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(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

(72) Inventors:
- **SAWAKI Naomi**
  Tokyo 100-0011 (JP)
- **KAWASHIRI Yuki**
  Tokyo 100-0011 (JP)

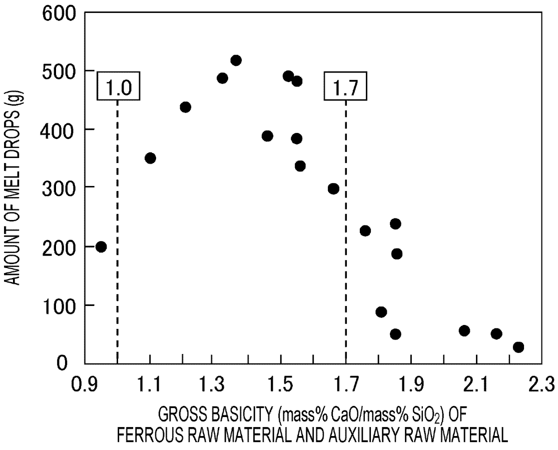
(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) OPERATION METHOD FOR BLAST FURNACE

(57) In a blast furnace operation that generates a high-concentration reducing gas in a raceway in the furnace, a blast furnace operation method is provided that improves properties of slag formed in a lower part of the furnace to ensure gas permeability through the cohesive zone and the dripping zone in the furnace even after FeO components in the slag have decreased.

A blast furnace operation method according to the present invention is a method of operating a blast furnace while charging a ferrous raw material, an auxiliary raw material, and coke from a blast furnace top, and injecting from a blast furnace tuyere a gas that generates a high-concentration reducing gas in a raceway in the blast furnace, and the method includes controlling the gross basicity of the ferrous raw material and the auxiliary raw material to a predetermined range. In this case, the gross basicity is preferably controlled to 1.0 or more and 1.7 or less.

FIG. 2



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Description

Technical Field

[0001] The present invention relates to a method of operating a blast furnace while generating a high-concentration reducing gas in a raceway in the blast furnace, and more particularly to a blast furnace operation method that improves slag properties in a cohesive zone and a dripping zone in a blast furnace and thereby enhances the gas permeability in the blast furnace.

Background Art

[0002] In recent years, there have been growing efforts to reduce the emissions of CO_2 gas (carbon dioxide gas) that is one of the greenhouse gases. Blast furnace iron manufacturing involves carbon materials as reducing agents and thus generates large amounts of CO_2 gas. Thus, the steel industry is one of the major CO_2 emitting industries and must respond to the social demands for cutting the CO_2 gas emissions. Specifically, it is urgent to further decrease the ratio of coal-derived reducing agents in the blast furnace operation. The ratio of coal-derived reducing agents is the total mass of coal-derived coke and coal-derived reducing gas required to produce 1 ton of molten pig iron.

[0003] Reducing agents have a role to generate heat in the furnace and thereby raise the temperature of the burden, and a role to reduce the ferrous raw material in the furnace, namely, iron ore, sintered iron ore, and iron ore pellets. In order to lower the reducing agent ratio and thereby to cut the CO_2 emissions, it is necessary to increase the reduction efficiency of the reducing agent while maintaining the amount of heat in the furnace.

[0004] Hydrogen has attracted attention as a reducing agent for the purpose of cutting CO_2 emissions. The reduction of iron ore with hydrogen is an endothermic reaction, but the endothermic amount is smaller than that in the direct reduction reaction (reaction formula: $FeO + C \rightarrow Fe + CO$). Furthermore, hydrogen outperforms CO gas in reduction rate. Therefore, the CO_2 emissions can be reduced and the reduction efficiency can be enhanced at the same time by the blowing of hydrogen-based gas into the blast furnace.

[0005] Stable operation of a blast furnace critically relies on the gas permeability through the blast furnace cohesive zone in which the ferrous raw material is fused. However, the gas permeability in a blast furnace is not clearly understood in blast furnace operations where a high-concentration reducing gas is generated in a raceway in the blast furnace, and in blast furnace operations in which the reducing gas concentration in the furnace is higher than in the conventional operation and the reduction reaction rate is high.

[0006] Manufacturing of pig iron in the blast furnace also yields a large amount of blast furnace slag (an oxide mixture composed of, for example, FeO, CaO, Al_2O_3, MgO, and SiO_2) as a byproduct. In order to maintain good gas permeability inside the furnace, raw materials should be designed so that the viscosity of the blast furnace slag that is produced will be kept low to ensure liquid permeability.

[0007] Conventional techniques for solving problems similar to those described above are disclosed in Patent Literatures 1 to 3.

[0008] Patent Literature 1 discloses a blast furnace operation in which coke is charged from the top of a furnace and an auxiliary fuel is injected from a tuyere. According to Patent Literature 1, blast furnace slag properties are improved, and the gas permeability and the liquid permeability can be enhanced by controlling the Al_2O_3 to SiO_2 ratio (Al_2O_3/SiO_2) in the coke and the auxiliary fuel to 0.6 or more, and the basicity (($CaO + Al_2O_3 + MgO)/SiO_2$) of blast furnace slag to 1.8 or more.

[0009] Patent Literature 2 discloses a blast furnace operation method in which 150 kg or more of pulverized coal per ton of tapped iron is injected together with hot blast into a blast furnace through a tuyere. According to Patent Literature 2, 80% or more of the burden excluding coke is represented by sintered ore containing 4.0 to 4.8 mass% SiO_2 components, 1.2 to 2.4 mass% MgO components, 6.0 to 9.0 mass% CaO components, and 1.9 to 2.5 mass% Al_2O_3 components. In this manner, the viscosity of dripping slag can be kept low even after FeO components in the slag composition have decreased.

[0010] Patent Literature 3 discloses a blast furnace operation method in which an auxiliary raw material is added in a ratio controlled in accordance with the amount of Al_2O_3 in usual sintered ore and thereby sintered ore is produced that is enhanced in strength (SI > 92%) and reducibility (RI > 70%). According to Patent Literature 3, an auxiliary raw material is injected from a blast furnace tuyere in an amount corresponding to the difference in the blend ratio of the auxiliary raw material between the sintered ore enhanced in strength and reducibility and the usual sintered ore. This control enables long-term stable operation with a high ore-to-coke ratio.

Citation List

Patent Literature

[0011]

PTL 1: Japanese Unexamined Patent Application Publication No. 2004-10948
PTL 2: Japanese Unexamined Patent Application Publication No. 9-13107
PTL 3: Japanese Unexamined Patent Application Publication No. 2005-298923

Summary of Invention

Technical Problem

[0012] However, these conventional techniques are directed to blast furnace operation that injects an auxiliary raw material, such as SiO_2 powder, an auxiliary fuel containing, for example, CaO and SiO_2, or pulverized coal through a tuyere. The techniques are silent with respect to raw material components that are charged or slag components in blast furnace operation that generates a high-concentration reducing gas in a raceway in the furnace.

[0013] In blast furnace operation in the present invention, a reducing gas generated in a raceway in the furnace has a very high concentration. Thus, the ferrous raw material in the furnace is reduced with an increased reduction ratio and the FeO concentration in the slag decreases to a level below the operation ranges described in the above conventional techniques. The conventional techniques described above do not consider a case where the FeO components in the slag further decrease.

[0014] Specifically, the ferrous raw material is reduced in a promoted manner from a low temperature compared to the conventional operation and reaches an increased reduction ratio at a lower part of the furnace when a high-concentration reducing gas is generated in a raceway in the furnace within the range of region A in Fig. 1 (Fig. 1 will be described later) (the range including H_2 gas = 0 to 100 vol%, N_2 gas = 0 to 71 vol%, and CO gas = 0 to 100 vol%). If the above range is applied to the conventional operation, the slag permeability is lowered by the decrease in FeO components in the slag and consequently the slag is accumulated in voids in the coke layers to raise the gas permeability resistance in the furnace, thus giving rise to a risk of gas channeling.

[0015] The present invention has been made in view of the circumstances discussed above. In a blast furnace operation that generates a high-concentration reducing gas in a raceway in the furnace, an object of the present invention is to provide a blast furnace operation method that improves slag properties to ensure gas permeability through the cohesive zone and the dripping zone in the blast furnace even after FeO components in slag have decreased.

Solution to Problem

[0016] A gist of the present invention that solves the problems described above is as follows.

[1] A blast furnace operation method of operating a blast furnace while charging a ferrous raw material, an auxiliary raw material, and coke from a blast furnace top, and injecting from a blast furnace tuyere a gas that generates a high-concentration reducing gas in a raceway in the blast furnace, the method including controlling the gross basicity of the ferrous raw material and the auxiliary raw material to a predetermined range.

[2] The blast furnace operation method according to [1], wherein the gross basicity is controlled to 1.0 or more and 1.7 or less.

[3] The blast furnace operation method according to [1], wherein the high-concentration reducing gas, when expressed by bosh gas composition, is composed of H_2 gas, N_2 gas, and CO gas; has a composition of H_2 gas, N_2 gas, and CO gas within a region enclosed by four points in a H_2 gas-N_2 gas-CO gas ternary diagram wherein the four points are a point at H_2 gas: 0 vol%, N_2 gas: 0 vol%, and CO gas: 100 vol%, a point at H_2 gas: 100 vol%, N_2 gas: 0 vol%, and CO gas: 0 vol%, a point at H_2 gas: 29 vol%, N_2 gas: 71 vol%, and CO gas: 0 vol%, and a point at H_2 gas: 0 vol%, N_2 gas: 37 vol%, and CO gas: 63 vol%; and includes H_2 gas in the range of 0 to 100 vol%, N_2 gas in the range of 0 to 71 vol%, and CO gas in the range of 0 to 100 vol%.

[4] The blast furnace operation method according to [2], wherein the high-concentration reducing gas, when expressed by bosh gas composition, is composed of H_2 gas, N_2 gas, and CO gas; has a composition of H_2 gas, N_2 gas, and CO gas within a region enclosed by four points in a H_2 gas-N_2 gas-CO gas ternary diagram wherein the four points are a point at H_2 gas: 0 vol%, N_2 gas: 0 vol%, and CO gas: 100 vol%, a point at H_2 gas: 100 vol%, N_2 gas: 0 vol%, and CO gas: 0 vol%, a point at H_2 gas: 29 vol%, N_2 gas: 71 vol%, and CO gas: 0 vol%, and a point at H_2 gas: 0 vol%, N_2 gas: 37 vol%, and CO gas: 63 vol%; and includes H_2 gas in the range of 0 to 100 vol%, N_2 gas in the range of 0 to 71 vol%, and CO gas in the range of 0 to 100 vol%.

[5] The blast furnace operation method according to any one of [1] to [4], wherein the volume of H_2 gas in the high-concentration reducing gas is in the range of 0 to 500 Nm^3/ton of molten pig iron.

Advantageous Effects of Invention

[0017] In a blast furnace operation that generates a high-concentration reducing gas in a raceway in the furnace, the present invention controls the gross basicity (mass% CaO/mass% SiO_2) of a ferrous raw material and an auxiliary raw material to a predetermined range. This control optimizes the viscosity of slag formed in the cohesive zone and the dripping zone in the blast furnace and the slag permeability in the blast furnace is controlled to an operable range. As a result, the gas permeability in the blast furnace can be maintained in good state, and the blast furnace can be operated stably.

Brief Description of Drawings

[0018]

[Fig. 1] Fig. 1 is a H_2 gas-N_2 gas-CO gas ternary diagram that illustrates the range of the bosh gas composition of a high-concentration reducing gas generated in a raceway in the furnace in a blast furnace operation method according to an embodiment.
[Fig. 2] Fig. 2 is a graph illustrating the influence of the gross basicity on the amount of melt drops in a test in which a high-concentration reducing gas was generated in a raceway in a furnace.
[Fig. 3] Fig. 3 is a graph illustrating the influence of the gross basicity on the gas permeability resistance index KS in a test in which a high-concentration reducing gas was generated in a raceway in a furnace.

Description of Embodiments

[0019] Hereinafter, an embodiment of the present invention will be described. A blast furnace operation method according to the present embodiment is a method of operating a blast furnace in such a manner that a ferrous raw material, an auxiliary raw material, and coke are alternately charged from a blast furnace top into the blast furnace to form alternate layers, and a gas is injected from a tuyere disposed at a lower position of the blast furnace and the gas that has been injected from the tuyere into the blast furnace generates a high-concentration reducing gas in the raceway in the blast furnace. For example, the ferrous raw material includes iron ore, sintered iron ore, iron ore pellets, reduced iron, and iron scraps. The auxiliary raw material includes SiO_2 and/or CaO. The types of the ferrous raw material, the auxiliary raw material, and the coke that are used are not particularly limited, and any ferrous raw materials, auxiliary raw materials, and cokes used in the conventional blast furnace operations may be suitably used in the present invention.

[0020] The gas for generating a high-concentration reducing gas contains a reductive component that reduces the ferrous raw material in the blast furnace. Here, the reductive component that reduces the ferrous raw material in the blast furnace may be CO gas, H_2 gas, or a hydrocarbon gas capable of reducing the ferrous raw material, or may be CO_2 gas, H_2O gas, or the like that generates a reducing gas through, for example, the reaction with the coke or the decomposition reaction.

[0021] Fig. 1 is a H_2 gas-N_2 gas-CO gas ternary diagram that illustrates the range of the bosh gas composition of a high-concentration reducing gas generated in a raceway in the furnace in the blast furnace operation method according to the present embodiment. The high-concentration reducing gas in the present embodiment is a reducing gas that reduces the ferrous raw material with an average reduction ratio of 80% or more when the high-concentration reducing gas is allowed to act on the material at 900°C for 180 minutes. This reducing gas, when expressed by bosh gas composition, is composed of H_2 gas, N_2 gas, and CO gas; has a composition of H_2 gas, N_2 gas, and CO gas (with the proviso that H_2 gas + N_2 gas + CO gas = 100 vol%) within the shaded region A in Fig. 1 (the range of the operation according to the present invention); and includes H_2 gas in the range of 0 to 100 vol%, N_2 gas in the range of 0 to 71 vol%, and CO gas in the range of 0 to 100 vol%.

[0022] In the H_2 gas-N_2 gas-CO gas ternary diagram, the region A is enclosed by four points including point O (H_2 gas: 0 vol%, N_2 gas: 0 vol%, CO gas: 100 vol%), point P (H_2 gas: 100 vol%, N_2 gas: 0 vol%, CO gas: 0 vol%), point Q (H_2 gas: 29 vol%, N_2 gas: 71 vol%, CO gas: 0 vol%), and point R (H_2 gas: 0 vol%, N_2 gas: 37 vol%, CO gas: 63 vol%). As a comparison, Fig. 1 also illustrates the range of the gas composition in conventional general blast furnace operations. In this region A, the average reduction ratio is 90% or more when the ferrous raw material is reduced at 900°C for 180 minutes in the region enclosed by four points including point O (H_2 gas: 0 vol%, N_2 gas: 0 vol%, CO gas: 100 vol%), point P (H_2 gas: 100 vol%, N_2 gas: 0 vol%, CO gas: 0 vol%), point Q' (H_2 gas: 43 vol%, N_2 gas: 57 vol%, CO gas: 0 vol%), and point R' (H_2 gas: 0 vol%, N_2 gas: 14 vol%, CO gas: 86 vol%). Thus, the FeO content in the slag components in the cohesive zone in the furnace is significantly low. When a high-concentration reducing gas falling in this composition range is generated in a raceway in the furnace, the control of the gross basicity (mass% CaO/mass% SiO_2) produces greater effects by restoring the dripping of melts including slag.

[0023] The present inventors conducted a test in which a high-concentration reducing gas was generated in a raceway in a 1/4 scale small test furnace simulating a blast furnace and slag components in the cohesive zone and the dripping zone in the furnace were studied. Table 1 describes some examples of the chemical compositions of ferrous raw materials used in the small test furnace.

[Table 1]

	Chemical compositions of ferrous raw materials (mass%)							
	T-Fe	M-Fe	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO
Sintered ore 1	57.30	0.03	9.04	71.77	5.36	1.83	9.05	1.25
Sintered ore 2	54.14	0.10	8.04	68.32	5.72	2.08	12.76	1.19
Iron ore 1	62.93	0.10	0.29	89.65	1.75	2.24	0.04	0.02
Iron ore 2	57.81	0.10	0.29	82.34	7.15	4.35	0.01	0.03

[0024] In the small test furnace, a ferrous raw material, an auxiliary raw material, and coke were charged in accordance with the operation method described in Patent Literature 2 while generating a high-concentration reducing gas in a raceway in the furnace. In the test, the gross basicity of the ferrous raw material and the auxiliary raw material was controlled to 2.0. Under these test conditions, the slag components in the cohesive zone in the furnace were calculated to include less than 3.5 mass% FeO components, 25.4 to 28.3 mass% SiO_2 components, 8.6 to 9.2 mass% Al_2O_3 components, 52.5 to 56.7 mass% CaO components, and 5.3 to 7.3 mass% MgO components. The basicity of the slag was as high as about 2.0, and the amount of slag drops decreased to about one-tenth of that in the conventional tests. As a result, the gas permeability was deteriorated to a level where stable test was no longer feasible.

[0025] The present inventors considered that the basicity of the slag produced should be lowered in order to increase the amount of slag drops. The present inventors then carried out a test in which a high-concentration reducing gas was generated in a raceway in the furnace while changing the gross basicity of the ferrous raw material and the auxiliary raw material within the range of 0.95 to 2.23. The influence of the gross basicity on the amount of melt drops and the gas permeability resistance index KS was thus studied.

[0026] The amount of melt drops was determined by recovering the melt that had dropped during the test after the experiment, and measuring the total weight of the melt with a weighing machine. The gas permeability resistance index KS was determined as an integral value of gas permeability resistance K (1/m) calculated based on the pressure loss measured in a region inside the furnace where the temperature was 1000°C or above, and properties estimated from the operation conditions.

<Method of Calculating the Gas Permeability Resistance Index KS>

[0027] The gas permeability resistance K (1/m) is calculated from the equation (1) below.

$$K = (\Delta P/H)/(\rho_{gas}^{0.7} \times \mu_{gas}^{0.3} \times v_{gas}^{1.7}) \quad \cdots (1)$$

[0028] Here, ΔP is the pressure loss (Pa), H is the thickness (m) of the packed bed in the furnace, ρ_{gas} is the gas density (kg/m^3), μ_{gas} is the gas viscosity (Pa·s), and v_{gas} is the gas flow velocity (m/s). ΔP is obtained by calculating the difference between the pressures measured with pressure gauges installed at the tuyere and on a furnace wall of an upper part of the test furnace (in the space above the packed bed). For example, H is determined by measuring the position of the surface of the packed bed with a measuring jig having been inserted through a hole perforated in an upper portion of the test furnace, and calculating the distance in the height direction between the position of the surface of the packed bed and the position where the tuyere is located. The position of the surface of the packed bed may be measured with a laser rangefinder. ρ_{gas} can be calculated from the type of the gas component introduced from the tuyere, the temperature inside the furnace, and the pressure inside the furnace. μ_{gas} can be calculated from the type of the gas component introduced from the tuyere, and the temperature inside the furnace. v_{gas} can be calculated from the flow rate of the gas introduced from the tuyere, the temperature inside the furnace, and the pressure inside the furnace. Here, the temperature inside the furnace is the average of temperatures measured with a plurality of thermometers installed at positions on the furnace wall corresponding to the packed bed. Similarly, the pressure inside the furnace is the average of pressures measured with a plurality of pressure gauges installed at positions on the furnace wall corresponding to the packed bed. The pressure inside the furnace may be the average of the pressure at the tuyere used to calculate ΔP and the pressure at the upper portion of the packed bed.

[0029] The gas permeability resistance index KS is calculated using the equation (2) below.
[Math. 1]

$$KS = \int_{1000℃}^{Tmax} K\,dt \quad \cdots(2)$$

[0030] In the equation (2), Tmax is the maximum temperature in the measurement of the pressure loss in the furnace and is approximately 1500 to 1650°C, although variable every time the measurement is performed.

[0031] Fig. 2 is a graph illustrating the influence of the gross basicity on the amount of melt drops in the test in which a high-concentration reducing gas was generated in a raceway in the furnace. The abscissa in Fig. 2 is the gross basicity (mass% CaO/mass% SiO_2) and the ordinate is the amount (g) of melt drops.

[0032] Fig. 3 is a graph illustrating the influence of the gross basicity on the gas permeability resistance index KS in the test in which a high-concentration reducing gas was generated in a raceway in the furnace. The abscissa in Fig. 3 is the gross basicity (mass% CaO/mass% SiO_2) and the ordinate is the gas permeability resistance index KS (10^5°C/m).

[0033] As illustrated in Fig. 2, the amount of melt drops increased when the gross basicity of the ferrous raw material and the auxiliary raw material was in the range of 1.0 to 1.7. Furthermore, as illustrated in Fig. 3, it was shown that the gas permeability resistance index KS fell to or below the target 2000 when the gross basicity of the ferrous raw material and the auxiliary raw material was in the range of 1.0 to 1.7. The target value of the gas permeability resistance index KS, namely, 2000, is a threshold for the feasibility of continuous stable testing. The term stable testing means that the surface height of the packed bed descends uniformly over time and the test is free from troubles, such as gas channeling.

[0034] These results have shown that a test in which a high-concentration reducing gas is generated in a raceway in the furnace can be performed stably by controlling the gross basicity of the ferrous raw material and the auxiliary raw material to the range of 1.0 to 1.7.

[0035] The blast furnace operation method according to the present embodiment has been developed based on the above test results. The blast furnace operation method is a method of operating a blast furnace while charging a ferrous raw material, an auxiliary raw material, and coke from a blast furnace top, and injecting from a blast furnace tuyere a gas that generates a high-concentration reducing gas in the raceway in the blast furnace; and includes controlling the gross basicity of the ferrous raw material and the auxiliary raw material that are charged, to a predetermined range.

[0036] Here, it is preferable that the gross basicity of the ferrous raw material and the auxiliary raw material that are charged be controlled to 1.0 or more and 1.7 or less. In this manner, melt drip characteristics and gas permeability at a lower part of the blast furnace can be enhanced. If the gross basicity of the ferrous raw material and the auxiliary raw material is less than 1.0, or if the gross basicity of the ferrous raw material and the auxiliary raw material is more than 1.7, the slag viscosity is disadvantageously increased beyond a stable operation range in both cases.

[0037] The gross basicity of the ferrous raw material and the auxiliary raw material that are charged is more preferably controlled to 1.1 or more and 1.7 or less, and still more preferably controlled to 1.4 or more and 1.5 or less. This control further reduces the slag viscosity, and melt drip characteristics and gas permeability can be further enhanced. The raw materials are preferably adjusted so that the amount of slag will be 400 kg or less per ton of molten pig iron. Controlling the amount of slag to 400 kg or less per ton of molten pig iron can eliminate or reduce the lowering in gas permeability due to the increase in the amount of melts occurring from a low temperature range.

[0038] The high-concentration reducing gas is preferably such that the volume of H_2 gas (including hydrogen in hydrocarbons) in the high-concentration reducing gas is in the range of 0 to 500 Nm^3/ton of molten pig iron. In this case, it is possible to eliminate or reduce the decrease in in-furnace temperature and the decrease in reduction reaction rate. If, on the other hand, the volume of H_2 gas in the high-concentration reducing gas is more than 500 Nm^3/ton of molten pig iron, the in-furnace temperature is disadvantageously lowered to give rise to a decrease in reduction reaction rate. When H_2 gas alone is injected, it is preferable that the H_2 gas be heated before blowing in order to maintain the raceway temperature within an operable range.

[0039] In a blast furnace operation that generates a high-concentration reducing gas in a raceway in the furnace, as described hereinabove, the blast furnace operation method according to the present embodiment charges a ferrous raw material and an auxiliary raw material while controlling the gross basicity of the ferrous raw material and the auxiliary raw material to a predetermined range. This control optimizes the viscosity of slag formed in the cohesive zone and the dripping zone in the blast furnace and the slag permeability in the blast furnace is controlled to an operable range. As a result, the gas permeability in the blast furnace can be maintained in good state, and the blast furnace can be operated stably.

EXAMPLES

[0040] A blast furnace operation test was performed in which a ferrous raw material, an auxiliary raw material, and coke were alternately charged from the top of a large blast furnace and a high-concentration reducing gas was generated in a raceway in the furnace. The gross basicity of the ferrous raw material and the auxiliary raw material charged from the furnace top was changed. Some illustrative test results are described in Table 2.

[Table 2]

	Items	Units	INV. EX. 1	INV. EX. 2	INV. EX. 3	INV. EX. 4	COMP. EX. 1	COMP. EX. 2	COMP. EX. 3
Raw materials charged	Fe_2O_3	mass%	73.26	72.43	82.23	75.82	70.09	74.08	74.08
	FeO	mass%	6.61	6.53	4.25	5.85	6.32	6.68	6.68
	SiO_2	mass%	6.68	7.73	4.19	5.89	10.72	5.63	5.63
	Al_2O_3	mass%	1.70	1.68	1.97	2.10	1.63	1.72	1.72
	CaO	mass%	10.33	10.21	6.47	9.09	9.88	10.44	10.44
	MgO	mass%	1.43	1.41	0.90	1.26	1.37	1.45	1.45
	Gross basicity (CaO/SiO_2)	-	1.55	1.32	1.54	1.54	0.92	1.85	1.85
Bosh gas	TFT*1	°C	2050	2050	2050	2100	2050	2050	2100
	Gas volume	Nm^3/t	1140	1140	1140	930	1140	1140	930
	CO	vol%	62	62	62	84	62	62	84
	H_2	vol%	38	38	38	15	38	38	15
	N_2	vol%	0	0	0	1	0	0	1
	H_2 volume	Nm^3/t	433	433	433	140	433	433	140
Operation data	Coke ratio	kg/t	390	390	390	290	390	390	290
	PCR*2	kg/t	0	0	0	250	0	0	250
	Methane ratio*3	kg/t	155	155	155	0	155	155	0
	Unit consumption of blast volume	Nm^3/t	350	350	350	300	350	350	300
	Oxygen enrichment	%(dry)	100	100	100	100	100	100	100
	Blast temperature	°C	25	25	25	25	25	25	25
	Blast moisture	g/Nm^3	0	0	0	0	0	0	0
Operation results	Drip characteristics	-	Good	Good	Good	Good	Poor	Poor	Poor
	Gas permeability	-	Good	Good	Good	Good	Poor	Poor	Poor

*1;; TFT (theoretical flame temperature) is the temperature reached by complete combustion under adiabatic conditions.
*2; PCR (pulverized coal ratio) is the amount of pulverized coal injected per ton of molten pig iron.
*3; The methane ratio is the amount of methane injected per ton of molten pig iron.

[0041] In INVENTIVE EXAMPLES 1 to 4, the ferrous raw material and the auxiliary raw material were charged from the furnace top with control of the gross basicity to the range of the present invention. As described in Table 2, it was confirmed that these examples achieved good drip characteristics and good gas permeability and made stable operation possible. In COMPARATIVE EXAMPLES 1 to 3, the gross basicity of the ferrous raw material and the auxiliary raw material charged from the furnace top was outside the range of the present invention. As a result, the dripping was insufficient and the gas permeability was also poor.

Claims

1. A blast furnace operation method of operating a blast furnace while charging a ferrous raw material, an auxiliary raw material, and coke from a blast furnace top, and injecting from a blast furnace tuyere a gas that generates a high-concentration reducing gas in a raceway in the blast furnace, the method comprising controlling the gross basicity of the ferrous raw material and the auxiliary raw material to a predetermined range.

2. The blast furnace operation method according to claim 1, wherein the gross basicity is controlled to 1.0 or more and 1.7 or less.

3. The blast furnace operation method according to claim 1, wherein the high-concentration reducing gas, when expressed by bosh gas composition, is composed of H_2 gas, N_2 gas, and CO gas; has a composition of H_2 gas, N_2 gas, and CO gas within a region enclosed by four points in a H_2 gas-N_2 gas-CO gas ternary diagram wherein the four points are a point at H_2 gas: 0 vol%, N_2 gas: 0 vol%, and CO gas: 100 vol%, a point at H_2 gas: 100 vol%, N_2 gas: 0 vol%, and CO gas: 0 vol%, a point at H_2 gas: 29 vol%, N_2 gas: 71 vol%, and CO gas: 0 vol%, and a point at H_2 gas: 0 vol%, N_2 gas: 37 vol%, and CO gas: 63 vol%; and includes H_2 gas in the range of 0 to 100 vol%, N_2 gas in the range of 0 to 71 vol%, and CO gas in the range of 0 to 100 vol%.

4. The blast furnace operation method according to claim 2, wherein the high-concentration reducing gas, when expressed by bosh gas composition, is composed of H_2 gas, N_2 gas, and CO gas; has a composition of H_2 gas, N_2 gas, and CO gas within a region enclosed by four points in a H_2 gas-N_2 gas-CO gas ternary diagram wherein the four points are a point at H_2 gas: 0 vol%, N_2 gas: 0 vol%, and CO gas: 100 vol%, a point at H_2 gas: 100 vol%, N_2 gas: 0 vol%, and CO gas: 0 vol%, a point at H_2 gas: 29 vol%, N_2 gas: 71 vol%, and CO gas: 0 vol%, and a point at H_2 gas: 0 vol%, N_2 gas: 37 vol%, and CO gas: 63 vol%; and includes H_2 gas in the range of 0 to 100 vol%, N_2 gas in the range of 0 to 71 vol%, and CO gas in the range of 0 to 100 vol%.

5. The blast furnace operation method according to any one of claims 1 to 4, wherein the volume of H_2 gas in the high-concentration reducing gas is in the range of 0 to 500 Nm^3/ton of molten pig iron.

FIG. 1

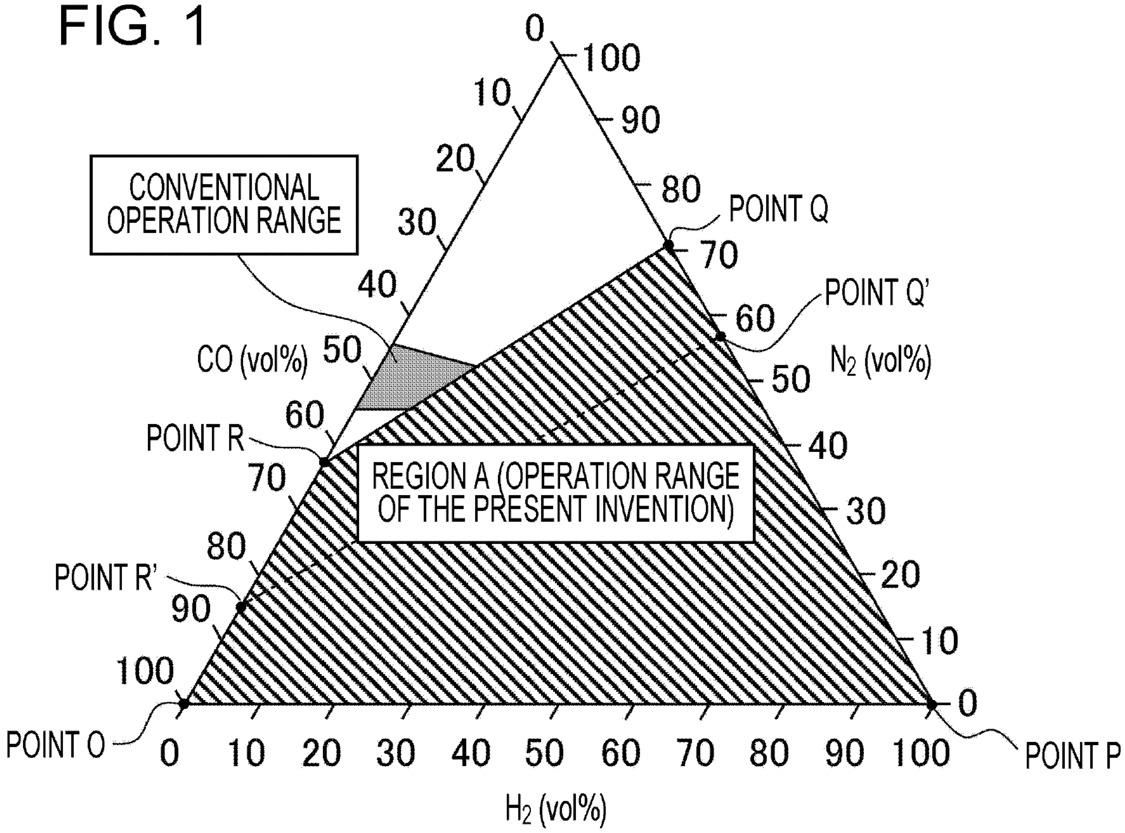

CONVENTIONAL OPERATION RANGE
CO (vol%)
N2 (vol%)
H2 (vol%)
POINT Q
POINT Q'
POINT R
POINT R'
POINT O
POINT P
REGION A (OPERATION RANGE OF THE PRESENT INVENTION)
0
10
20
30
40
50
60
70
80
90
100

FIG. 2

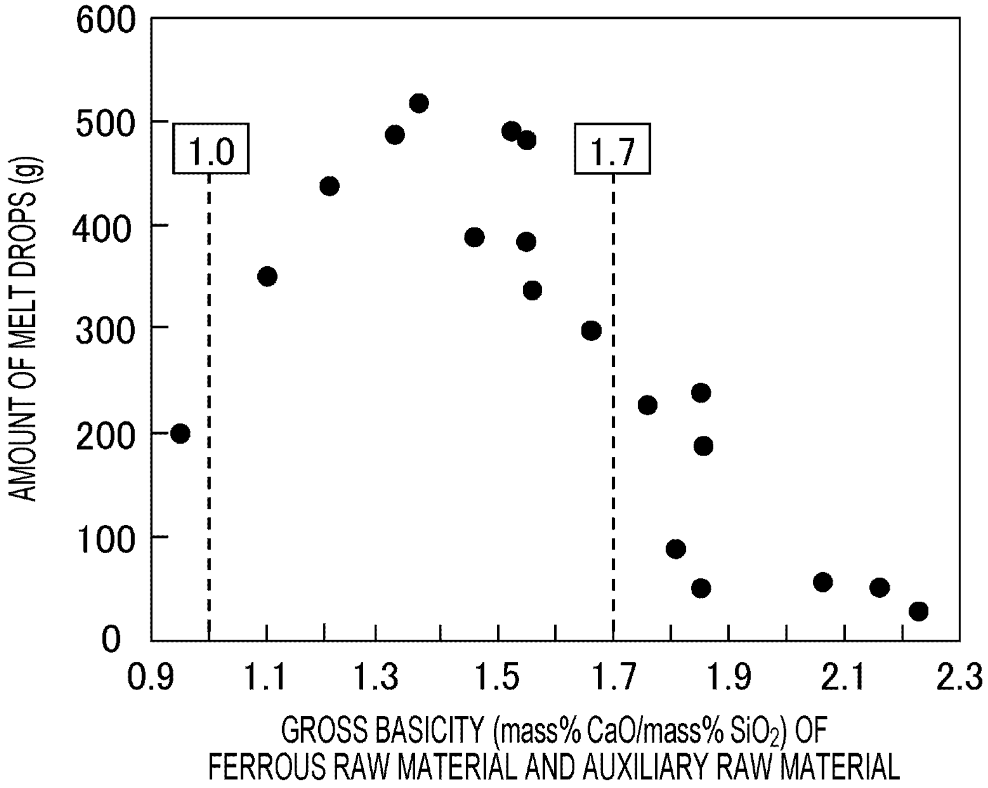
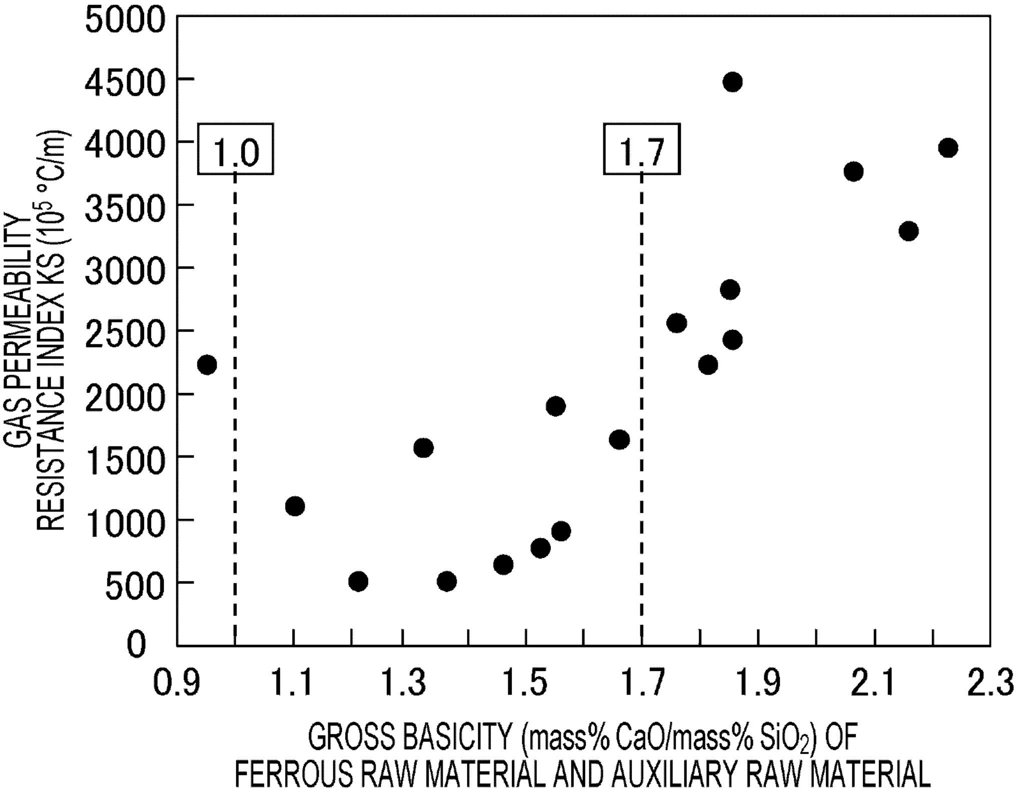

AMOUNT OF MELT DROPS (g)
0
100
200
300
400
500
600
1.0
1.7
0.9
1.1
1.3
1.5
1.7
1.9
2.1
2.3
GROSS BASICITY (mass% CaO/mass% SiO2) OF FERROUS RAW MATERIAL AND AUXILIARY RAW MATERIAL

FIG. 3


5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.9
1.1
1.3
1.5
1.7
1.9
2.1
2.3
1.0
1.7
GAS PERMEABILITY RESISTANCE INDEX KS (10^5 °C/m)
GROSS BASICITY (mass% CaO/mass% SiO2) OF FERROUS RAW MATERIAL AND AUXILIARY RAW MATERIAL

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/046305

A. CLASSIFICATION OF SUBJECT MATTER

C21B 5/00(2006.01)i
FI: C21B5/00 301; C21B5/00 321

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)

C21B5/00

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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.
X	JP 2015-199978 A (NIPPON STEEL & SUMITOMO METAL CORP) 12 November 2015 (2015-11-12) claims, see table 1, paragraphs [0028], [0043]	1, 2
Y	claims, see table 1, paragraphs [0028], [0043]	3-5
X	WO 2011/021577 A1 (NIPPON STEEL CORPORATION) 24 February 2011 (2011-02-24) claims, paragraphs [0002], [0065], table 6	1, 2
Y	claims, paragraphs [0002], [0065], table 6	3-5
X	JP 2002-060809 A (NIPPON STEEL CORPORATION) 28 February 2002 (2002-02-28) claims, paragraphs [0003], [0006]	1, 2
Y	claims, paragraphs [0003], [0006]	3-5
Y	大野陽太郎・松浦正博, 酸素高炉プロセスにおける炉内装入物の昇温，反応特性, 鉄と鋼, 1990, vol. 76, no. 8, pp. 60-67, in particular, table 1 table 1, (OHNO, Yotaro. MATSUURA, Masahiro. Heating-up and Reaction Characteristics of Burdens in Oxygen Blast Furnace Process. Tetsu-to-Hagane.)	3-5

☑ 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
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"&" document member of the same patent family

Date of the actual completion of the international search **07 February 2023**	Date of mailing of the international search report **21 February 2023**
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.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/046305

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2013-082971 A (NIPPON STEEL & SUMITOMO METAL CORP) 09 May 2013 (2013-05-09)	1-5
A	JP 9-143516 A (NIPPON STEEL CORPORATION) 03 June 1997 (1997-06-03)	1-5

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/046305

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2015-199978 A	12 November 2015	(Family: none)	
WO 2011/021577 A1	24 February 2011	CN 102482730 A claims, paragraphs [0003], [0126]-[0129], table 6 KR 10-2012-0042981 A claims, paragraphs [0003], [0105]-[0108], table 6	
JP 2002-060809 A	28 February 2002	(Family: none)	
JP 2013-082971 A	09 May 2013	(Family: none)	
JP 9-143516 A	03 June 1997	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

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- JP 9013107 A **[0011]**
- JP 2005298923 A **[0011]**