iron in an electric furnace using each iron source have been proposed (Patent Documents 1 to 5).

[0004] On the other hand, slag generated in a converter contains a considerable amount of iron oxide and phosphate, and method have been proposed in which the iron oxide and the phosphate are reduced and recovered to be converted into an iron source and a phosphorus product (Patent Documents 6 to 8).

[0005] Patent Document 9 discloses a method for melting a solid iron source accompanied by slag reduction, in which a solid iron source is charged into an electric furnace in which hot heel is accommodated, steelmaking slag in a molten state or a high-temperature solidified state is charged from above a deposited portion of the solid iron source, the solid iron source is partially melted by DC or AC arc heating, a carbon material as a reducing agent and a flux for composition adjustment containing at least one of SiO_2 and Al_2O_3 as a component are then charged into a molten pool, to reduce the slag and carburize the molten iron, the molten pig iron is discharged from a tap hole while the hot heel remains, and then the reduced slag is discharged from a slag hole.

[0006] According to the method described in Patent Document 9, in the electric furnace, high phosphorus molten pig iron containing phosphorus separated from the molten slag is recovered, and the molten slag which is the steelmaking slag is reduced and modified, so that high quality reduced slag equivalent to blast furnace slag is recovered. Since the reduced slag has lower concentrations of FeO and P_2O_5 than those before reduction, it can be recycled into a cement raw material and a ceramic product.

[0007] Further, the high phosphorus molten pig iron recovered from the electric furnace is subjected to a dephosphorization treatment in a ladle to oxidize phosphorus in the molten pig iron and transfer it into the slag. As a result, the high phosphorus molten pig iron is separated into high phosphate slag and low phosphorus molten pig iron. The high phosphate slag can be commercialized as a phosphate fertilizer and a phosphate raw material. In addition, the low phosphorus molten pig iron is recycled to a steelmaking step, mixed with blast furnace molten pig iron, and then charged into a converter.

[Citation List]

[Patent Document]

[0008]

[Patent Document 1]
PCT International Publication No. WO 1999/011826
[Patent Document 2]
Japanese Unexamined Patent Application, First Publication No. 2011-80143
[Patent Document 3]
Japanese Unexamined Patent Application, First Publication No. 2017-57431
[Patent Document 4]
Japanese Unexamined Patent Application, First Publication No. 2018-193574
[Patent Document 5]
PCT International Publication No. WO 2018/110171
[Patent Document 6]
Japanese Unexamined Patent Application, First Publication No. 2015-140294
[Patent Document 7]
PCT International Publication No. WO 2014/003123

[Patent Document 8]
Japanese Unexamined Patent Application, First Publication No. 2017-128747
[Patent Document 9]
Japanese Unexamined Patent Application, First Publication No. 2021-134386

[Summary of Invention]

[Problems to be Solved by the Invention]

[0009] Patent Document 1 and Patent Document 3 describe a method for obtaining molten pig iron by charging reduced iron, Patent Document 2 describes a method for obtaining molten pig iron by charging iron-containing scrap, and Patent Document 4 describes a method for obtaining molten pig iron by charging iron-containing scrap and iron-containing dust into an electric furnace, as raw material(s), respectively. In addition, Patent Document 5 describes an electric furnace capable of directly charging molten slag. Although there is a difference in charging method or reduction method, in order to cope with a change in raw material circumstances and facilitate recycling of byproducts such as slag, a method of supplying a wide variety of raw materials to one electric furnace to efficiently and continuously manufacture molten pig iron is required. Therefore, the furnace lid needs a sufficient space for supplying various raw materials.

[0010] In Patent Document 9, molten pig iron manufactured by melting a solid iron source in an electric furnace and molten pig iron manufactured in a blast furnace are supplied to a steelmaking step at a ratio of 1: 1 to manufacture molten steel. In order to significantly reduce CO_2 generation in ironmaking, it is important to stop using blast furnace process. However, when an attempt is made to replace blast furnace molten pig iron using the method described in Patent Document 9, a large electric furnace capacity is required. Even if an attempt is made to increase the power supply capacity of the electric furnace, in an AC electric furnace, the power capacity is limited due to the manufacturing limit of electrode size, and it is difficult to scale up. In addition, in a tilting-type electric furnace, since energization and stop of energization are repeated, productivity decreases (Patent Document 9).

[0011] An object of the present invention is to provide a molten pig iron manufacturing method, which makes it possible to significantly reduce CO_2 generation in ironmaking by using a fixed-type DC electric furnace instead of a blast furnace and to efficiently and continuously manufacture molten pig iron.

[Means for Solving the Problem]

[0012] That is, the gist of the present invention is as follows.

(1) According to one aspect of the present invention, there is provided a molten pig iron manufacturing method using a fixed-type DC electric furnace, in which if, in a furnace, a space in which a horizontal separation distance from an outer periphery of an upper electrode at a height position between a slag bath surface and a lower end of the upper electrode inserted from a furnace lid is 0.5 times or less a diameter of the upper electrode is defined as an upper electrode facing space, and if in the furnace, a space in which a horizontal separation distance from an inner wall surface of a furnace wall at a height position above a height position of the slag bath surface is within the shortest distance between the furnace wall and the upper electrode facing space is defined as a furnace inner peripheral wall space, an auxiliary raw material is supplied to the fixed-type DC electric furnace and molten pig iron having a C concentration of 2 to 4 mass% at a temperature of 1400°C to 1550°C is tapped from a tap hole in a state in which a solid iron source is present in the furnace inner peripheral wall space and in a state in which the solid iron source is not present in the upper electrode facing space.
(2) In the molten pig iron manufacturing method according to (1), a top portion of the solid iron source in the furnace inner peripheral wall space may be present at a position higher than the lower end of the upper electrode.
(3) In the molten pig iron manufacturing method according to (1) of (2), the solid iron source may be present along the whole circumference of the furnace inner peripheral wall space.
(4) In the molten pig iron manufacturing method according to any one of (1) to (3), the fixed-type DC electric furnace may include: two or more of the upper electrodes; and two or more lower electrodes provided in a refractory at a bottom portion of the fixed-type DC electric furnace; and the two or more lower electrodes may be provided at positions corresponding to the two or more upper electrodes in a plane view of the fixed-type DC electric furnace.
(5) In the molten pig iron manufacturing method according to any one of (1) to (4), a supply port or a solid iron source supply pipe for supplying the solid iron source may be disposed above the furnace inner peripheral wall space.
(6) In the molten pig iron manufacturing method according to (5), a supply port for supplying the solid iron source may be disposed above the furnace inner peripheral wall space, and the solid iron source may be supplied from the supply port using a solid iron source charging implement on which the solid iron source is loaded.
(7) In the molten pig iron manufacturing method according to any one of (1) to (6), the solid iron source may be at

least one of iron-containing scrap, reduced iron, and iron-containing dust.

(8) In the molten pig iron manufacturing method according to any one of (1) to (7), the solid iron source may contain at least reduced iron, the reduced iron may be reduced iron having a C concentration of 0 to 4 mass% by reducing iron ore using at least one of hydrogen gas, natural gas, and CO gas, and the reduced iron may be DRI or HBI.

(9) In the molten pig iron manufacturing method according to any one of (1) to (8), the auxiliary raw material may be at least one of a carbon material and a flux for composition adjustment.

(10) In the molten pig iron manufacturing method according to (9), the auxiliary raw material may be a carbon material having a particle size of 0.5 mm to 10 mm, and the carbon material may be supplied from a plurality of locations around the upper electrodes to the slag bath surface formed in the upper electrode facing space.

(11) In the molten pig iron manufacturing method according to any one of (1) to (10), steelmaking slag may be supplied to the fixed-type DC electric furnace.

(12) In the molten pig iron manufacturing method according to (11), at least one type of slag selected from converter slag, molten pig iron desulfurization slag, secondary refining slag, and dephosphorization slag may be used as the steelmaking slag, and the steelmaking slag may be supplied in a molten state to the solid iron source present in the furnace inner peripheral wall space.

(13) In the molten pig iron manufacturing method according to any one of (1) to (12), one or a plurality of bottom-blown tuyeres having a flow rate variable small diameter circle or a flat gas flow path may be provided at positions separated by a horizontal distance of 1 m or more from immediately below the upper electrode at a bottom portion of the fixed-type DC electric furnace, and from the one or the plurality of bottom-blown tuyeres, a maximum of 200 Nm^3/h of an inert gas per one bottom-blown tuyere may be blown into the fixed-type DC electric furnace.

(14) In the molten pig iron manufacturing method according to any one of (1) to (13), an electric furnace slag having a T.Fe concentration of 5 mass% or less, a CaO/SiO_2 concentration ratio of 1.0 to 1.3, and an Al_2O_3 concentration of 8 to 20 mass% may be discharged from a slag hole.

(15) In the molten pig iron manufacturing method according to any one of (1) to (14), when the molten pig iron has a P concentration of higher than 0.15%, dephosphorization treatment by ladle dephosphorization refining may be performed until the P concentration of the molten pig iron becomes 0.15% or less.

[Effects of the Invention]

[0013] According to the present invention, it is possible to significantly reduce CO_2 generation in ironmaking by using a fixed-type DC electric furnace instead of a blast furnace and to efficiently and continuously manufacture molten pig iron.

[Brief Description of the Drawings]

[0014]

FIG. 1 are diagrams showing overall flows of an ironmaking and steelmaking step, in which (A) is a conventional example and (B) is an example of the present invention.

FIG. 2 are views showing an example of a fixed-type DC electric furnace, in which (A) is a front cross-sectional view taken along line A-A, (B) is a side cross-sectional view taken along line B-B, and (C) is a side cross-sectional view taken along line C-C.

FIG. 3 is a view showing an example of ladle dephosphorization.

FIG. 4 is a flowchart of a molten pig iron manufacturing method according to the present embodiment.

FIG. 5 is a schematic view showing a situation where iron-containing scrap is charged by using a chute.

[Embodiment of the Invention]

[0015] A molten pig iron manufacturing method according to an embodiment of the present invention will be described with reference to FIGS. 1 to 5.

1. Electric furnace 10

[0016] An example of a fixed-type DC electric furnace 10 (hereinafter, the electric furnace 10) used in the molten pig iron manufacturing method according to the present embodiment will be described below.

[0017] As shown in FIG. 2, the electric furnace 10 includes a lower portion 11, a furnace wall 12, a furnace lid 13, upper electrodes 14, and lower electrodes 15.

[0018] The lower portion 11 of the electric furnace 10 includes a bottom portion 11a and a wall portion 11b.

[0019] The bottom portion 11a is provided with a bottom-blown tuyere 11a1 for blowing gas into the electric furnace 10.

[0020] The wall portion 11b is provided with a tap hole 11b1 for tapping molten pig iron 210 and a slag hole 11b2 for discharging electric furnace slag 220.

[0021] The furnace wall 12 is attached to the upper end of the wall portion 11b of the lower portion 11 of the electric furnace 10.

[0022] The furnace lid 13 is provided with a solid iron source supply pipe 13a, an auxiliary raw material supply pipe 13b, a supply port 13c, and a duct coupling opening 13d.

[0023] Also, the furnace lid 13 includes an inclined portion 13A extending so as to be inclined toward the inside of the electric furnace 10 upward from the upper end of the furnace wall 12, and a horizontal portion 13B continuing to the upper end of the inclined portion 13A and extending in the horizontal direction.

[0024] The solid iron source supply pipe 13a and the auxiliary raw material supply pipe 13b are provided so as to penetrate the horizontal portion 13B of the furnace lid 13.

[0025] The supply port 13c and the duct coupling opening 13d are provided so as to penetrate the inclined portion 13A of the furnace lid 13.

[0026] A lid 13d for opening and closing the opening part is provided in the supply port 13c, and a duct 17 for sucking gas inside the electric furnace 10 is connected to the duct coupling opening 13d.

[0027] The shape of the furnace lid 13 is merely an example, and for example, the supply port 13c may be provided in the horizontal portion 13B.

[0028] The upper electrode 14 is inserted so as to penetrate the furnace lid 13 of the electric furnace 10. The lower electrode 15 is provided in refractory at the bottom portion 11a of the electric furnace 10.

[0029] Here, a space in which a horizontal separation distance (radial separation distance) from the outer periphery of the upper electrode 14 at a height position between a slag bath surface 221 and the lower end of the upper electrode 14 inside the electric furnace 10 is within 0.5 times the diameter of the upper electrode 14 is defined as an upper electrode facing space α.

[0030] In addition, a space in which a horizontal separation distance from the inner wall surface of the furnace wall 12 at a height position above the height position of the slag bath surface inside the electric furnace 10 is within "the shortest distance between the furnace wall 12 and the upper electrode facing space α" is defined as a furnace inner peripheral wall space β.

[0031] Further, in FIG. 2, (A) is a front cross-sectional view taken along line A-A, (B) is a side cross-sectional view taken along line B-B, and (C) is a side cross-sectional view taken along line C-C.

[0032] In the molten pig iron manufacturing method according to the present embodiment, at least one of a carbon material 121 and the flux for composition adjustment 123 used as an auxiliary raw material is supplied to the electric furnace 10 in a state where a solid iron source 100 used as a main raw material is present in the furnace inner peripheral wall space β (that is, in a state where the solid iron sources 100 are stacked along the furnace wall 12) and in a state where the solid iron source 100 is not present in the upper electrode facing space α (that is, in a state where the slag bath surface 221 is exposed).

[0033] The reason why the solid iron sources 100 can be stacked is that the electric furnace 10 is a fixed-type, and is a molten pig iron manufacturing furnace that does not require complete melting and falling in continuous operation. In the case of the molten steel manufacturing furnace, batch operation is performed, and the entire amount is melted, tilted and tapped, so that the raw material stacking operation cannot be always performed.

[0034] In addition, by generating a circulation flow in the molten iron by the gas blown from the bottom-blown tuyere 11a1, it is possible to promote heat transfer, carburization and melting in the vicinity of the surface of the solid iron source 100.

[0035] Furthermore, in the electric furnace 10, the number of electrodes is reduced by adopting a DC electric furnace, and an effective space for disposing the solid iron source supply pipe 13a, the auxiliary raw material supply pipe 13b, and the supply port 13c in the furnace lid 13 is secured, so that it is possible to supply a wide variety of raw materials to one electric furnace 10.

[0036] In an AC electric furnace, the power capacity is limited due to the manufacturing limit of electrode size, and it is difficult to scale up. However, according to the present embodiment, since the DC electric furnace is used, there is no such limitation.

[0037] In addition, since energization and stop of energization are repeated in a tilting electric furnace, productivity decreases, but since the electric furnace 10 used in the present embodiment is a fixed type and uses the tap hole 11b1 for tapping the molten pig iron 210 and the slag hole 11b2 for discharging the electric furnace slag 220, it is possible to efficiently and continuously manufacture molten pig iron 210.

[0038] The electric furnace 10 preferably includes two or more upper electrodes 14 and two or more lower electrodes 15 (furnace bottom refractory electrodes). Further, the two or more lower electrodes 15 are preferably provided at positions corresponding to the two or more upper electrodes 14 in a plane view of the electric furnace 10.

[0039] In addition, the electric furnace 10 is a sealed electric furnace configured to be able to substantially shut off air intrusion, and preferably includes a tap hole 11b1 and a slag hole 11b2 having different heights from a hearth.

[0040] Since the fixed-type DC electric furnace is used as the electric furnace 10 applied in the molten pig iron manufacturing method according to the present embodiment, the number of electrodes of the upper electrodes 14 can be at least one. On the other hand, by including the two or more upper electrodes 14 and the lower electrodes 15 (furnace bottom refractory electrodes) corresponding to the upper electrodes 14, a plurality of upper electrodes 14 of the DC electric furnace are disposed, and the furnace shape and size are determined according to the electrodes, so that the power supply capacity can be easily increased, and a molten pig iron manufacturing electric furnace of a scale replacing the blast furnace 55 becomes possible.

[0041] In addition, by substantially eliminating the opening part of the furnace body and suppressing the air intrusion, it is possible to reduce oxidation loss of the carbon material 121 staying on the slag bath surface 221 in the furnace and improve the carburizing efficiency. For example, three 30 inch DC upper electrodes 14 are linearly disposed, and the furnace shape is formed into a shape close to a rectangular parallelepiped, so that the scale of a power supply capacity of 200 MW is realized, and a tapping capacity of 2 million t/y corresponding to the scale of 1/2 of a large blast furnace can be provided.

2. Supply of solid iron source 100

[0042] As the solid iron source 100, at least one of three raw materials of iron-containing scrap 101, reduced iron 103a, and iron-containing dust 103b is supplied to the electric furnace 10 (see step S1 in FIG. 4). That is, only the iron-containing scrap 101, only the reduced iron 103a, or only the iron-containing dust 103b may be used as the solid iron source 100, and two or all of the iron-containing scrap 101, the reduced iron 103a, and the iron-containing dust 103b may be mixed and used as the solid iron source 100. The solid iron source 100 is supplied from the solid iron source supply pipe 13a or the supply port 13c.

[0043] From the solid iron source supply pipe 13a, iron-containing scrap 101 (for example, small punch scrap), the reduced iron 103a and the iron-containing dust 103b that are solid iron sources 100 of relatively small individual size (for example, in the case of a columnar shape, solid iron sources 100 having a maximum length of 100 mm or less) are mainly supplied to the electric furnace 10. As the reduced iron 103a, direct reduced iron (DRI), hot briquetted iron (HBI), and the like can be used. The DRI includes high temperature DRI and low temperature DRI. HBI is reduced iron briquetted at high temperature.

[0044] As the iron-containing dust 103b, converter dust can be used.

[0045] On the other hand, from the supply port 13c, iron-containing scrap 101 (for example, heavy scrap) that is a solid iron source 100 of relatively large individual size and difficult to be stably supplied from the solid iron source supply pipe (for example, in the case of a columnar shape, a solid iron source 100 having a maximum length of more than 100 mm) is mainly supplied to the electric furnace 10.

[0046] For example, as shown in FIG. 5, it is preferable to stack the iron-containing scraps 101 (solid iron sources 100) along the furnace wall 12 by supplying the iron-containing scraps 101 from the supply port 13c disposed above the furnace inner peripheral wall space β using a solid iron source charging implement 18 (for example, a chute or a bucket). For example, the iron-containing scrap 101 of relatively large individual size can be supplied to the electric furnace 10 in the following procedure.

(1) The iron-containing scrap 101 is loaded on the solid iron source charging implement 18.
(2) Then, the lid 13c1 of the supply port 13c is opened to supply the iron-containing scrap 101 to the furnace inner peripheral wall space β of the electric furnace 10 via the solid iron source charging implement 18 while maintaining the slag bath surface 221.

[0047] In addition to the iron-containing scrap 101 of relatively large individual size, the solid iron source 100 such as the reduced iron 103a and the iron-containing dust 103b of relatively small individual size can also be supplied from the supply port 13c to the electric furnace 10 in the above procedure. On the other hand, the iron-containing scrap 101 may also be charged from the solid iron source supply pipe 13a as long as it has a size that can be charged from the solid iron source supply pipe 13a.

[0048] Further, as a method for supplying the iron-containing dust 103b, the iron-containing dust 103b can be:

(1) granulated and supplied from the solid iron source supply pipe 13a;
(2) supplied from the supply port 13c together with the iron-containing scrap 101 as a dehydrated cake of a large mass; or
(3) supplied as iron oxide powder together with carbon material powder from the auxiliary raw material supply pipe 13b to the slag bath surface 221.

[0049] The solid iron source supply pipe 13a is disposed such that the solid iron sources 100 to be supplied are stacked along the furnace wall 12. Therefore, the solid iron source supply pipe 13a is preferably disposed above the furnace inner peripheral wall space β.

[0050] Similarly, the supply port 13c is disposed such that the solid iron sources 100 to be supplied are stacked along the furnace wall 12. Therefore, the supply port 13c is preferably disposed above the furnace inner peripheral wall space β.

[0051] The supplied solid iron sources 100 are stacked along the furnace wall 12 (that is, arranged so as to be present in the furnace inner peripheral wall space β) after being supplied from the solid iron source supply pipe 13a and the supply port 13c.

[0052] On the other hand, the solid iron source 100 is not present in the upper electrode facing space α of the electric furnace 10, that is, the slag bath surface 221 of the electric furnace slag 220 is exposed. Such a slag bath surface 221 of the upper electrode facing space α where the solid iron source 100 is not present is formed in a region between the upper electrode 14 and the lower electrode 15.

[0053] As described above, the solid iron sources 100 supplied so as to be present in the furnace inner peripheral wall space β of the electric furnace 10 are arranged in a stacked state along the furnace wall 12. As a result, the upper portion of the stacked solid iron sources 100 is preheated by arc and radiation heat of the slag bath surface 221, and the solid iron sources 100 immersed in the lower portion of the slag bath surface 221 are melted. In addition, since the solid iron sources 100 are stacked along the furnace wall 12, it protects refractory of the furnace wall 12, reduces heat removal loss from the furnace wall 12, and contributes to improvement of thermal efficiency. In order to more suitably obtain this effect, a top portion of the solid iron sources 100 supplied so as to be present in the furnace inner peripheral wall space β of the electric furnace 10 preferably is present at a position higher than the lower end of the upper electrode 14. Furthermore, the upper electrode facing space α is preferably formed in a region whose whole circumference is surrounded by the solid iron sources 100 stacked along the furnace wall 12.

[0054] In addition, in order to more suitably obtain the effects of protecting the furnace wall 12 and reducing the heat loss from the furnace wall 12, the supplied solid iron sources 100 are preferably stacked along the whole circumference of the furnace wall 12. That is, the solid iron source 100 is preferably present along the whole circumference of the furnace inner peripheral wall space β.

[0055] The reduced iron 103a to be supplied to the electric furnace 10 in the present embodiment is preferably DRI or HBI having a C concentration of 0 to 4 mass% by reducing iron ore using at least one of hydrogen gas, natural gas, and CO gas. This is because the ratio of reduction by carbon derived from fossil fuel is suppressed to contribute to reduction of CO_2 emission. The reduced iron 103a further preferably has a C concentration of 2 to 4 mass%. This is because, although the carburizing efficiency is low when the carbon material 121 is supplied in the electric furnace, the carburizing treatment can be reduced by using reduced iron having a C concentration of 2 to 4 mass%.

[0056] It is to be noted that reduced iron manufactured from pellets containing a carbon material such as charcoal may be used as the reduced iron 103a.

3. Supply of steelmaking slag 140

[0057] The electric furnace 10 can be supplied with steelmaking slag 140 (see step S2 in FIG. 4).

[0058] In the molten pig iron manufacturing method according to the present embodiment, the steelmaking slag 140 is a generic name of slag generated in steelmaking equipment 51 or ladle dephosphorization refining equipment 57. As the steelmaking slag 140, at least one slag of molten pig iron desulfurization slag generated in the steelmaking equipment 51, converter slag generated in the steelmaking equipment 51, secondary refining slag generated in the steelmaking equipment 51, and dephosphorization slag 320 generated in the ladle dephosphorization refining equipment 57 can be used. In addition, the steelmaking slag 140 in a molten state at high temperature is referred to as molten slag.

[0059] The steelmaking slag 140 can be supplied even in a solidified state at low temperature, but is desirably supplied in a molten state at high temperature to the solid iron source 100 present in the furnace inner peripheral wall space β of the electric furnace 10 from the viewpoint of effective use of heat. When the molten slag having a high degree of oxidation is supplied as it is to the exposed slag bath surface 221, a direct reaction occurs due to mixing of the molten slag having a high oxidation degree (electric furnace slag 220) with the molten pig iron 210 to cause severe slag foaming in a bumping state. In order to prevent this, it is preferable to supply the molten slag to the upper portion of at least one of the iron-containing scraps 101, the reduced iron 103a, and the iron-containing dust 103b arranged in a stacked manner. Thereby, the direct reaction between the supplied molten slag and the molten pig iron 210 can be avoided, and bumping can be prevented.

[0060] In the example shown in FIG. 2, the iron-containing scrap 101 is first supplied from the supply port 13c provided in the furnace lid 13 (the inclined portion 13A or the horizontal portion 13B) of the electric furnace 10 to stack the iron-containing scraps 101 along the furnace wall 12 of the electric furnace 10, and then the molten steelmaking slag 140 is supplied from the same supply port 13c. The steelmaking slag 140 is poured over the stacked iron-containing scraps 101.

[0061] Moreover, when the steelmaking slag 140 to be supplied is in a solidified state, the steelmaking slag may be supplied from any one or more of the supply port 13c, the solid iron source supply pipe 13a, and the auxiliary raw material supply pipe 13b.

[0062] Among the steelmaking slag 140, the converter slag and the dephosphorization slag 320 contain P_2O_5 as a component, and high phosphorus reduced iron also contains P and P_2O_5 as components. By supplying these to the electric furnace 10 and reducing them in the electric furnace 10, phosphorus is transferred to the molten pig iron 210, and high phosphorus molten pig iron is manufactured, whereby phosphorus can be recovered.

[0063] Also, among the steelmaking slag 140, CaO and Al_2O_3 contained in the molten pig iron desulfurization slag and the secondary refining slag can be used for composition adjustment of the electric furnace slag 220.

[0064] As described above, all the steelmaking slag 140 generated in the steelmaking equipment 51 can be supplied to the electric furnace 10.

[0065] The resulting generated electric furnace slag 220 can be used as a raw material of blast furnace cement or the like by adjusting its composition to be equivalent to that of the blast furnace slag 42.

[0066] The use of high phosphorus reduced iron as described above means that high phosphorus iron ore is used as a raw material when manufacturing high phosphorus reduced iron. Therefore, the usable range of low-grade iron ore having a high P concentration is expanded.

[0067] The high phosphorus reduced iron is reduced iron (DRI, HBI, and the like) obtained by reducing high phosphorus iron ore as a raw material, and means reduced iron having a P concentration of 0.15 mass% or more.

[0068] The electric furnace 10 is supplied with the carbon material 121 and the flux for composition adjustment 123 in a state where the solid iron sources 100 are stacked along the furnace wall 12 and in a state where the slag bath surface 221 is exposed to the upper electrode facing space α (see steps S3 and S4 in FIG. 4).

4. Supply of carbon material 121

[0069] The carbon material 121 is used as a reducing material for oxides (the steelmaking slag 140, iron oxide in the iron-containing dust 103b, unreduced iron oxide in the reduced iron 103a, and the like) and a carburizer. As the carbon material 121, coke, coal, charcoal or the like can be used.

[0070] The particle size of the carbon material 121 is preferably 0.5 mm to 10 mm. When the carbon material 121 has a particle size of 0.5 mm to 10 mm, scattering loss is small because the carbon material is not a fine powder, and the reaction speed is high because of the small particle size. Here, the particle size is defined by a network of sieves through which particles can pass, and a particle size of 10 mm or less means that particles can pass through a sieve of 10 mm. Further, the particle size of 80 mass% or more of the carbon material 121 to be supplied may be 0.5 mm to 10 mm.

[0071] By adding the carbon material 121, the reduction reaction of the oxides proceeds, and the C concentration of the molten iron is increased by carburizing the molten iron.

[0072] Then, molten pig iron 210 having a C concentration of 2 to 4 mass% or more at a temperature of 1400°C to 1550°C is obtained, and is tapped from the tap hole 11b1. This makes it possible to supply molten pig iron alone to the steelmaking step as it is or after dephosphorizing the molten pig iron.

[0073] In the case of manufacturing the molten pig iron 210 by carburizing the molten iron in the electric furnace 10, only by supplying the carbon material 121 to the slag bath surface 221 from above to the molten iron, there is a case where the carbon material 121 floats on the slag bath surface 221 due to a difference in specific gravity and cannot reach the molten iron.

[0074] In the present embodiment, a DC electric furnace is used as the electric furnace 10. In the DC electric furnace, a strong downward flow is generated in slag of molten iron immediately below the electrode, whereby the carbon material 121 is fed into the molten iron below, and melting of the carbon material 121 can be promoted.

[0075] Moreover, in the present embodiment, the carbon material 121 is preferably supplied from a plurality of locations around the upper electrode 14 of the electric furnace 10 to the slag bath surface 221 formed in the upper electrode facing space α. By supplying the carbon material 121 in this manner, in-furnace slag (slag inside the electric furnace 10) is reduced, and at the same time, the floating carbon material powder is rapidly transported and melted in the molten iron due to a circulating flow of the slag, and the molten iron can be carburized so that the molten iron has a C concentration of 2% or more.

[0076] Further, by using the DC electric furnace, a downward flow is formed in the slag and the molten iron immediately below the upper electrode 14 by electromagnetic force, and the carbon material powder supplied to the slag bath is easily conveyed to the molten iron below. With respect to the carbon material supply position, around the upper electrode 14 is preferably at a horizontal distance of 1 m or less from the upper electrode 14. The plurality of locations is preferably two or more locations per electrode.

[0077] In addition, it is preferable that one or a plurality of bottom-blown tuyeres 11a1 having a flow rate variable small diameter circle of a flat gas flow path are provided at positions separated by a horizontal distance of 1 m or more from immediately below the upper electrode 14 at the bottom portion 11a of the electric furnace 10, and the electric furnace 10 includes the bottom-blown tuyeres 11a1 for blowing a maximum of 200 Nm^3/h of an inert gas per one bottom-blown tuyere into the electric furnace 10. By blowing the gas into a position 1 m or more away from immediately below the electrode, the flow of the molten iron and the slag is promoted, and the strong downward flow immediately below the central portion electrode is accelerated, whereby the carbon material 121 is fed into the molten iron below, and the melting of the carbon material 121 can be promoted. With respect to the position where the bottom-blown tuyere 11a1 is provided at the bottom portion 11a of the electric furnace 10, the upper limit value of the separation distance from immediately below the upper electrode 14 may be, for example, 5 m or 3 m.

[0078] The reason why the upper limit of the bottom-blown flow rate is limited to 200 Nm^3/h or less is to suppress the erosion speed of the bottom-blown tuyere 11a1 and to reduce the frequency of tuyere replacement. As the bottom blowing gas, it is preferable to use an inexpensive nitrogen gas that can maintain the inside of the electric furnace in a reducing atmosphere.

[0079] In addition, since the carbon material 121 floating on the slag bath surface 221 is easily combusted by the air entering inside the electric furnace 10, it is effective to make the electric furnace 10 a sealed type as much as possible in order to prevent combustion. By eliminating the opening part of the furnace body and preventing air intrusion, it is possible to reduce oxidation loss of the carbon material 121 staying on the slag bath surface 221 in the furnace and improve the carburizing efficiency.

5. Supply of flux for composition adjustment 123

[0080] The flux for composition adjustment 123 is a flux containing at least one of CaO, SiO_2, and Al_2O_3 as a component.

[0081] In order to rapidly advance melting and reduction of the oxides contained in the steelmaking slag 140 and the solid iron source 100 and smoothly discharge the electric furnace slag 220 from the slag hole 11b2, it is necessary to adjust the slag composition and lower the melting point and viscosity to secure reactivity and fluidity. Therefore, in the present embodiment, the flux for composition adjustment 123 containing at least one of CaO, SiO_2, and Al_2O_3 as a component is charged into the electric furnace 10. The electric furnace slag composition after the addition of the carbon material 121 and the flux for composition adjustment 123 are preferably within the range of:

- T.Fe concentration: 5 mass% or less
- CaO/SiO_2 concentration ratio: 1.0 to 1.3,
- Al_2O_3 concentration: 8 to 20 mass%.

[0082] Even when the steelmaking slag 140 is not supplied, the flux for composition adjustment 123 is supplied.

[0083] Suitable ranges of the CaO concentration, the SiO_2 concentration and the Al_2O_3 concentration in the flux for composition adjustment 123, and the amount of the flux for composition adjustment 123 to be added also vary depending on the components of the oxides contained in the steelmaking slag 140 and the solid iron source 100 to be supplied. After the components of the oxides contained in the steelmaking slag 140 and the solid iron source 100 are mixed with the flux for composition adjustment 123, the composition of the electric furnace slag may fall within the above preferred range. For example,

- quicklime having a CaO concentration of 95 mass%,
- silica sand having a SiO_2 concentration of 99 mass%,
- brick waste having an Al_2O_3 concentration of 83 mass%, and
- fly ash having a SiO_2 concentration of 59 mass% and an Al_2O_3 concentration of 23 mass%

are appropriately blended, whereby the slag composition can be adjusted to an optimum range, and slag melting can be suitably promoted. As the flux for composition adjustment 123, in addition to quicklime, silica sand, brick waste, and fly ash, sewage sludge ash, aluminum dross, and the like can be used. In addition, steelmaking slag itself can also be used as the flux for composition adjustment.

[0084] In the example shown in FIG. 2, the carbon material 121 and the flux for composition adjustment 123 are supplied toward the slag bath surface 221 exposed from the auxiliary raw material supply pipes 13b.

[0085] The molten pig iron 210 manufactured inside the electric furnace 10 is tapped from the tap hole 11b1. Further, the electric furnace slag 220 is discharged from the slag hole 11b2. The oxides contained in the steelmaking slag 140 and the solid iron source 100 are reduced and modified, and high quality reduced slag equivalent to the blast furnace slag 42 is recovered as the electric furnace slag 220. Since the electric furnace slag 220 has lower concentrations of FeO, P_2O_5 and the like than that before reduction, it can be used as, for example, a cement raw material or a ceramic product. In addition, since it has low expansivity, it can be used as a civil engineering material such as a roadbed material, an aggregate, and a stone.

6. Ladle dephosphorization refining

[0086] When steelmaking slag or high phosphorus reduced iron is used, the molten pig iron 210 tapped from the electric furnace 10 is high phosphorus molten pig iron having a high P concentration. When the molten pig iron 210 has a P concentration of higher than 0.15%, the molten pig iron 210 is accommodated in a ladle 24 (see FIG. 3), and dephosphorization treatment by ladle dephosphorization refining is performed until the P concentration becomes 0.15% or less to manufacture dephosphorized molten pig iron 310 and dephosphorization slag 320 (step S5 in FIG. 4).

[0087] As shown in FIG. 1(B), the dephosphorized molten pig iron 310 is sent to steelmaking equipment 51 including molten pig iron desulfurization equipment 52, a converter 53, and secondary refining equipment 54 to manufacture molten steel (see step S6A in FIG. 4).

[0088] The molten pig iron 210 having a high P concentration is discharged from the electric furnace 10, and then dephosphorized to the P concentration level or less of the ordinary molten pig iron in the ladle 24, so that the dephosphorization load in the converter 53 in the next step can be reduced, and at the same time, high phosphate slag 321 having a high P_2O_5 concentration can be obtained. The high phosphate slag 321 can be used as a phosphate fertilizer or a phosphate product raw material.

[0089] When the P_2O_5 concentration of the dephosphorization slag 320 obtained by the ladle dephosphorization refining is lower than the target value, the dephosphorization slag 320 is supplied again to the electric furnace 10, the P concentration of the molten pig iron 210 is increased, and is again dephosphorized by ladle refining, so that the P_2O_5 concentration of the dephosphorization slag 320 can be further increased. When the P_2O_5 concentration is sufficiently high, it can be used as a phosphate fertilizer or a phosphate raw material. That is, the dephosphorization slag 320 formed by the ladle dephosphorization refining is recycled to the electric furnace 10 or is used as a phosphate fertilizer or a phosphate raw material as the high phosphate slag 321 according to the P_2O_5 concentration (see step S6B in FIG. 4).

[0090] By using the above method, the usable range of low-grade iron ore having a high P concentration is expanded, and all the slag generated in the steelmaking equipment 51 can be converted into slag equivalent to blast furnace slag having a higher added value. Furthermore, valuable iron and phosphorus can be recovered and made into products such as iron sources and phosphate fertilizers.

[0091] When the dephosphorization slag 320 has a P_2O_5 concentration of less than 8%, the dephosphorization slag 320 is recycled to the electric furnace 10, and when the dephosphorization slag 320 has a P_2O_5 concentration of 8% or more, the dephosphorization slag 320 is preferably used as a phosphate fertilizer containing P_2O_5, CaO, SiO_2, and MgO or a phosphate raw material. With respect to the P_2O_5 concentration, the reason why 8% is used as a boundary is that the fertilizer effect as a phosphate fertilizer is significantly reduced when the P_2O_5 concentration is 8% or less. Of course, as the phosphate raw material, the higher P_2O_5 is, the more efficiently the dephosphorization slag 320 can be commercialized.

[0092] As a dephosphorization treatment method performed in the ladle dephosphorization refining, as shown in FIG. 3, it is preferable that oxygen top blowing from a lance 21 and upward addition of iron oxide and a lime-based dephosphorization agent are performed, and a gas of 0.5 to 5 NL/t/min is blown from a ladle bottom porous plug 23 or an immersion lance 25 for blowing stirring gas. Dephosphorylation refining is performed by oxygen top blowing from the lance 21 and supplying iron oxide.

[0093] In the ladle dephosphorization refining equipment 57, if dephosphorization is performed to lower the P concentration to around 0.1%, the basicity of the slag is 2 or less, and dephosphorization can be performed without using fluorite containing F (fluorine) that inhibits the fertilizer effect.

[0094] When high basicity (for example, basicity of 2.5 or more) slag is required to further lower the P concentration, a portion of the lime-based dephosphorization agent is desirably projected by a fuel burner 22 and melted by passing powder of the lime-based dephosphorization agent through combustion flame of the fuel burner 22. In addition, by blowing a stirring gas of 0.5 to 5 NL/t/min from the ladle bottom porous plug 23 or the immersion lance 25, the molten pig iron 210 is stirred, and it is possible to easily improve the dephosphorization reaction efficiency, improve the thermal efficiency of the fuel burner 22, and control T.Fe concentration level in the slag. By setting the nitrogen gas blowing rate to a suitable range of 5 NL/t/min or less, the T.Fe concentration in the slag can be set to a suitable range. In addition, by setting the nitrogen gas blowing rate to an appropriate flow rate of 0.5 NL/t/min or more, the surface-renewal of the slag bath can be promoted by gas stirring, and the thermal efficiency of the fuel burner 22 can be improved.

[Examples]

[0095] FIG. 1 shows a schematic diagram of a molten pig iron manufacturing step of the present application (FIG. 1(B)) in comparison with a conventional example (FIG. 1(A)). In addition, FIG. 2 shows schematic views of a molten pig iron manufacturing electric furnace, and FIG. 3 shows a schematic view of a dephosphorization treatment device.

[0096] In the present example, iron-containing scrap 101, reduced iron 103a, iron-containing dust 103b, molten steelmaking slag 140, a carbon material 121, and a flux for composition adjustment 123 are supplied to an electric furnace

10 by respective methods, and
a manufacturing step of molten pig iron and molten steel using:

- a sealed fixed-type DC electric furnace for manufacturing electric furnace slag 220 which is melted and reduced by a carbon source from the carbon material 121 to be reduced to molten pig iron 210; and
- ladle dephosphorization refining equipment 57 for dephosphorizing the obtained molten pig iron 210 (high phosphorus molten pig iron) to manufacture dephosphorized molten pig iron 310 (ordinary molten pig iron) which can be recycled to a converter 53 and high phosphate slag 321 to be a phosphate fertilizer or a phosphate raw material for ladle

is used.

[0097] Examples will be specifically described below.

[0098] As the electric furnace 10, a fixed-type DC electric furnace including a maximum power supply capacity of 200 MW, three upper electrodes 14, and conductive refractory electrodes immediately below the upper electrodes 14 as lower electrodes 15 (furnace bottom refractory electrodes) to separate by non-conductive refractories, and having two tap holes 11b1 and two slag holes 11b2 having different height positions (levels) was used. The specifications of the electric furnace 10 are shown in Table 1.

[Table 1]

Electric furnace specifications	
Input power (DC)	180 MW
Number of upper electrodes	30 inch × 3
Bottom-blown tuyere	Flow rate variable 20 Nm^3/h × 8
Tap hole, slag hole	Each two

[0099] The reduced iron 103a and the iron-containing dust 103b were supplied by selectively using twelve solid iron source supply pipes 13a provided in the vicinity of a furnace wall 12 in a furnace lid 13. The iron-containing scraps 101 were supplied by a chute with a lid 13c1 of each of two supply ports 13c provided in the furnace lid 13 opened, and was supplied so as to be stacked along the furnace wall 12 of the electric furnace 10 (see FIG. 2). On the other hand, except when the lid 13d of the supply port 13c for supplying the iron-containing scrap 101 was open, carbon material powder to be a reducing material and a carburizer, and the flux for composition adjustment 123 such as fly ash, silica sand, and brick waste were continuously supplied from six auxiliary raw material supply pipes 13b provided in the furnace lid 13 in the vicinity of the upper electrodes 14 to the exposed surface of a slag bath surface 221 in the furnace.

[0100] Also, for the purpose of recovering iron and phosphorus and adjusting compositions of the electric furnace slag 220, slag discharged from the converter 53 (steelmaking slag 140) was accommodated in a slag pot 16, and supplied in a molten state from the supply port 13c to the electric furnace 10 (see FIG. 2). Specifically, in order to avoid direct reaction between the molten slag and the molten pig iron 210 and to prevent bumping, the molten slag was supplied from the supply port 13c toward the reduced iron 103a or the iron-containing scraps 101 arranged in a stack.

[0101] In the electric furnace 10 in continuous operation, 300 t of the molten pig iron 210 was always present in the furnace as hot heel, 300 t of the molten pig iron 210 was discharged from the tap holes 11b1 every 40 minutes, and as for the slag, the electric furnace slag 220 above the slag holes 11b2 was discharged. A part of the molten pig iron 210 was directly subjected to a water granulating treatment to obtain a cement raw material.

[0102] In addition, slag discharged from the tap holes 1 1b1 together with the molten pig iron 210 was separated by a skimmer and subjected to a slow cooling treatment to obtain a calcium silicate fertilizer or a civil engineering material. Arc irradiation by the upper electrodes 14 was continuously performed at the time of the tapping and the deslagging.

[0103] At the bottom portion 11a of the electric furnace 10, for the purpose of promoting the dissolution of the carbon material 121 to the molten iron and the melting of the solid iron source 100, bottom-blown tuyeres 11a1 were provided at a total of eight positions outside the position of the lower electrodes 15 (furnace bottom refractory electrodes) (at positions 3 m away from immediately below the upper electrodes 14), and gas was blown.

[0104] The molten pig iron 210 discharged from the electric furnace 10 was subjected to iron reception in a ladle 24 having a capacity of 300 t and subjected to a treatment in ladle dephosphorization refining equipment 57 (see FIG. 3). The specifications of ladle dephosphorization device 20 are shown in Table 2. The ladle dephosphorization device 20 includes:

- a device for adding a lime-based dephosphorization agent and iron oxide upward;

- a lance 21 for oxygen top blowing;
- a fuel burner 22 (LPG burner lance) capable of projecting powder; and
- a ladle bottom porous plug 23 (bottom-blown porous tuyere).

[0105] In Case 1 and Case 3 shown in Table 4, the supply of the lime-based dephosphorization agent and the oxygen top blowing were performed, and the temperature was adjusted by cooling by supplying iron oxide.

[0106] In addition, in Case 2 and Case 4, since the basicity was slightly high as 2.0, oxygen top blowing was stopped halfway, iron oxide was supplied while a lime-based dephosphorization agent was projected by a burner, and P_2O_5 was absorbed into dephosphorization agent particles.

[Table 2]

Ladle dephosphorization device	
Capacity	300 t/heat
Oxygen lance	Max. 6,000 Nm^3/h one lance
Fuel burner	CaO Max 200 kg/min
Bottom Blowing	300 NL/min N_2 (1 NL/t/min)

[0107] Since the dephosphorized molten pig iron 310 obtained in the ladle dephosphorization refining equipment 57 had the same level of P concentration as that of the ordinary molten pig iron, the molten pig iron was directly conveyed to steelmaking equipment 51. In addition, since the dephosphorization slag 320 has a relatively high (P_2O_5) concentration, the dephosphorization slag 320 was used as a phosphate fertilizer. When a fertilizer having a higher (P_2O_5) concentration is desired, the dephosphorization slag 320 may be supplied to the electric furnace 10 for reduction to increase the P concentration in the molten pig iron.

[0108] In the steelmaking equipment 51, the dephosphorized molten pig iron 310 obtained in the ladle dephosphorization refining equipment 57 was subjected to a desulfurization treatment in molten pig iron desulfurization equipment 52 and supplied to the converter 53. Blast furnace molten pig iron was not supplied to the converter 53. Decarburization and final dephosphorization were performed in the converter 53, and casting was performed in continuous casting equipment 56 through secondary refining equipment 54 (see FIG. 1). In addition, since the C concentration in the molten pig iron at the time of supply to the converter 53 was 2.0%, which was considerably lower than that of the blast furnace molten pig iron, and the heat source was insufficient, the iron-containing scrap 101 was not supplied, and the main raw material was all molten pig iron.

[0109] The equipment and the preconditions of the operation of the example of the present method are shown below.

[0110] The treatment of Cases 1 to 4 shown in Table 4 was performed. As for the reduced iron 103a among the main raw materials to be supplied to the electric furnace 10, DRI derived from high phosphorus iron ore having the compositions shown in Table 3 was used. As for the flux for composition adjustment 123 to be supplied to the electric furnace 10, silica sand was used as SiO_2 source, alumina brick waste was used as Al_2O_3 source, and supply intensity was each described in the columns of "SiO_2" and "Al_2O_3" in the column of "flux for composition adjustment" in Table 4.

[Table 3]

Reduced iron quality				
Content (mass%)				Metallization ratio (%)
C	P_2O_5	SiO_2	Al_2O_3	
2	0.33	5	1	94

[Table 4]

Step	Specifications				Case 1	Case 2	Case 3	Case 4
Electric furnace	Supply	Iron-containing scrap	kg/t		0	0	543	543
		Reduced iron	kg/t	Total	1087	1087	543	543
				High phosphorus reduced iron	1087	1087	543	543
		steelmaking slag	kg/t	Converter slag	88.5	88.5	88.5	98.2
				Dephosphorization slag	0	46.8	0	0
		Flux for composition adjustment	kg/t	SiO_2	40.8	37.2	8.2	5.5
				Al_2O_3	7.4	10.4	6.0	6.6
	Product	Molten pig iron	% of Component	[C]	2.63	3.25	2.32	2.34
				[Si]	0.25	0.25	0.25	0.25
				[P]	0.226	0.35	0.163	0.138
		Electric furnace slag	Mass supply	intensity kg/t	183	212	115	121
			% of Component	(T. Fe)	2	2	2	2
				(CaO)	42.7	43.4	39.6	38.8
				(SiOz)	36.6	36.2	33	32.3
				(P_2O_5)	0.2	0.2	0.2	0.2
				(Al_2O_3)	10	10	10	10
Ladle dephosphorization refining	Supply	Flux	kg/t	CaO	17.8	26.1	11.9	18.5
	Product	Molten pig iron	% of Component	[C]	2	2	2	2
				[P]	0.1	0.1	0.1	0.07
		Dephosphorization slag	Mass kg/t		46.8	64.5	32.4	42.2
			% of Component	(T. Fe)	12	12	12	15.5
				(CaO)	38	40.4	36.7	43.8
				(SiOz)	25.3	20.2	28.2	21.9
				(P_2O_5)	6.2	8.9	4.5	3.7

(continued)

Step	Specifications				Case 1	Case 2	Case 3	Case 4
Converter	Supply	Flux	kg/t	CaO	37.2	37.2	37.2	41.2
	Product	Molten steel	% of Component	[C]	0.05	0.05	0.05	0.05
				[P]	0.015	0.015	0.015	0.010
		Converter slag	Mass kg/t		88.5	88.5	88.5	98.2
			% of Component	(T. Fe)	18	18	18	18
				(CaO)	42	42	42	42
				(SiOz)	12	12	12	12
				(PzOs)	2.2	2.2	2.2	1.4

<<Case 1>>

[0111] 100% of the reduced iron 103a shown in Table 3 (DR1 derived from high phosphorus iron ore) was used as the solid iron source 100, and the entire amount of the converter slag were supplied in a molten state to the electric surface 10 as the steelmaking slag 140 with the components and supply intensity shown in the converter process "slag" of Case 1 in Table 4.

[0112] Since the molten pig iron 210 as a product obtained by electric furnace refining had a P concentration of 0.23%, the molten pig iron 210 was dephosphorized until the P concentration reached 0.10% in the ladle dephosphorization refining equipment 57, and the obtained dephosphorized molten pig iron 310 was sent to the steelmaking equipment 51.

[0113] The dephosphorized molten pig iron 310 was supplied to the converter 53, and as a result of converter blowing, the molten steel had a P concentration of 0.015%.

[0114] Since the dephosphorization slag 320 in the ladle dephosphorization refining equipment 57 had a (P_2O_5) concentration of 6.2%, the dephosphorization slag 320 was recycled to the electric furnace 10 in Case 2 as the next charge.

[0115] The transition of the concentration in the entire process is as follows.

- P concentration of molten pig iron 210: 0.23%,
- P concentration of dephosphorization slag 320: 0.10%,
- (P_2O_5) concentration of dephosphorization slag 320: 6.2%,
- P concentration of converter-tapped steel: 0.015%

«Case 2»

[0116] 100% of the reduced iron 103a shown in Table 3 (DR1 derived from high phosphorus iron ore) was used as the solid iron source 100, and the entire amount of the converter slag were supplied in a molten state to the electric surface 10 as the steelmaking slag 140 with the components and supply intensity shown in the converter process "slag" of Case 2 in Table 4.

[0117] In addition, the dephosphorization slag 320 of Case 1 as a pre-charge was also supplied to the electric furnace 10 to enrich phosphate.

[0118] Since the molten pig iron 210 as a product obtained by electric furnace refining had a P concentration of 0.35%, the molten pig iron 210 was dephosphorized until the P concentration reached 0.10% in the ladle dephosphorization refining equipment 57, and the obtained dephosphorized molten pig iron 310 was sent to the steelmaking equipment 51.

[0119] The dephosphorized molten pig iron 310 was supplied to the converter 53, and as a result of converter blowing, the molten steel had a P concentration of 0.015%.

[0120] Since the dephosphorization slag 320 in the ladle dephosphorization refining equipment 57 had a (P_2O_5) concentration of 8.9%, the dephosphorization slag 320 was used as a phosphate fertilizer.

[0121] The transition of the concentration in the entire process is as follows.

- P concentration of molten pig iron 210: 0.35%,
- P concentration of dephosphorization slag 320: 0.10%,
- (P_2O_5) concentration of dephosphorization slag 320: 8.9%,
- P concentration of converter-tapped steel: 0.015%

«Case 3»

[0122] 50% of the reduced iron 103a shown in Table 3 (DRI derived from high phosphorus iron ore) was used as the solid iron source 100, 50% of the iron-containing scrap 101, and the entire amount of the converter slag were supplied in a molten state to the electric surface 10 as the steelmaking slag 140 with the components and supply intensity shown in the converter process "slag" of Case 3 in Table 4.

[0123] Since the molten pig iron 210 as a product obtained by electric furnace refining had a P concentration of 0.16%, the molten pig iron 210 was dephosphorized until the P concentration reached 0.10% in the ladle dephosphorization refining equipment 57, and sent to the steelmaking equipment 51.

[0124] The dephosphorized molten pig iron 310 was supplied to the converter 53, and as a result of converter blowing, the molten steel had a P concentration of 0.015%.

[0125] Since the dephosphorization slag 320 in the ladle dephosphorization refining had a (P_2O_5) concentration of 4.5%, the dephosphorization slag 320 was recycled to the electric furnace 10 for the next charge.

[0126] The transition of the concentration in the entire process is as follows.

- P concentration of molten pig iron 210: 0.16%,

- P concentration of dephosphorization slag 320: 0.10%,
- (P_2O_5) concentration of dephosphorization slag 320: 4.5%,
- P concentration of converter-tapped steel: 0.015%

«Case 4»

[0127] 50% of the reduced iron 103a shown in Table 3 (DRI derived from high phosphorus iron ore) was used as the solid iron source 100, 50% of the iron-containing scrap 101, and the entire amount of the converter slag were supplied in a molten state to the electric surface 10 as the steelmaking slag 140 with the components and supply intensity shown in the converter process "slag" of Case 4 in Table 4.

[0128] Since the molten pig iron 210 as a product obtained by electric furnace refining had a P concentration of 0.14%, the molten pig iron 210 was dephosphorized until the P concentration reached 0.07% in the ladle dephosphorization refining equipment 57, and sent to the steelmaking equipment 51.

[0129] The dephosphorized molten pig iron 310 was supplied to the converter 53, and as a result of converter blowing, the P concentration of the molten steel was lowered to 0.010%, and an ultra-low phosphorus steel could be melt-manufactured.

[0130] Since the dephosphorization slag 320 in the ladle dephosphorization refining had a (P_2O_5) concentration of 3.7%, the dephosphorization slag 320 was recycled to the electric furnace 10 for the next charge.

[0131] The transition of the concentration in the entire process is as follows.

- P concentration of molten pig iron 210: 0.14%,
- P concentration of dephosphorization slag 320: 0.07%,
- (P_2O_5) concentration of dephosphorization slag 320: 3.7%,
- P concentration of converter-tapped steel: 0.010%

[Field of Industrial Application]

[0132] According to the present invention, it is possible to significantly reduce CO_2 generation in ironmaking by using a fixed-type DC electric furnace instead of a blast furnace and to efficiently and continuously manufacture molten pig iron.

[Brief Description of the Reference Symbols]

[0133]

10 Fixed-type DC electric furnace
α Upper electrode facing space
β Furnace inner peripheral wall space
11 Lower portion
11a Bottom portion
11a1 Bottom-blown tuyere
11b Wall portion
11b1 Tap hole
11b2 Slag hole
12 Furnace wall
13 Furnace lid
13A Inclined portion
13B Horizontal portion
13a Solid iron source supply pipe
13b Auxiliary raw material supply pipe
13c Supply port
13c1 Lid
13d Duct coupling opening
14 Upper electrode
15 Lower electrode (furnace bottom refractory electrode)
16 Slag pot
17 Duct
18 Solid iron source charging implement
20 Ladle dephosphorization device

21 Lance
22 Fuel burner
23 Ladle bottom porous plug
24 Ladle
25 Immersion lance
42 Blast furnace slag
51 Steelmaking equipment
52 Molten pig iron desulfurization equipment
53 Converter
54 Secondary refining equipment
55 Blast furnace
56 Continuous casting equipment
57 Ladle dephosphorization refining equipment
100 Solid iron source
101 Iron-containing scrap
103a Reduced iron
103b Iron-containing dust
121 Carbon material
123 Flux for composition adjustment
140 Steelmaking slag
210 Molten pig iron
220 Electric furnace slag
221 Slag bath surface
310 Dephosphorized molten pig iron
320 Dephosphorization slag
321 High phosphate slag

Claims

1. A molten pig iron manufacturing method using a fixed-type DC electric furnace, wherein

if, in a furnace, a space in which a horizontal separation distance from an outer periphery of an upper electrode at a height position between a slag bath surface and a lower end of the upper electrode inserted from a furnace lid is 0.5 times or less a diameter of the upper electrode is defined as an upper electrode facing space, and
if, in the furnace, a space in which a horizontal separation distance from an inner wall surface of a furnace wall at a height position above a height position of the slag bath surface is within the shortest distance between the furnace wall and the upper electrode facing space is defined as a furnace inner peripheral wall space,
an auxiliary raw material is supplied to the fixed-type DC electric furnace and molten pig iron having a C concentration of 2 to 4 mass% at a temperature of 1400°C to 1550°C is tapped from a tap hole in a state in which a solid iron source is present in the furnace inner peripheral wall space and in a state in which the solid iron source is not present in the upper electrode facing space.

2. The molten pig iron manufacturing method according to claim 1, wherein
a top portion of the solid iron source in the furnace inner peripheral wall space is present at a position higher than the lower end of the upper electrode.

3. The molten pig iron manufacturing method according to claim 1 or 2, wherein
the solid iron source is present along a whole circumference of the furnace inner peripheral wall space.

4. The molten pig iron manufacturing method according to claim 1 or 2, wherein
the fixed-type DC electric furnace includes:

two or more of the upper electrodes; and
two or more lower electrodes provided in a refractory at a bottom portion of the fixed-type DC electric furnace; and
the two or more lower electrodes are provided at positions corresponding to the two or more upper electrodes in a plane view of the fixed-type DC electric furnace.

5. The molten pig iron manufacturing method according to claim 1 or 2, wherein
a supply port or a solid iron source supply pipe for supplying the solid iron source is disposed above the furnace inner peripheral wall space.

6. The molten pig iron manufacturing method according to claim 5, wherein

a supply port for supplying the solid iron source is disposed above the furnace inner peripheral wall space, and
the solid iron source is supplied from the supply port using a solid iron source charging implement on which the solid iron source is loaded.

7. The molten pig iron manufacturing method according to claim 1 or 2, wherein
the solid iron source is at least one of iron-containing scrap, reduced iron, and iron-containing dust.

8. The molten pig iron manufacturing method according to claim 1 or 2, wherein

the solid iron source contains at least reduced iron,
the reduced iron is reduced iron having a C concentration of 0 to 4 mass% by reducing iron ore using at least one of hydrogen gas, natural gas, and CO gas, and
the reduced iron is DRI or HBI.

9. The molten pig iron manufacturing method according to claim 1 or 2, wherein
the auxiliary raw material is at least one of a carbon material and a flux for composition adjustment.

10. The molten pig iron manufacturing method according to claim 9, wherein

the auxiliary raw material is a carbon material having a particle size of 0.5 mm to 10 mm, and
the carbon material is supplied from a plurality of locations around the upper electrodes to the slag bath surface formed in the upper electrode facing space.

11. The molten pig iron manufacturing method according to claim 1 or 2, wherein steelmaking slag is supplied to the fixed-type DC electric furnace.

12. The molten pig iron manufacturing method according to claim 11, wherein

at least one type of slag selected from converter slag, molten pig iron desulfurization slag, secondary refining slag, and dephosphorization slag is used as the steelmaking slag, and
the steelmaking slag is supplied in a molten state to the solid iron source present in the furnace inner peripheral wall space.

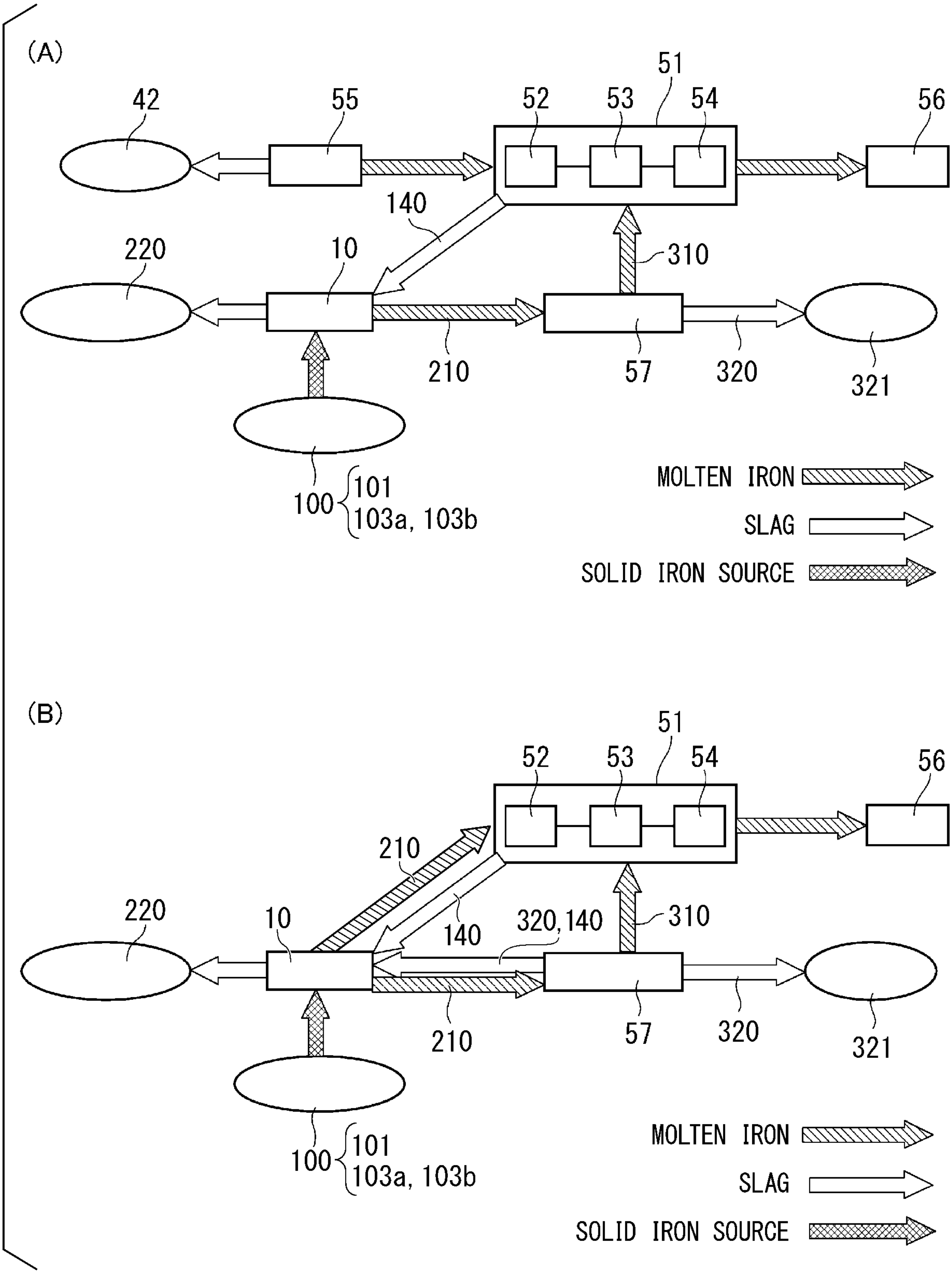
13. The molten pig iron manufacturing method according to claim 1 or 2, wherein

one or a plurality of bottom-blown tuyeres having a flow rate variable small diameter circle or a flat gas flow path are provided at positions separated by a horizontal distance of 1 m or more from immediately below the upper electrode at a bottom portion of the fixed-type DC electric furnace, and
from the one or the plurality of bottom-blown tuyeres, a maximum of 200 Nm^3/h of an inert gas per one bottom-blown tuyere is blown into the fixed-type DC electric furnace.

14. The molten pig iron manufacturing method according to claim 1 or 2, wherein
an electric furnace slag having a T.Fe concentration of 5 mass% or less, a CaO/SiO_2 concentration ratio of 1.0 to 1.3, and an Al_2O_3 concentration of 8 to 20 mass% is discharged from a slag hole.

15. The molten pig iron manufacturing method according to claim 1 of 2, wherein
when the molten pig iron has a P concentration of higher than 0.15%, dephosphorization treatment by ladle dephosphorization refining is performed until the P concentration of the molten pig iron becomes 0.15% or less.

FIG. 1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MOLTEN IRON
SLAG
SOLID IRON SOURCE
(B)
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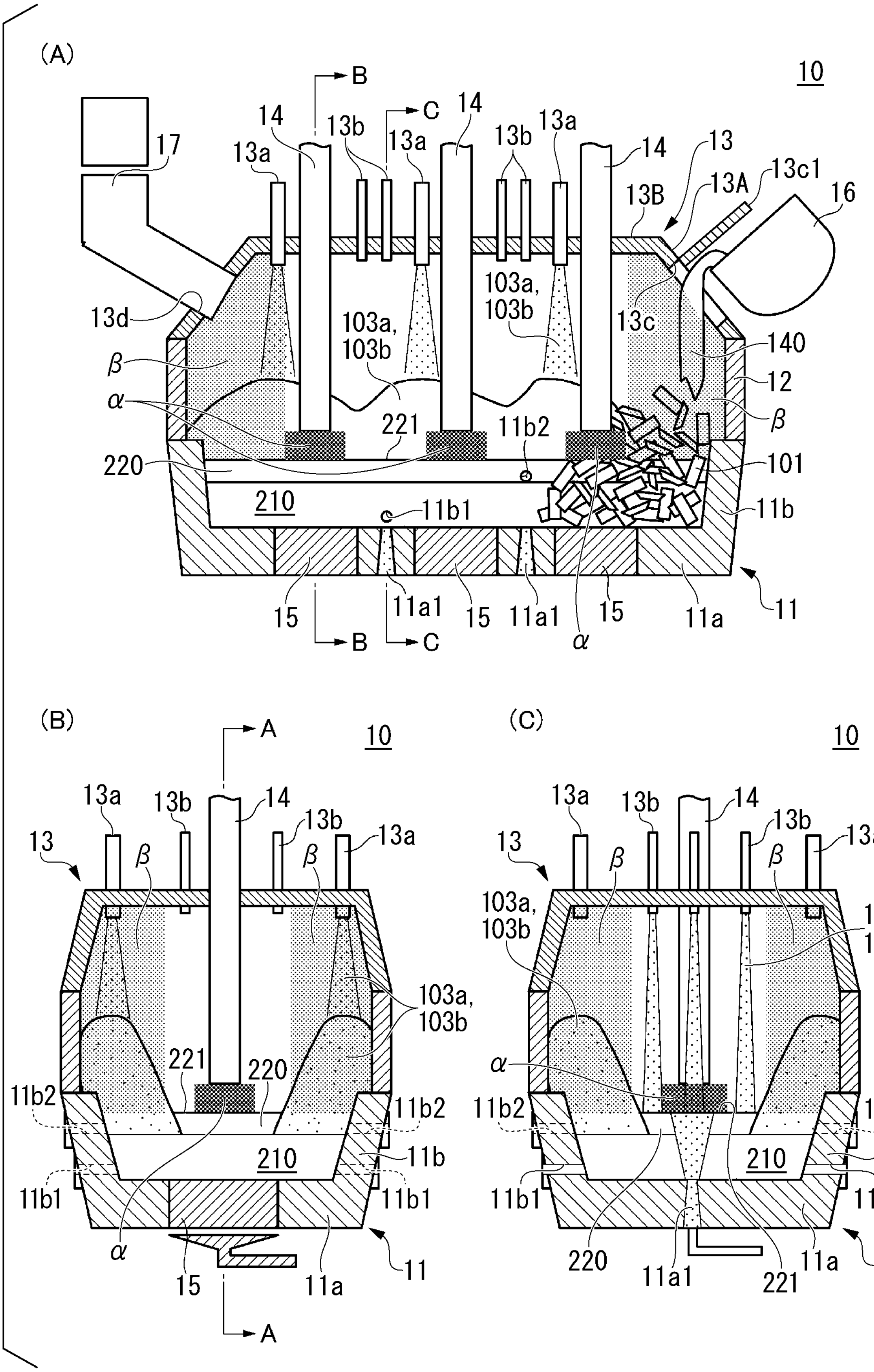
SLAG
SOLID IRON SOURCE

FIG. 2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11a1
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11a
11

FIG. 3

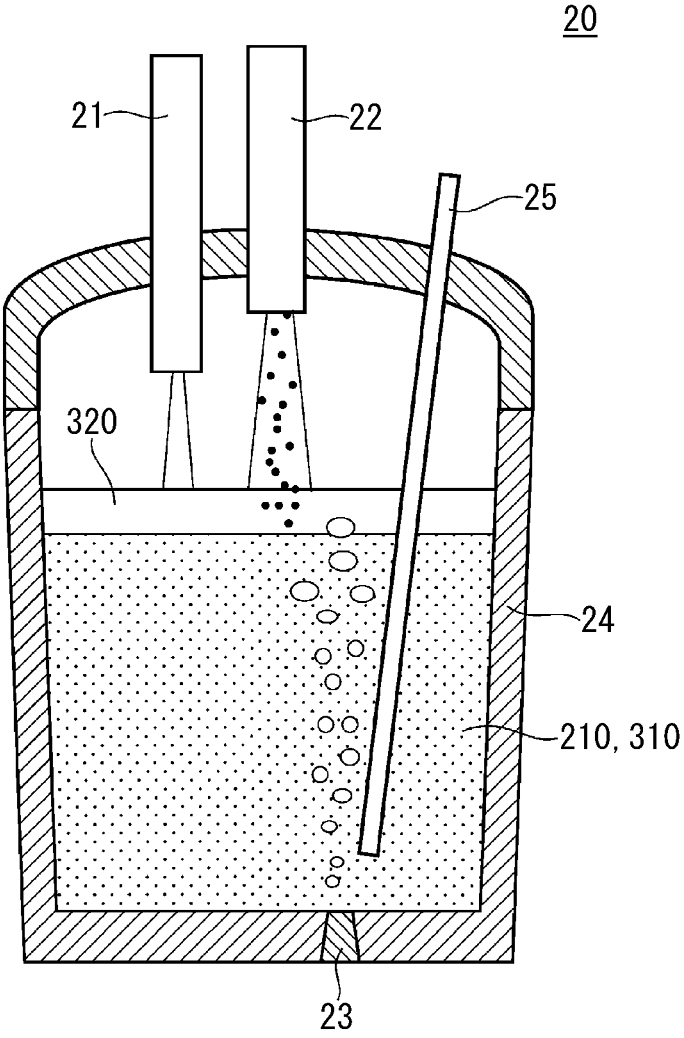


FIG. 4

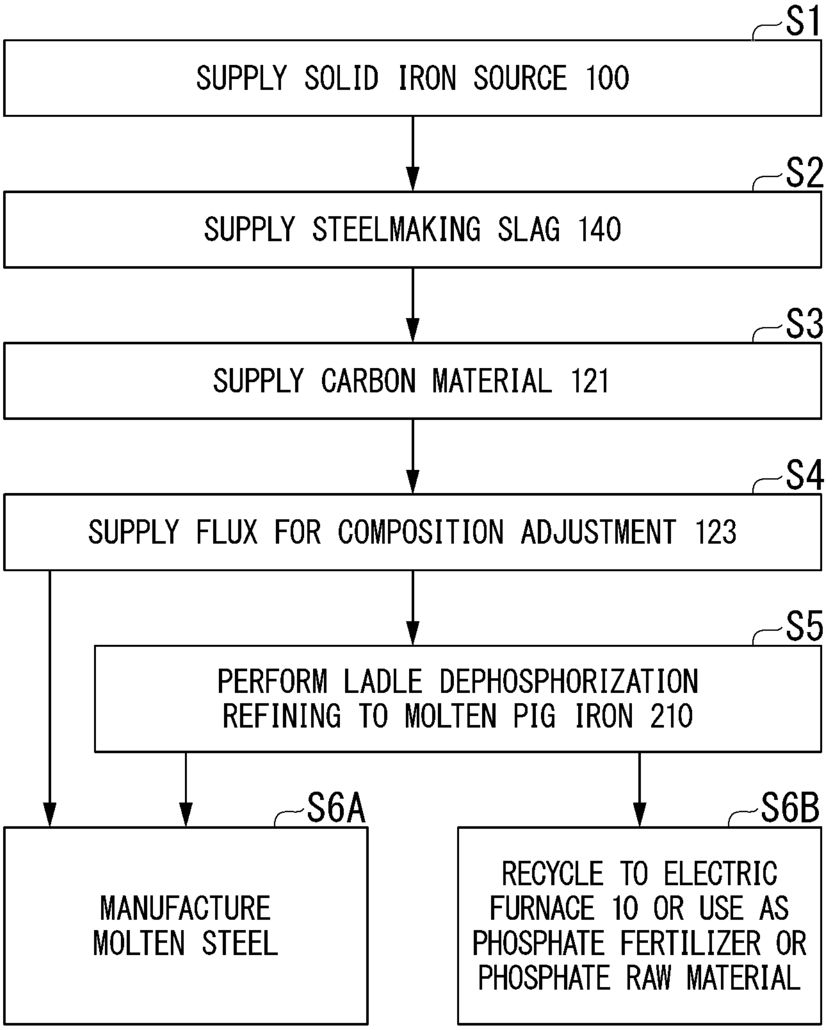
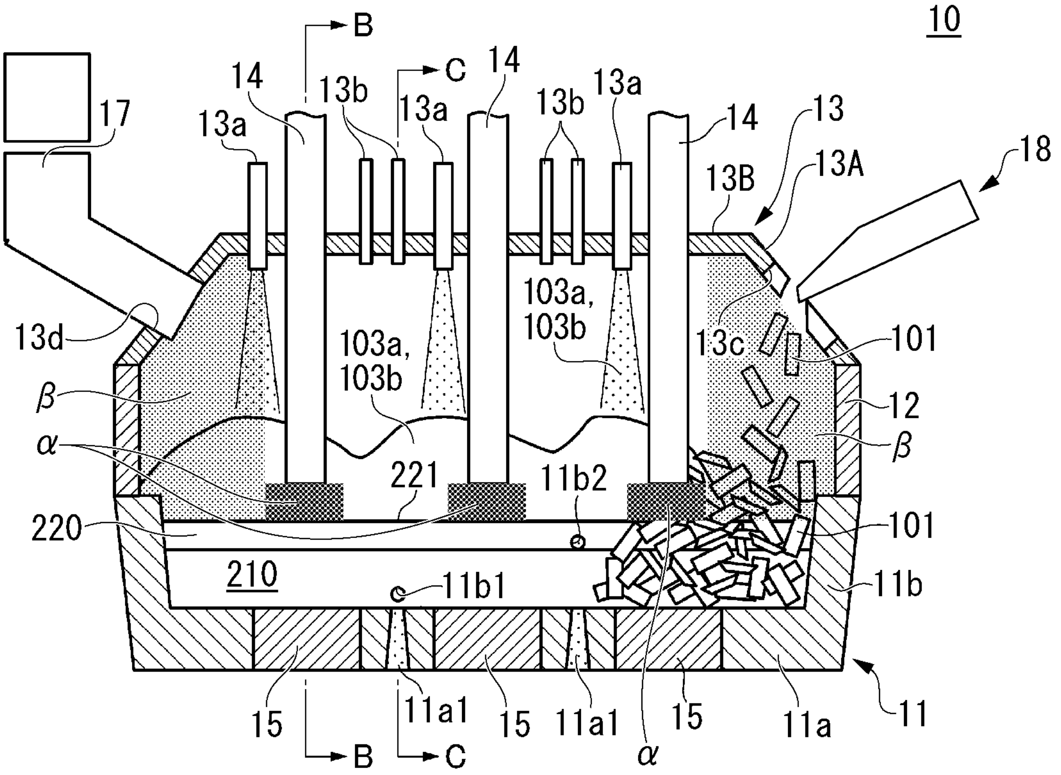

S1
SUPPLY SOLID IRON SOURCE 100
S2
SUPPLY STEELMAKING SLAG 140
S3
SUPPLY CARBON MATERIAL 121
S4
SUPPLY FLUX FOR COMPOSITION ADJUSTMENT 123
S5
PERFORM LADLE DEPHOSPHORIZATION REFINING TO MOLTEN PIG IRON 210
S6A
MANUFACTURE MOLTEN STEEL
S6B
RECYCLE TO ELECTRIC FURNACE 10 OR USE AS PHOSPHATE FERTILIZER OR PHOSPHATE RAW MATERIAL

FIG. 5



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11a
11
α
B
C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/035903

A. CLASSIFICATION OF SUBJECT MATTER

C21C 7/00(2006.01)i; ***C21B 11/10***(2006.01)i; ***C21C 1/02***(2006.01)i; ***C21C 5/28***(2006.01)i
FI: C21C7/00 K; C21B11/10; C21C1/02 110; C21C1/02 101; C21C5/28 A

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21C7/00; C21B11/10; C21C1/02; C21C5/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 51-78711 A (KAWASAKI HEAVY IND LTD) 08 July 1976 (1976-07-08) p. 1, lower right column, lines 4-9, p. 2, lower left column, lines 3-16, p. 3, lower left column, line 6 to p. 3, lower right column, line 20, fig. 1-4	1-15
Y	JP 2021-80540 A (KOBE STEEL LTD) 27 May 2021 (2021-05-27) paragraphs [0033]-[0035], [0045]-[0079], fig. 3	1-15
Y	JP 9-227925 A (NIPPON STEEL CORP) 02 September 1997 (1997-09-02) paragraphs [0006]-[0016], fig. 1	4, 10-15
Y	JP 2021-134386 A (NIPPON STEEL CORP) 13 September 2021 (2021-09-13) paragraphs [0042]-[0053]	11-12, 14-15

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search **25 November 2022**	Date of mailing of the international search report **06 December 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/035903

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JP 2021-80540 A	27 May 2021	EP 4032990 A1 paragraphs [0034]-[0036], [0046]-[0079], fig. 3 WO 2021/100565 A1 KR 10-2022-0098213 A AU 2020387088 A CA 3157144 A	
JP 9-227925 A	02 September 1997	(Family: none)	
JP 2021-134386 A	13 September 2021	(Family: none)	

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- WO 2014003123 A **[0008]**
- JP 2017128747 A **[0008]**
- JP 2021134386 A **[0008]**