



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

(43) Date of publication:
30.06.2010 Bulletin 2010/26

(51) Int Cl.:
C21B 11/02 (2006.01) F27B 1/20 (2006.01)

(21) Application number: **08778301.5**

(86) International application number:
PCT/JP2008/063074

(22) Date of filing: **14.07.2008**

(87) International publication number:
WO 2009/031367 (12.03.2009 Gazette 2009/11)

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

(30) Priority: **07.09.2007 JP 2007233197**
07.07.2008 JP 2008177041

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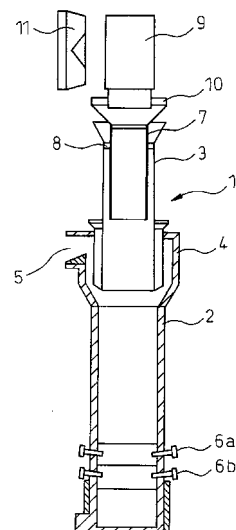
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(54) **VERTICAL FURNACE**

(57) A vertical furnace provided in its top peripheral wall with a gas intake port and operated with an upper furnace unit sealed by raw materials present inside the furnace above the gas intake port, which is equipped with: (i) a right circular steel cylinder provided in the sealed zone in the upper furnace unit for partitioning charged raw material deposition zones, and (ii) a raw material charging unit installed above the furnace top for operating in cooperation with the right circular steel cylinder to separately charge raw materials with different properties inside and outside the right circular steel cylinder.

Fig.1



Description

FIELD OF THE INVENTION

[0001] This invention relates to a vertical furnace provided above the furnace top with a charging unit for separately charging raw materials with different properties and in an upper furnace unit with a right circular cylinder installed for partitioning the deposition zones of the separately charged raw materials.

DESCRIPTION OF THE RELATED ART

[0002] Production of pig iron by melting iron scraps, cast iron scraps, pig iron and other sources of iron in a vertical furnace (cupola) is a common practice. As reduction is not conducted in this type of vertical furnace, reduction gas need not be produced at the tuyere zone, so the source of heat required for heating and melting the raw materials is obtained by burning coke.

[0003] In the vertical furnace, the mixed and charged raw materials (iron source and coke) are ordinarily melted at a combustion efficiency η_{CO} ($= CO_2 / (CO + CO_2)$) of 40 to 50%. In order to obtain a gas of an η_{CO} of around 40 to 50%, the usual practice is to inhibit the solution loss reaction after coke combustion by using large grain size coke for foundries.

[0004] However, coarse foundry coke is expensive, so recent years have seen attempts to reduce fuel cost by using a fine coke like blast furnace coke.

[0005] But when fine coke is used, solution loss reaction, which is endothermic, progresses to lower the coke combustion efficiency η_{CO} . As a result, heat for melting the iron source cannot be sufficiently obtained, so the operation inevitably becomes unstable.

[0006] Another mode of vertical furnace operation that has recently been put into practice uses self-reducing ore pellets and iron scraps as the principal materials and melts the iron scraps while concomitantly reducing the self-reducing ore pellets.

[0007] Goksel et al. (Transactions of the American Foundrymen's Society, Vol. 85, AFS Des Plaines, Ill, (1977), pp. 327-332) report that a vertical furnace requiring reduction capability was operated at a blast temperature under 600 °C without forming raceways in front of the tuyeres. Patent Application Publication Hei 01-501401 teaches a melting furnace of complicated body structure that uses fine coke and a large amount of self-reducing ore pellets and melts iron scraps at a high combustion efficiency η_{CO} .

[0008] However, when the vertical furnace is operated with self-reducing ore pellets and iron scraps as the principal materials, using a large amount of fine solid fuel (fine coke, blast furnace coke) to melt the iron scraps while concomitantly reducing the self-reducing ore pellets, there are encountered the long-recognized technological issue of it being technically difficult to achieve efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging.

[0009] In light of this, Japanese Patent Publication (A) No. H10-036906 teaches an improvement on the operating method of charging an iron source requiring reduction, an iron source requiring only melting, and solid fuel into a vertical furnace and conducting reduction and melting by blowing in oxygen-enriched air of normal temperature or 600 °C or less through tuyeres provided in the furnace wall, wherein the improvement lies in conducting a calculation based on the average iron source metallization rate to determine the optimum combustion efficiency η_{CO} (gas utilization rate) for the reduction and melting, and regulating the height of the furnace charge to control the η_{CO} of the exhausted gas to the optimum range.

[0010] However, this method restricts the mixing ratio of the iron sources because it requires the optimum η_{CO} (gas utilization rate) to be calculated every time the mixing ratio of the iron source requiring reduction and the iron source requiring only melting changes.

[0011] Moreover, although this operating method top-charges high-metallization-rate iron source into the furnace center region and low metallization rate iron source mixed with solid fuel into the furnace peripheral region, the height of the coke bed at the bottom of the furnace must be regulated.

[0012] In addition, at the time of charging the mixed solid fuel and iron source into the furnace center, the weight ratio of the C in the solid fuel to the Fe in the iron source must be made 0.01 to 0.05, and the charging level (stock level) at the furnace periphery relative to that at the furnace center must be varied in accordance with the average metallization rate of the iron source.

[0013] Thus, the operating method proposed by Japanese Patent Publication (A) No. H10-036906 involves numerous control factors and is therefore difficult to implement in actual operation.

[0014] Japanese Patent Publication (A) No. H09-203584 and Japanese Patent 3586355 respectively teach a method of charging raw materials and a charging hopper for charging raw materials aimed at enabling efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging.

[0015] The raw material charging method taught by Japanese Patent Publication (A) No. H09-203584 is characterized

in that, at the time of charging self-reducing ore pellets, dust agglomerates, iron scraps and other iron sources, and fine-grain solid fuel and other raw materials into a vertical furnace, the weight ratio and the like of iron sources to solid fuel is varied at every charge, and the furnace peripheral region and furnace center region are separately charged. However, the method is not always the best for an actual operation because complex procedures are required in order to vary the weight ratio and the like of the iron sources to the solid fuel at every charging.

[0016] Japanese Patent Publication (A) No. H09-203584 sets out a charging mode in which a charging guide is used at the time of charging to separately charge the furnace periphery region and center region (see FIG. 3). But when the charged raw materials are deposited on the existing raw materials, they flow into the furnace peripheral region or center region and do not necessarily accumulate at the predetermined region, so that the expected effect sometimes cannot be realized.

[0017] The raw material charging hopper proposed by Japanese Patent 3586355 comprises a guide unit for selectively charging raw materials into the furnace center region and furnace peripheral region, which is equipped with a conical bell and a horizontally moveable raw material guide member that is provided at the bottom with a discharge port divided multiply in the radial direction and reduced in diameter downward like a taper. But when the raw materials passing through the guide unit are deposited on the existing raw materials, they flow into the furnace peripheral region or center region and do not necessarily accumulate at the predetermined region, so that the expected effect sometimes cannot be realized.

[0018] Since, in the final analysis, the prior art raw material charging methods and raw material charging hoppers merely charge separated raw materials, the separated raw materials do not accumulate at the respective specified regions. As a result, it is difficult for a vertical furnace that conducts reduction and melting to achieve efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging.

SUMMARY OF THE INVENTION

[0019] In view of the impact that the mode of raw material charging has on the operation of a vertical furnace that conducts reduction and melting, this invention addresses the issue of separately charging raw materials with different properties from the top of the furnace and ensuring that the charged raw materials accumulate at the predetermined regions as intended.

[0020] The object of the invention is, by finding means for dealing with this issue, to provide a vertical furnace capable of conducting efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging.

[0021] The inventors studied raw material charging means for overcoming the aforesaid issues in a vertical furnace provided in its top peripheral wall with a gas intake port and operated with an upper furnace unit sealed by raw materials present inside the furnace above the gas intake port. But, as discussed in the foregoing, they found that expedients focusing solely on the raw material charging mode cannot provide a solution. In light of this situation, the inventors carried out an in-depth study looking beyond just the charging mode to also include the structure of the upper furnace unit where the raw materials are deposited.

[0022] The study led to the discovery that it is possible to achieve efficient, stable furnace operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging, by (i) providing a right circular steel cylinder in the sealed zone in the upper furnace unit for partitioning the raw material deposition zones, (ii) installing a raw material charging unit above the furnace top for operating in cooperation with the right circular steel cylinder to separately charge raw materials with different properties inside and outside the right circular steel cylinder, and suitably charging the separated raw materials inside and outside the right circular steel cylinder.

[0023] The present invention was accomplished based on this finding, and the gist thereof is as set out below.

(1) A vertical furnace provided in its top peripheral wall with a gas intake port and operated with an upper furnace unit sealed by raw materials present inside the furnace above the gas intake port, which vertical furnace comprises:

- (i) a right circular steel cylinder provided in the sealed zone in the upper furnace unit for partitioning charged raw material deposition zones; and
- (ii) a raw material charging unit installed above the furnace top for operating in cooperation with the right circular steel cylinder to separately charge raw materials with different properties inside and outside the right circular steel cylinder.

(2) A vertical furnace according to (1), wherein the raw material charging unit comprises:

- (ii-i) a conical guide member having a bottom surface that closes an opening of the right circular steel cylinder;

- (ii-2) an inverted conical guide member having a bottom opening communicating with the opening of the right circular steel cylinder; and
 (ii-3) a seat/unseat mechanism for seating/unseating the conical guide member and the inverted conical guide member directly on/from the right circular steel cylinder.

(3) A vertical furnace according to (2), wherein the seat/unseat mechanism is driven in accordance with a raw material charging schedule.

(4) A vertical furnace according to (2) or (3), wherein the seat/unseat mechanism is equipped with a rotation mechanism for causing the conical guide member and the inverted conical guide member to move independently from standby locations, within vertical planes, around support points provided on opposite sides of the furnace top to seat directly on the right circular steel cylinder.

(5) A vertical furnace according to (4), wherein the rotation mechanism is provided on the other side of the support points from the conical guide member and the inverted conical guide member with counterweights each matched to the weight of the associated guide member.

(6) A vertical furnace according to (2) or (3), wherein the seat/unseat mechanism is equipped with a rotation mechanism for rotating the conical guide member and the inverted conical guide member from standby locations within horizontal planes around support points provided on opposite sides or one side of the furnace top to seat directly on the right circular steel cylinder.

(7) A vertical furnace according to (2) or (3), wherein the seat/unseat mechanism is equipped with a reciprocating mechanism for driving a long structural member having the conical guide member and the inverted conical guide member mounted on its opposite ends to reciprocate within a horizontal plane across the furnace top.

(8) A vertical furnace according to (2) or (3), wherein the seat/unseat mechanism is equipped with a reciprocating mechanism for reciprocating a carriage on which the conical guide member and the inverted conical guide member are mounted across the furnace top.

(9) A vertical furnace according to any of (1) to (8), wherein the upper furnace unit is equipped with a level measuring unit for measuring the raw material levels inside and outside the right circular steel cylinder.

(10) A vertical furnace according to any of (1) to (9), wherein the right circular steel cylinder is mounted on a support member provided on the inner wall of the furnace top opening region.

(11) A vertical furnace according to any of (1) to (10), wherein the ratio of the area of the right circular steel cylinder opening to the area between the inner wall of the furnace top and the right circular steel cylinder is defined in accordance with the charge ratio of the raw materials with different properties.

(12) A vertical furnace according to (11), wherein the ratio of the area of the right circular steel cylinder opening to the area between the inner wall of the furnace top and the right circular steel cylinder is about 2 to 1.

(13) A vertical furnace according to any of (1) to (12), wherein the right circular steel cylinder is made of stainless steel.

[0024] This invention provides a vertical furnace capable of conducting efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

FIG. 1 is a diagram showing one mode of implementing the vertical furnace according to the present invention (the invention furnace).

FIG. 2 is a diagram showing charging modes established by operating a seat/unseat mechanism to place an inverted conical guide member or a conical guide member on top of a right circular steel cylinder, where (a) shows a charging mode in which the inverted conical guide member is placed on top of the right circular steel cylinder and (b) a charging mode in which the conical guide member is placed on top of the right circular steel cylinder.

FIG. 3 is a diagram schematically illustrating the state in which raw materials are deposited in the vertical furnace.

BEST MODE FOR CARRYING OUT THE INVENTION

[0026] The invention will be explained with reference to the drawings.

[0027] FIG. 1 shows one mode of implementing the vertical furnace according to the present invention (the invention furnace), in the condition uncharged with raw materials. The vertical furnace, designated by reference numeral 1, composed basically of a furnace body 2 equipped at the lower part with upper tuyeres 6a and lower tuyeres 6b, a gas intake 4 provided in the upper part of the furnace body 2, and an upper furnace unit 3 installed to pass through the gas intake 4 and seal the upper part of the vertical furnace 1 with raw materials contained therein.

[0028] The furnace top 3 is constituted as a shell and the exterior of the portion inserted into the gas intake 4 is covered with a refractory.

[0029] As shown in FIG. 1, the tuyeres are basically composed of the upper tuyeres 6a and lower tuyeres 6b provided in two tiers in the direction of furnace height. The upper tuyeres 6a are installed immediately above the surface of a coke bed 20 charged into the lower part of the furnace, and the lower tuyeres 6b are installed at a height within the coke bed 20.

[0030] In order to prevent the formation of raceways in front of the tuyeres, the tuyere diameter is defined so that the blast velocity is slower than in a blast furnace. Whilst the furnace of this embodiment is equipped with tuyeres arranged in two tiers, the invention is not limited to this configuration and, depending on the blast conditions, operation is possible using tuyeres arranged in a single tier.

[0031] When air is blown in through the upper tuyeres 6a and lower tuyeres 6b arranged in two tiers, air of room temperature or of 600 °C or less is blown in through the lower tuyeres 6b, mainly for burning coke, and room temperature air is blown in through the upper tuyeres 6a to burn CO gas generated by solution reaction (endothermic reaction) between part of the combustion gas (CO₂) and coke, thereby compensating for the decrease in iron source melting heat caused by the (endothermic) solution reaction of coke.

[0032] When air is blown in through a single tier of tuyeres, the tuyeres are installed at the same height as the lower tuyeres 6b. In this case, it is necessary to promote coke combustion so as to generate more iron source melting heat by increasing the oxygen concentration, i.e., by oxygen-enriching the air of room temperature or 600 °C or less blown in through the tuyeres.

[0033] On the other hand, when air is blown in through the two tiers of tuyeres shown in FIG. 1, heat compensation is possible with the air blown in through the upper tuyeres 6a. This makes it unnecessary to enrich the oxygen content of the air of room temperature or 600 °C or less blown in through the lower tuyeres 6b for the purpose of promoting coke combustion and generating more heat iron source melting heat.

[0034] The raw materials to be reduced or melted in the vertical furnace 1 are fed out from their respective hoppers (not shown). Each is weighed with a weight scale (not shown), then fed into a bucket 9 serving as a charging unit, transported as contained in the bucket 9 to above the furnace top 3, and charged from the bucket 9 through the furnace top 3 of the common rail 1 onto a coke bed 20 formed at the bottom of the vertical furnace 1 so that solid fuel and iron source assume a layered or mixed state.

[0035] The fuel used is fine carbonaceous solid fuel. Specifically, the fuel consists mainly of a large amount of fine coke (blast furnace coke). As raw materials are used a combination of iron sources requiring only melting, such as hot briquetted iron (HBI), direct reduced iron (DRI), iron scraps, formed iron and the like, and iron sources requiring reduction, such as self-reducing ore pellets (C-containing agglomerates), reduced iron of low metallization rate and the like.

[0036] The invention furnace is equipped with a right circular steel cylinder 7 supported inside the furnace top 3 by a right circular cylinder support 8 so that its lower end extends to near the upper end of the gas intake 4. Raw materials with different properties are deposited inside and outside of the right circular steel cylinder 7.

[0037] The invention furnace is structurally characterized in the point that the installation of the right circular steel cylinder inside the upper furnace unit enables the furnace to conduct efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging. The right circular steel cylinder is preferably made of stainless steel excellent in abrasion resistance.

[0038] The area of right circular steel cylinder opening is determined in accordance with the weight ratio of the raw materials to be separately charged inside and outside the right circular steel cylinder 7.

[0039] Since, as shown in FIG. 1, the right circular steel cylinder is attached within the upper furnace unit 3 by the right circular cylinder support 8, it can be suitably exchanged.

[0040] In the invention furnace, efficient and stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging, is achieved, even when using a large amount of fine coke (blast furnace coke), by charging and accumulating the raw materials inside and outside the right circular steel cylinder separately in accordance with their properties.

[0041] Specifically, iron sources requiring only melting, or such iron sources and solid fuel (hereinafter sometimes called "melt raw materials"), are charged into and deposited inside the right circular steel cylinder 7, while the iron sources requiring reduction, or such iron sources and solid fuel (hereinafter sometimes called "reduction raw materials"), are charged into and deposited between the inner wall of the upper furnace unit and the right circular steel cylinder 7.

[0042] In FIG. 1, reference numeral 10 designates an inverted conical guide member that operates in cooperation with the right circular steel cylinder 7 mounted inside the upper furnace unit 3 to charge melt raw materials inside the right circular steel cylinder 7.

[0043] As illustrated, the inverted conical guide member 10 is provided at the bottom with an opening of a diameter approximately equal to the diameter of the right circular steel cylinder 7. The melt raw materials contained in the bucket 9 therefore pass through the bottom opening of the inverted conical guide member 10 to be charged into and accumulate inside the right circular steel cylinder 7.

[0044] Also shown in FIG. 1 is a conical guide member 11 for charging reduction raw materials between the inner wall

of the upper furnace unit and the right circular steel cylinder 7. The conical guide member 11 is shown in a standby location in the drawing. However, in the course of operation, the inverted conical guide member 10 and conical guide member 11 are independently moved from their respective standby locations by a seat/unseat mechanism to be placed on top of the right circular steel cylinder 7 in accordance with a raw material charging schedule.

[0045] The bottom of the conical guide member 11 is of a size that fits into the furnace top. The bottom surface is formed at the middle with a conical bottom portion of approximately the same diameter as that of the right circular steel cylinder 7 and the periphery with an opening for passage of raw material.

[0046] As shown in FIG. 2, the seat/unseat mechanism is hydraulically operated to place one or the other of the inverted conical guide member and the conical guide member on top of the right circular steel cylinder. FIG. 2(a) shows the inverted conical guide member placed on top of the right circular steel cylinder, and FIG. 2(b) shows the conical guide member placed on top of the right circular steel cylinder.

[0047] As shown in FIGs. 2(a) and 2(b), a base 18 is provided on the working floor. On the base 18 are installed, independently in association with each of the inverted conical guide member 10 and conical guide member 11, a shaft fixation member 16 for fixing a shaft 15 that rotatably supports a guide member support frame 14 retaining the associated guide member, a hydraulic mechanism 12 whose one end is connected to the guide member support frame 14 near the shaft 15, and support members 17 that support the opposite ends of the guide member support frame 14 when the associated guide member is placed on top of the right circular steel cylinder 7.

[0048] A counterweight 13 is attached to one end of each guide member support frame 14 to enable smooth rotation of the guide member support frame 14 by the associated hydraulic mechanism 12.

[0049] FIG. 2(a) shows the inverted conical guide member 10 placed on top of the right circular steel cylinder 7 at the upper furnace unit 3, and the conical guide member 11 retracted to the standby location. When this condition has been established, the bottom of the bucket (not shown) is opened to charge melt raw materials X inside the right circular steel cylinder 7.

[0050] When charging of the required amount of the melt raw materials X has been completed, the hydraulic mechanisms 12 are driven to retract the inverted conical guide member 10 to its standby location and place the conical guide member 11 on top of the right circular steel cylinder 7, as shown in FIG. 2(b). When this condition has been established, the bottom of the bucket (not shown) containing reduction raw materials Y is opened to commence charging of the reduction raw materials Y.

[0051] The hydraulic mechanisms 12 are operated under the control of a hydraulic mechanism controller (not shown). The hydraulic mechanism controller drives the hydraulic mechanisms 12 in accordance with a raw material charging schedule to charge raw materials with different properties (the melt raw materials X and reduction raw materials Y) into prescribed regions (inside and outside the right circular steel cylinder 7) at the start of operation and in the course of operation. This is a characterizing feature of the present invention.

[0052] The seat/unseat mechanism shown in FIG. 2 is a rotation mechanism that causes the conical guide member and the inverted conical guide member to move independently from standby locations, within vertical planes, around shafts (support points) provided on opposite sides of the furnace top to place them on and retract them from the right circular steel cylinder. However, the mechanism for seating and retracting the conical guide member and inverted conical guide member is not limited to this rotation mechanism.

[0053] The rotation mechanism can instead be one that rotates the conical guide member and the inverted conical guide member from standby locations within horizontal planes around support points provided on opposite sides or one side of the furnace top to seat directly on the right circular steel cylinder.

[0054] Further, the seat/unseat mechanism can be one equipped with a reciprocating mechanism that drives a long structural member having the conical guide member and the inverted conical guide member mounted on its opposite ends to reciprocate within a horizontal plane across the furnace top. Alternatively, it can be one equipped with a reciprocating mechanism that reciprocates a carriage on which the conical guide member and the inverted conical guide member are mounted across the furnace top.

[0055] FIG. 3 shows the state in which the melt raw materials X and reduction raw materials Y are deposited in the vertical furnace during operation. The invention vertical furnace is operated with raw materials deposited in the upper furnace unit 3 located above the gas intake, thereby forming a sealed zone in the upper furnace unit (called a "material seal") that seals the furnace top.

[0056] The iron sources in the raw materials charged into the upper furnace unit of the vertical furnace 1 from above are melted during descent within the furnace by the heat of coke (C) combustion by oxygen in the air blown in through the tuyeres, and the iron oxide contained in some of the iron sources is reduced by reduction gas (CO), solid carbon (C), or carbon (C) in the molten iron, to further descend to the coke bed 20 and accumulate at the furnace bottom.

[0057] A connecting pipe 23 communicating with a pig and slag storage unit 22 provided outside the furnace is installed at the height level of the upper surface of a bottom plate of the furnace bottom, and molten pig and slag accumulated at the bottom inside the furnace flow through the connecting pipe 23 into the pig and slag storage unit 22. The upper molten slag layer and lower molten pig layer of the molten pig and slag are separated, and the molten pig of the lower

layer is extracted through a tap hole 21.

[0058] The melting and reduction zone where the melting and part of the reduction of the iron sources is conducted is formed mainly within the furnace height range of about 1 to 2.5 m above the surface of the coke bed 20 (equivalent to about 1 to 2.5 charges of the raw material contained in the bucket 9).

[0059] Even if the raw materials are separated by property and charged into the prescribed regions of the vertical furnace, they may flow into other regions upon colliding with raw materials deposited previously or mix together during descent in the process of moving downward within the furnace. In such cases, it may be impossible to reduce the reduction raw materials, or hanging may occur to degrade air permeability, leading to a situation that makes adequate melting of the melt raw materials impossible.

[0060] In the invention furnace, the raw materials descend without mixing together during operation because the melt raw materials X and reduction raw materials Y are separately charged inside and outside the right circular steel cylinder 7 so that they are deposited inside and outside the right circular steel cylinder 7 where they cannot mix with each other. In other words, the melt raw materials X and reduction raw materials Y are present one inside and one outside the right circular steel cylinder 7 where they form descending flows that do not interfere with each other.

[0061] Even though the melt raw materials X and reduction raw materials Y make contact and mix to some degree after passing beyond the right circular steel cylinder 7, each continues its descending flow, so that a highly orderly state of raw material deposition can be realized wherein the melt raw materials X are deposited in the middle portion inside the furnace body 2 of the invention furnace and the reduction raw materials Y are deposited in the surrounding region. This is the most salient characteristic of the invention furnace.

[0062] During the operation of the vertical furnace, air (sometimes oxygen-enriched air) of 600 °C or lower temperature is blown in through the lower tuyeres 6b to generate reducing gas by the reaction $C + O_2 \rightarrow 2CO$, thereby reducing the melt raw materials X. In addition, normal temperature air is blown in through the upper tuyeres 6a to secure the heat required for melting the melt raw materials X (by the exothermic reaction $2CO + O_2 \rightarrow 2CO_2$), thereby melting the melt raw materials X.

[0063] As the melt raw materials X and reduction raw materials Y descend during operation, the deposition heights (stock levels) of the raw material inside and outside the right circular steel cylinder naturally fall. Therefore, in order to ensure stable raw material melting while sealing the upper furnace unit 3, the stock level is measured with a level meter (not shown) attached to the upper furnace unit 3, and the raw material charge timing is controlled to maintain the raw material deposition heights (stock levels) at predetermined levels.

[0064] As set out in the foregoing, the invention furnace achieves a highly orderly state of raw material deposition inside the furnace. Therefore, despite the use of a large amount of fine coke, it is nevertheless possible to dramatically enhance the reducing efficiency by reducing gas and the melting efficiency by reaction heat, thereby enabling efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of the solid fuel, while also avoiding charge hanging.

EXAMPLE

[0065] An example of the present invention will be explained next. The conditions of the example were adopted solely for the purpose of ascertaining the feasibility of implementation and the effects of the present invention, and the invention is not limited thereto. The present invention can be carried out using a broad range of conditions, insofar as the object of the invention can be achieved without departing from the gist of the invention.

Example

[0066] As an example of invention furnace operation, operation was conducted under the raw material mixing conditions shown in Table 1 using iron sources and solid fuel (coke). With the raw material mixing patterns defined as shown in Table 2, the vertical furnace shown in FIG. 1 was charged from the furnace top in the charging cycle of raw material A1 - A1 - A2. The following were measured for the case of continuous operation over seven days: gas utilization rate (η_{CO}) of exhausted furnace top gas, exhausted furnace top gas temperature (°C), furnace pressure (hPa), blast pressure (kPa), number of blast volume reductions, number of blast shutdowns, and productivity (T/H). Specifically, operation was conducted in charge cycles each consisting of the three charges A1 - A1 - A2 to establish an average mixing ratio of iron sources shown in Table 1 of 70% high metallization rate iron source and 30% low metallization rate iron source.

[0067] A comparative example was conducted using a conventional vertical furnace continuously charged according to raw material mixing pattern B shown in Table 2, which was also charged in the vertical furnace shown in FIG. 1, and, as in the invention example, the following were measured for the case of continuous operation over seven days: gas utilization rate (η_{CO}) of exhausted furnace top gas, exhausted furnace top gas temperature (°C), furnace pressure (hPa), blast pressure (kPa), number of blast volume reductions, number of blast shutdowns, and productivity (T/H). In other words, operation was conducted and the aforesaid operating factors were measured under repeated charging of un-

separated iron sources at the rates of 70% high metallization rate iron source and 30% low metallization rate iron source.

[0068] The results are shown in Table 3.

[0069] Gas utilization rate η_{CO} (TOP) of exhausted furnace top gas was defined as:

$$\eta_{CO} \text{ (TOP)} = \frac{\text{CO}_s \text{ content [vol\%] of exhausted gas}}{\text{CO content [vol\%] of exhausted gas} + \text{CO}_s \text{ content [vol\%] of exhausted gas}}.$$

[0070] Average metallization rate M was defined as:

$$M = \frac{\text{Metallic (M.Fe) (mass\%) in iron sources}}{\text{total iron in iron sources (T.Fe) (mas\%)}}.$$

Raw material condition	High metallization rate iron source			Low metallization rate iron source		Solid fuel			
	Shredder scraps	Plate scraps (M:>99 mass%) (M: 99 mass%)	Reduction iron (M:96 mass%)	Dust pellets C: 10 mass, M:2 mass%)	Self-reducing agglomerates (C:15 mass M:5 mass%)	Blast furnace coke			Ratio of solid fuel to iron source (exclusive ratio) (mass%)
						Grain size (mm)	Ash (mass%)	Mixing ratio (mass%)	
A	50	20	0	30	0	50	13	100	25
Note: M is average metallization rate. C is carbon content.									

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Table 2

Raw material condition	High metallization rate iron source	Low metallization rate iron source	Solid fuel	Charging position
	Scrap (t/ch)	Dust pellets (t/ch)	Blast furnace coke (t/ch)	
A1	4.2	0.5	0.9	Center
A2		2.6	0.8	Periphery
B	2.8	1.2	0.87	Unseparated

Example type and number	Raw material condition	Superficial gas velocity (Nm/s)	Furnace pressure (hPa)	Gas utilization furnace rate of exhausted furnace gas (η_{CO} (%))	Exhausted top gas temp. ($^{\circ}$ C)	Blast pressure (kPa)	Number of blast volume reductions	Number of blast shutdowns	Productivity (T/H)
Invention 1	A	1.0	240	22	150	24	2	0	33
Comparative 1	A	1.0	280	22	150	28	5	2	25
Comparative 2	A	0.9	260	22	150	26	3	1	27

[0071] The Invention Example was conducted using the invention charging unit for separate charging to differentiate the raw material mixing ratios between the center and peripheral regions so as to charge the center region with much scrap of large solid size not requiring reduction and the peripheral region with dust pellets of small solid size requiring reduction. As shown in Table 3, in the case of the Invention Example, when the iron sources were melted using solid fuel constituted 100 mass% of blast furnace coke, it was possible to maintain the average furnace pressure at a stable operating level, minimize blast volume reductions and blast shutdowns necessitated by increased blast pressure, and maintain high productivity of molten iron throughout the operating period.

[0072] In contrast, Comparative Examples 1 and 2 shown In Table 3 represent cases of operation in which the invention charging unit for separate charging was not used and the scrap and dust pellets were charged at a rate per charge equivalent to the average rate per cycle in Example 1.

[0073] In Comparative Example 1, in which operation was conducted under the same blast conditions as in the Invention Example, the average furnace blast pressure was high during operation, the increase in blast pressure led to unstable operation, circumstances leaving no choice other than to implement blast volume reduction or blast shutdown frequently arose, and productivity was low throughout the operation.

[0074] In Comparative Example 2, which was directed to stabilizing operation by lowering the average furnace blast pressure, operation had to be conducted at lower blast volume per unit time than in the Invention Example. As a result, incidents of blast pressure increase causing operation instability that required blast volume reduction or shutdown were less frequent than in Comparative Example 1, but there was a decline in melting rate that lowered productivity throughout the operating period to a considerably lower level than in the Invention Example.

[0075] Thus, in an operation using a large amount of cheap blast furnace coke as solid fuel and using dust pellets, or other such small solid size raw material requiring reduction, at a high mixing ratio, it is possible by applying the present invention to maintain the furnace blast pressure at a stable operation level, thereby avoiding blast volume reduction and blast shutdown to the utmost so as to enable stable production of pig iron consistently at high productivity.

INDUSTRIAL APPLICABILITY

[0076] As set out in the foregoing, the present invention provides a vertical furnace capable of conducting efficient, stable operation over the long term, without lowering the combustion efficiency η_{CO} of solid fuel, while also avoiding charge hanging. The applicability of the present invention in the iron and steel manufacturing industry is therefore considerable.

Claims

1. A vertical furnace provided in its top peripheral wall with a gas intake port and operated with an upper furnace unit sealed by raw materials present inside the furnace above the gas intake port, which vertical furnace comprises:

- (i) a right circular steel cylinder provided in the sealed zone in the upper furnace unit for partitioning charged raw material deposition zones; and
- (ii) a raw material charging unit installed above the furnace top for operating in cooperation with the right circular steel cylinder to separately charge raw materials with different properties inside and outside the right circular steel cylinder.

2. A vertical furnace according to claim 1, wherein the raw material charging unit comprises:

- (ii-i) a conical guide member having a bottom surface that closes an opening of the right circular steel cylinder;
- (ii-2) an inverted conical guide member having a bottom opening communicating with the opening of the right circular steel cylinder; and
- (ii-3) a seat/unseat mechanism for seating/unseating the conical guide member and the inverted conical guide member directly on/from the right circular steel cylinder.

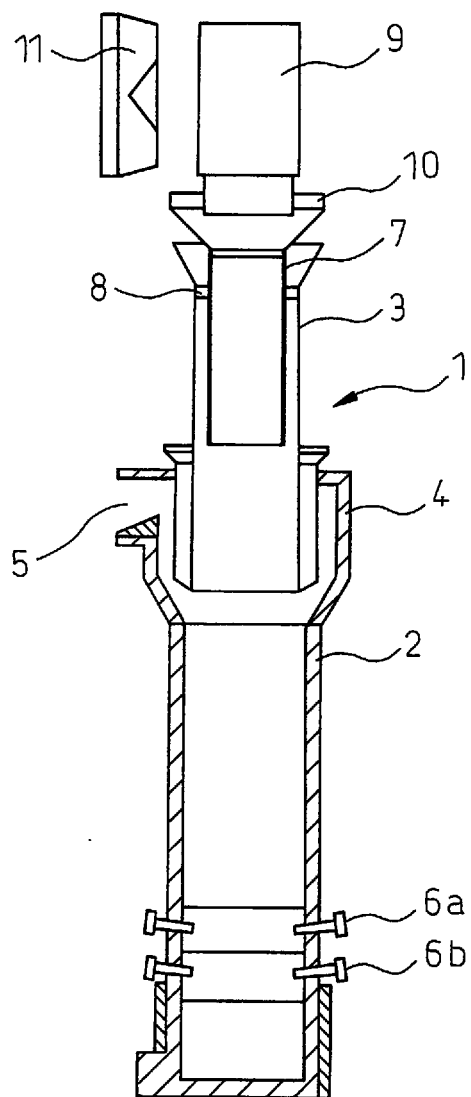
3. A vertical furnace according to claim 2, wherein the seat/unseat mechanism is driven in accordance with a raw material charging schedule.

4. A vertical furnace according to claim 2 or 3, wherein the seat/unseat mechanism is equipped with a rotation mechanism for causing the conical guide member and the inverted conical guide member to move independently from standby locations, within vertical planes, around support points provided on opposite sides of the furnace top to seat directly on the right circular steel cylinder.

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5. A vertical furnace according to claim 4, wherein the rotation mechanism is provided on the other side of the support points from the conical guide member and the inverted conical guide member with counterweights each matched to the weight of the associated guide member.
- 5 6. A vertical furnace according to claim 2 or 3, wherein the seat/unseat mechanism is equipped with a rotation mechanism for rotating the conical guide member and the inverted conical guide member from standby locations within horizontal planes around support points provided on opposite sides or one side of the furnace top to seat directly on the right circular steel cylinder.
- 10 7. A vertical furnace according to claim 2 or 3, wherein the seat/unseat mechanism is equipped with a reciprocating mechanism for driving a long structural member having the conical guide member and the inverted conical guide member mounted on its opposite ends to reciprocate within a horizontal plane across the furnace top.
- 15 8. A vertical furnace according to claim 2 or 3, wherein the seat/unseat mechanism is equipped with a reciprocating mechanism for reciprocating a carriage on which the conical guide member and the inverted conical guide member are mounted across the furnace top.
- 20 9. A vertical furnace according to any of claims 1 to 8, wherein the upper furnace unit is equipped with a level measuring unit for measuring the raw material levels inside and outside the right circular steel cylinder.
10. A vertical furnace according to any of claims 1 to 9, wherein the right circular steel cylinder is mounted on a support member provided on the inner wall of the furnace top opening region.
- 25 11. A vertical furnace according to any of any of claims 1 to 10, wherein the ratio of the area of the right circular steel cylinder opening to the area between the inner wall of the furnace top and the right circular steel cylinder is defined in accordance with the charge ratio of the raw materials with different properties.
- 30 12. A vertical furnace according to claim 11, wherein the ratio of the area of the right circular steel cylinder opening to the area between the inner wall of the furnace top and the right circular steel cylinder is about 2 to 1.
13. A vertical furnace according to any of claims 1 to 12, wherein the right circular steel cylinder is made of stainless steel.

Fig.1



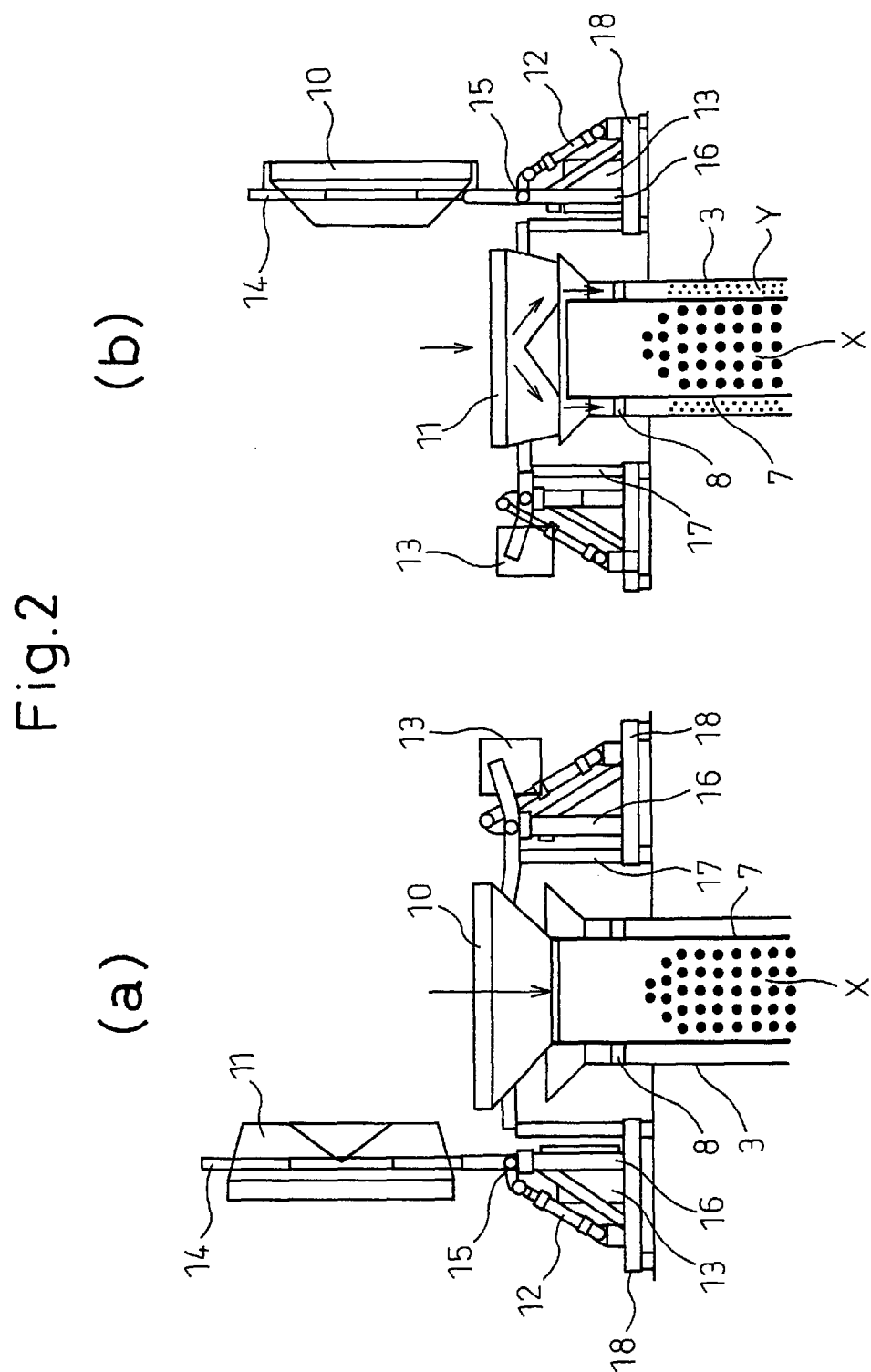
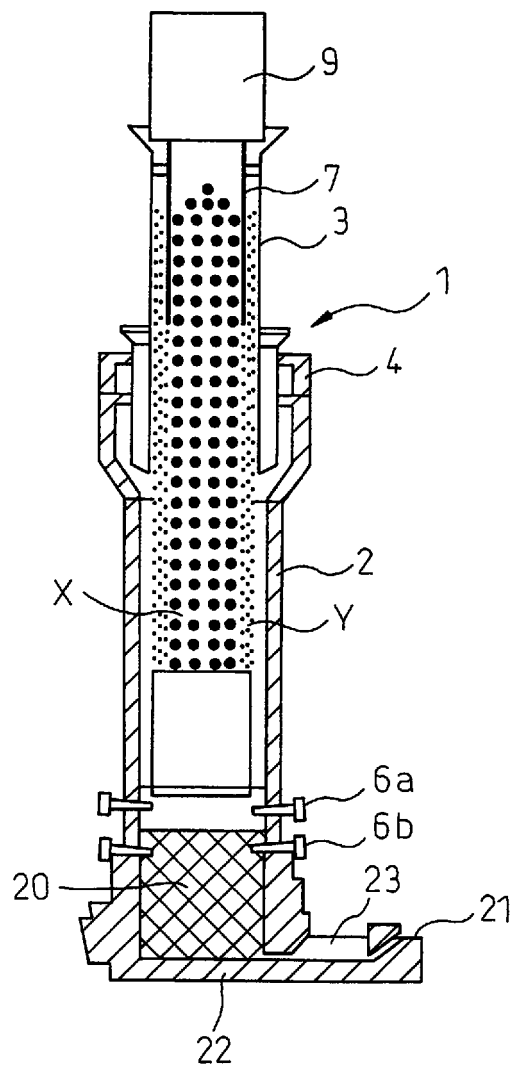


Fig.3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/063074

A. CLASSIFICATION OF SUBJECT MATTER C21B11/02 (2006.01) i, F27B1/20 (2006.01) i		
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) C21B11/02, F27B1/20		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2008 Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008		
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.
A	JP 58-171520 A (Kabushiki Kaisha Yoshida Tekkosho, Toru ISHINO), 08 October, 1983 (08.10.83), Claims; drawings (Family: none)	1-13
A	JP 10-267539 A (Nippon Steel Corp., Iwate Iron Co., Ltd.), 09 October, 1998 (09.10.98), Claims 1 to 3; Par. No. [0012]; Figs. 1 to 3 (Family: none)	1-13
A	JP 10-36906 A (Nippon Steel Corp.), 10 February, 1998 (10.02.98), Par. Nos. [0035], [0036]; Fig. 1 & US 6129776 A & EP 0818543 A1	1-13
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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 16 September, 2008 (16.09.08)		Date of mailing of the international search report 30 September, 2008 (30.09.08)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/063074

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 10-267538 A (Nippon Steel Corp., Iwate Iron Co., Ltd.), 09 October, 1998 (09.10.98), Claims 1 to 9; Figs. 1 to 3 (Family: none)	1-13

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REFERENCES CITED IN THE DESCRIPTION

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