Patent 5012138 overview of Sumitomo Metal Company

Method for operating blast furnace

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Problem to be solved

To provide an operating method for injecting a large quantity of fine powdery coals into a blast furnace with which while restricting the worsening of gas-permeability in the blast furnace, the protection of a furnace top facility and the improvement of molten iron treating cost can be achieved.

Solution

In the blast furnace operation having ≥100 (kg/ton of molten iron) injecting quantity of the fine powdery coals and ≤30 mass% of ratio of bulky ore in an ores charging material; this blast furnace operating method is performed, that is, 5–30 (kg/ton of molten iron) magnesium hydroxide ore is charged into the furnace from the top part of the blast furnace. In the operating method, it is desirable that the magnesium hydroxide ore is as the bulky ore and the charging position of this ore in the furnace is the position of 0.4–1 times of the furnace radius from the furnace center. Further, this operating method is desirable to apply at the time when the bulky ore having ≥4.5 mass % SiO_2 content, is charged into the furnace from the furnace top part of the blast furnace.

At the blast furnace operation method, which the amount of powdery coal injection is 100 kg or more of 1 ton of molten iron, and the ratio of lump size ore is under 30% (mass), magnesium hydroxide contain mineral is supplied from a shaft furnace top and its feed quantity is controlled by 5–30 kg of 1ton of molten iron.

When the aforementioned magnesium hydroxide ore is a massive ore, the direction distance of a furnace in radius from a furnace center to a charge position of a magnesium hydroxide ore is set to r in a stock level of charge and distance from a furnace center to a furnace wall is set to R, The blast furnace operation method according to claim 1 charging in a furnace so that a relation as which the charge position is expressed in following the (1) type in the aforementioned magnesium hydroxide ore may be satisfied.

$$0{,}4 \le r/R \le 1 \quad (1)$$

The blast furnace operation method according to claim 1 or 2, wherein SiO_2 content of charged lump ore has min 4.5 % of SiO_2 contents

Points regarding about Brucite

In the above-mentioned powdery coal injection operation, when a lot of fine coal is charged, the height of cohesion zone, where heated materials begin to soften and to form cohesion before dripping, arise, because the heat flow ratio, which indicates the ratio of heat capacity of solid material to the capacity of gas material, falls downward and surplus heating reduction can be occurred. When the height position of a fused zone rises, then the furnace gas temperature which is exhausted from the shaft furnace upper part hikes up. It has a possibility that equipment may be damaged, according to increase of the heat load to furnace top equipment.

The Si content in molten iron rises with the increase in the amount of the fine coal injection. This is because the transfer reaction of Si to the inside of the molten iron expressed by the following (1) type and (2) types arises. Namely, in a tuyere point near raceway, it is returned by the coks (C) in which SiO_2 in dust coal burned, SiO gas is emitted, and this SiO gas and dropping molten iron contact as expressed by (1) type, The reaction shown by (2) formulas between C in molten iron is caused, SiO is returned, and it moves into molten iron as Si. It is because dropping distance will become long, the contact frequency of liquid molten iron particles and SiO gas will increase. If the height position of a fused zone rises, so the occurrence frequency of (2) types increases and the Si content in molten iron begins to rise.

$$SiO_2 + C \rightarrow SiO\ (gas) + CO\ (gas) \quad (1)$$

$$SiO\ (gas) + C \rightarrow Si + CO\ (gas) \quad (2)$$

A Patent document 1 (application No. 2001–140007) has disclosed the method of making furnace top temperature being deteriorated using the decomposition reaction of crystal water by charging with a high-crystal-water containing ore by high quantity of powdery coal injection operation.

However, generally, high-crystal-water containing ore will be a porous by the heating and the physical strength at the high temperature is going to worse and air permeability in the furnace goes unstable, because it generates a lot of powder ore. In recent years the quality of iron ore is deteriorated and the SiO_2 content in an ore is higher than ever. If the charge of high-crystal-water iron ore with high SiO_2 content is increased under such a situation, the slag amount in a furnace increases, and it not only worsens the air permeability of a shaft furnace, but by the rise of the required quantity of energy for the creation of slag, a reducing material ratio will increase and it will cause the rise of operating cost.

A Patent document 2 (Application No. 1986–261407) has disclosed the method of controlling the charge of auxiliary materials, such as a Dolomite, by using the shaft furnace gas temperature as an index, and controlling the slag basicity, MgO concentration and S content in molten iron. There is a problem of changing and unstableness of the slag basicity in this method, by charging with auxiliary materials, such as a Dolomite. Slag basicity is the numerical value which is the ratio of the CaO mass % to SiO_2 mass % in a slag component, and it influences the melting point of blast furnace slag, viscosity, desulfurizing ability, etc.

Therefore, slag basicity is designed from the comprehensive viewpoint also including the stability of blast furnace operation and the molten iron treatment cost. Since the change of basicity will change, the melting starting temperature of charged materials will change. Then a furnace operation condition will unstable, because the thickness of cohesion zone in the shaft, which causes a biggest pressure loss in the furnace, will thicker. And the change of components of molten iron needs more process to amend its characteristics. It increases an operation cost.

It is recommended that the slag basicity must be maintained in a designed level in the each blast furnace operation. By the use of Dolomite, the addition of auxiliary material of SiO_2 contain sources, such as Serpentine and silica rock, are needed to maintain the basicity value. It increases slag amount and cause inconvenient air permeability in the furnace. And if the control of basicity for the furnace will be achieved by control of basicity of sintered material, the lower content of CaO in the sintered ore is expected. It means lower productivity of sintering production and lower quality of sinter product, and higher cost of sinter process.

The patent document 3 (Application No. 1993–311217) explain the solution for a decrease of Si in a molten iron and a content of S (sulfur) by the additional charge of Dolomite, Serpentine or Limestone in the coke layer zone around the furnace wall. But this solution causes also more creation of slag, because of the control of basicity in the furnace and brings the furnace undesirable conditions.

In addition, the patent document 4 (Application No. 1983–061204) introduces the methods of reducing a content of Si in the molten iron. By this methods some sort of minerals, which has a different basicity grade, are supplied in the circular position, which distribution of basicity conforms to the distribution of temperature at the level of tuyere, in order to control the content of Si in the molten iron. However, by this solution the smelting fluxes are supplied in the circular position, some fluxes remain in the coke layer, and it makes inconvenient air permeability in the furnace and the effectivity of the flux becomes worse, because the flux must be supplied also outside area of the Raceway.

By the solution, which is stated in the patent document 5 (Application No. 2003–183711), the smelting flux, which is consist of the mixing of at least FeO, CaO and MgO, is blown with powdery coal from the tuyere, in order to reduce the temperature. But this method involves a risk of excessive cool down of the furnace. And at the same time SiO_2 must be supplied in order to avoid non-activation in deadman area, the volume of the slag increases, and the condition of blast furnace will be worse because of inconvenient air permeability in the furnace.

The problems of former solutions are follows. As the auxiliary materials for reducing the Si content in the molten iron Dolomite and Serpentine are used, which are containing a lot of CaO and SiO_2, and Magnesite, which releases a CO_2 gas by the heat decomposition. In the case of using some auxiliary materials, which contain CaO and SiO_2, the excess amount of these materials must be supplied to control the basicity in the furnace. It means the more slag will be produced and as the result bad air permeability in the furnace and the condition of the furnace will be unstable.

A carbonate material, such as a Magnesite, releases CO_2 gas by the heat-decomposition. At the upper side of a blast furnace the indirect reduction for the iron ore is carried out by mainly CO gas, which is described the equations as follows (3) and (4). When the CO_2 gas is released by the heating, reduction ability of CO gas is obstructed and the reduction of iron ore will be delayed. Because of this delayed reduction, un-reduced iron ore comes to the level of tuyere and it begins direct reduction as (5). This reduction is an endothermic reaction. The increasing of this direct reduction means the drop of the temperature around tuyere level and the frequency of direct contact of tuyere and molten iron will be higher and the risk of damage for the tuyere will be higher.

$$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2 \quad (3)$$

$$Fe_3O_4 + CO \rightarrow 3FeO + CO_2 \quad (4)$$

$$FeO + C \rightarrow Fe + CO \quad (5)$$

In order to solve the above mentioned problem, the inventor studied the operation method which can control the air permeability in the furnace, reduce the temperature of the top level in the furnace and reduce a content of Si and S in the molten iron, and reached the following knowledge as (a) and (b).

(a) It is most effective to use the magnesium hydroxide minerals, which is charged from the top of the furnace for the purpose of dropping the temperature at the top of furnace and reduce the content of Si and S in the molten iron.

1) Magnesium hydroxide mineral is called generally Brucite. Its main component is $Mg(OH)_2$ and by the chemical analysis Brucite has MgO at least 50 % mass. It is not expected to supply an additional flux by the supply to the blast furnace because Brucite does not change the basicity in the furnace.

2) Magnesium hydroxide does not release CO_2 gas by the heat decomposition. It does not give any effects to the reduction reaction in the furnace and Brucite is superior to reduce the temperature at the top of furnace and reduce the content of Si and S in the molten iron than other auxiliary materials.

(b) It is recommended that magnesium hydroxide mineral is charged at the top of the furnace and its position should be in the circular area of radius 0.4 to 1.0 of the furnace top level. If the radius of the charged circular area is smaller than 0.4, un-melted auxiliary materials remain in the coke and it cause an inconvenient air permeability and bad dropping conditions for molten iron in the center area of furnace, an decreased effect to inhibit the creation of SiO gas and S gas, which occurs at the wall of the furnace, mainly near area of raceway and brings about the worse effect to reduce the contents of Si and S in the molten iron.

Appendix

Table 1

Auxiliary materials	Endothermic energy amount, kJ/kg	Decomposition Reaction
Limestone	1060	$CaCO_3 \rightarrow CaO + CO_2$
Dolomite	878	$CaMg(CO_3)_2 \rightarrow CaO + MgO + 2CO_2$
Serpentine	450	$Mg_3Si_2O_5(OH)_4 \rightarrow 3MgO + 2SiO_2 + 2H_2O$
Brucite	1207	$Mg(OH)_2 \rightarrow MgO + H_20$

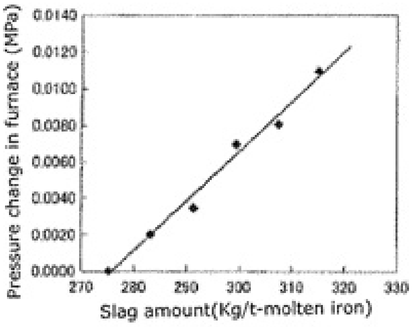
Table 2

Test №	Category	Test condition		Test results				
		Auxiliary material	Charge, kg/t-p	Slag amount, kg/t-p	Pressure change in furnace, Mpa	Temp. change at furnace top, °C	Si change in molten iron, %	S change in molten iron, %
1	This invention	Brucite	15	+10	+0.006	-18	-0.07	-0.005
2	Comparison	Dolomite	15	+27	+0.014	-18	-0,06	-0.002
3	Comparison	Serpentine	15	+32	-0.024	-23	-0.04	-0.002

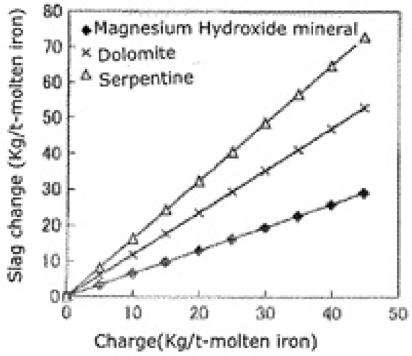
Table 3

Test №	Category	Test condition		Test results		
		Change of Magnesium Hydroxid mineral, kg/t-p	Charge of high crystal water iron ore, mass %	Pressure change in furnace, Mpa	Si change in molten iron, %	S change in molten iron, %
4	This invention	15	6	+0.001	-0.06	-0.005
5	Comparison	0	6	+0.010	0	0

【図1】



【図2】



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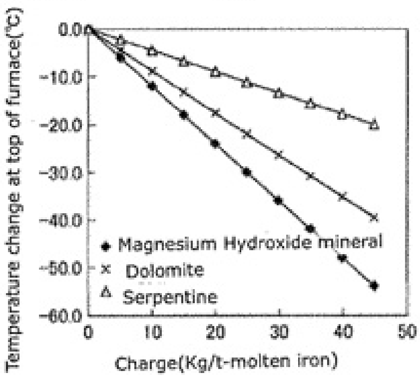
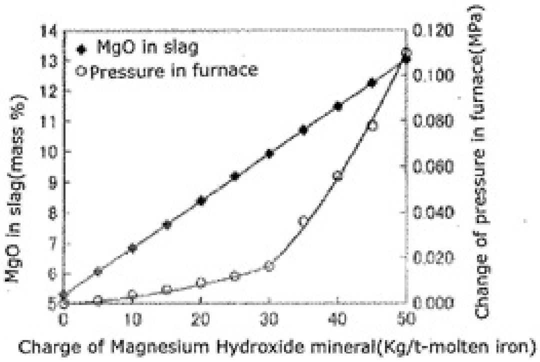


【図4】



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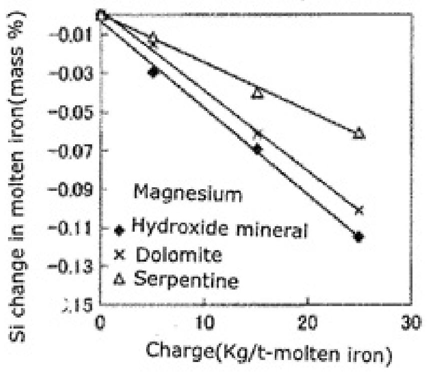
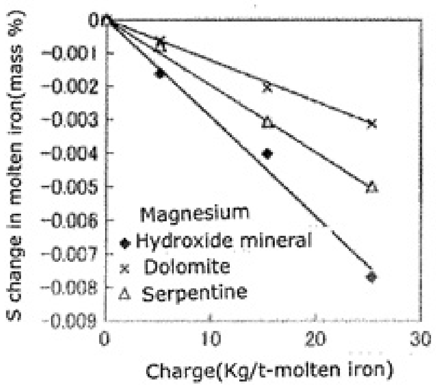
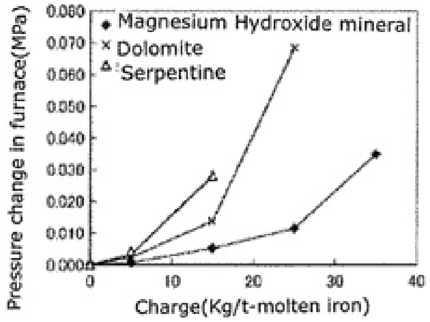

Si change in molten iron(mass %)
-0.01
-0.03
-0.05
-0.07
-0.09
-0.11
-0.13
-0.15
0
10
20
30
Charge(Kg/t-molten iron)
Magnesium
◆ Hydroxide mineral
× Dolomite
△ Serpentine

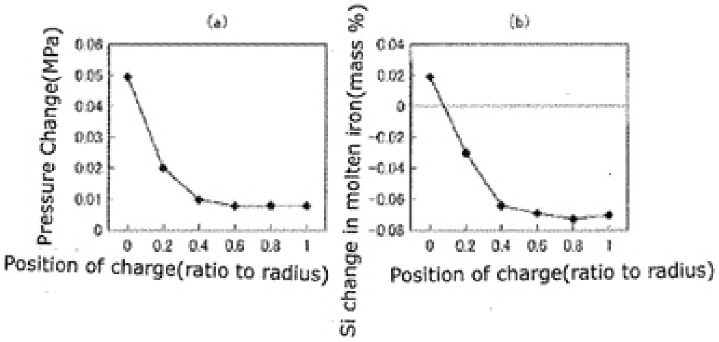
【図6】


S change in molten iron(mass %)
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
0
10
20
30
Charge(Kg/t-molten iron)
Magnesium
◆ Hydroxide mineral
× Dolomite
△ Serpentine

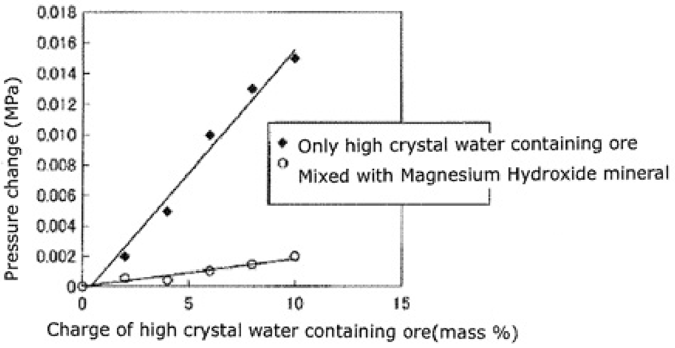
【図7】


Pressure change in furnace(MPa)
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
10
20
30
40
Charge(Kg/t-molten iron)
◆ Magnesium Hydroxide mineral
× Dolomite
△ Serpentine

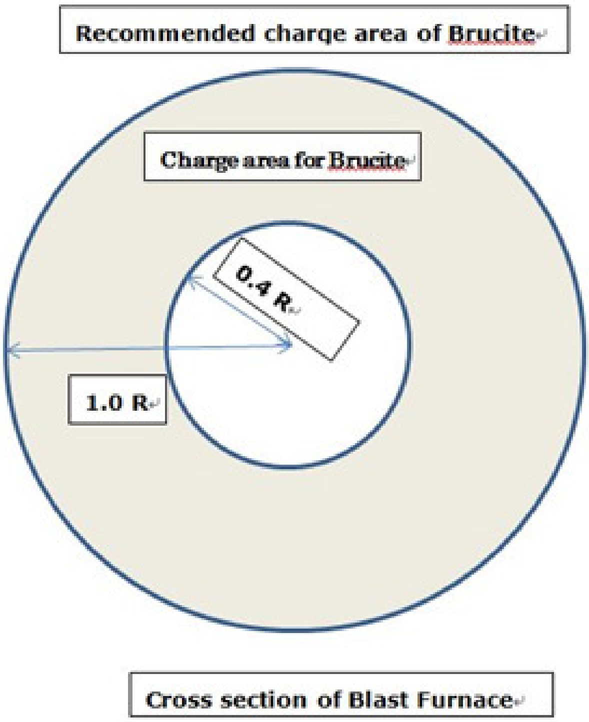
【図8】

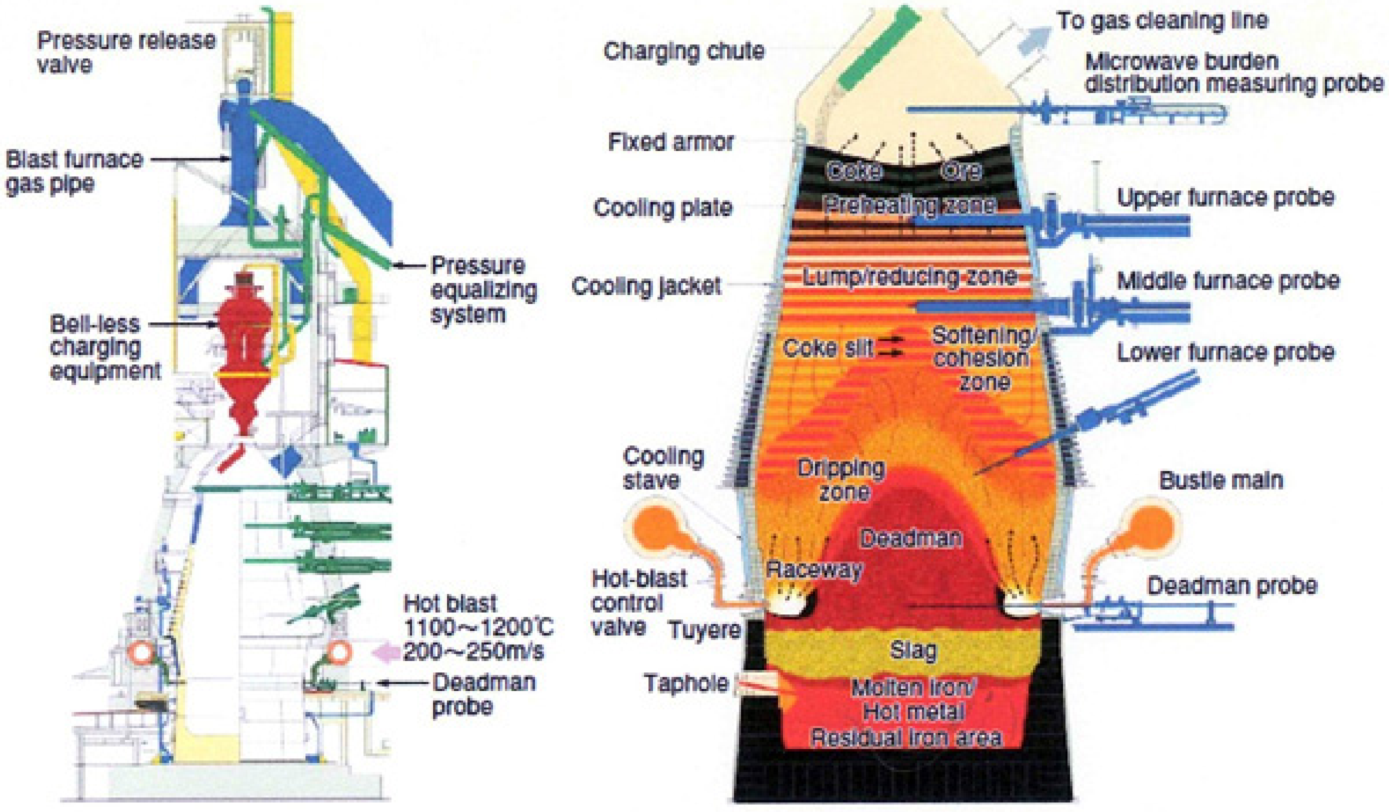

(a)
Pressure Change(MPa)
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.2
0.4
0.6
0.8
1
Position of charge(ratio to radius)
(b)
Si change in molten iron(mass %)
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
0
0.2
0.4
0.6
0.8
1
Position of charge(ratio to radius)

【図9】


Pressure change (MPa)
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0
0
5
10
15
Charge of high crystal water containing ore(mass %)
◆ Only high crystal water containing ore
○ Mixed with Magnesium Hydroxide mineral

Reference (not in the patent document)

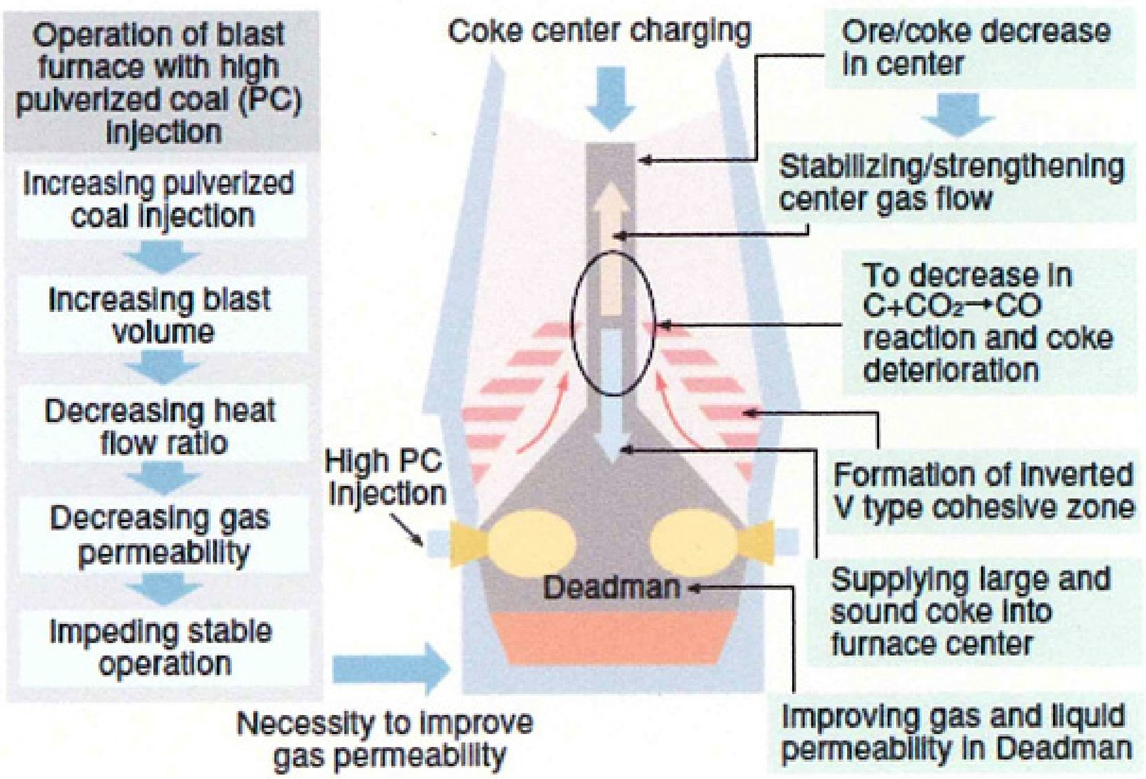




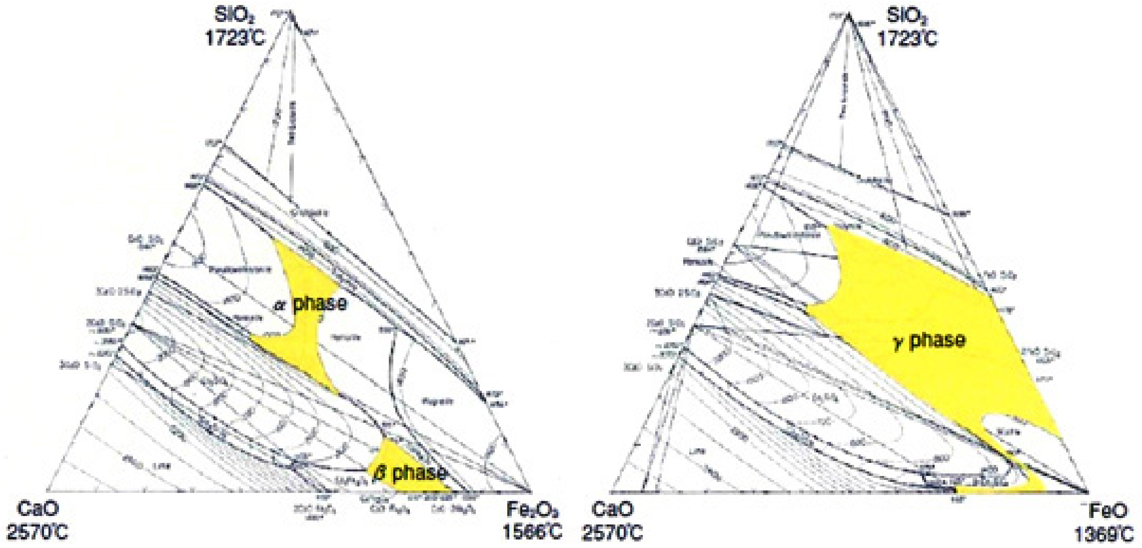
a. General view of blast furnace

b. Internal Cross Section of Blast Furnace

General configuration of blast furnace and internal cross section



High PC injection and coke center charging



Initial melt growth areas in sintering process

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