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Description

The present invention relates to a multi-step steelmaking refining method, comprising refining steps, beginning when the molten pig iron is tapped from the blast furnaces and ending when the molten steel is cast, carried out in a single reaction vessel, wherein the decarburization of molten pig iron, which has been desiliconized and dephosphorized, is carried out in the reaction vessel by means of oxygen which is soft-blown onto the surface of the molten pig iron by a multi-aperture lance or a plurality of lances while a stirring fluid is blown beneath the level of the molten pig iron within said reaction vessel during the decarburization treatment.

The impurities of molten pig iron produced by a blast furnace are removed exclusively in a converter, according to the conventional steelmaking refining method, by means of pure-oxygen being blown into the converter. In other words, the function of removing the impurities is concentrated on the converter refining. More specifically, the desiliconization, dephosphorization, desulfurization and decarburization reactions proceed in a converter concurrently or successively to one another. Since the impurities to be removed have chemical properties different from each other, and since the removal reactions take place concurrently or successively, it is not always possible for the conditions in a converter to be suitable for the removal of each impurity to be removed. More specifically, silicon, which is one of the impurities to be removed, is oxidized to SiO_2 usually in the initial oxygen-blowing period of a converter so that a slag layer having a low basicity (the ratio of CaO/SiO_2) is formed. This slag having a low basicity is not suitable for the removal of phosphorus and sulfur. In order to carry out the dephosphorization and desulfurization, the basicity of the slag must be maintained at a high level. According to a practice employed for this purpose, a large amount of auxiliary materials, mainly composed of lime, is incorporated in a converter. This causes the generation of an enormous amount of slag, for example, from 100 to 130 kg per ton of molten steel, which, in turn, brings about the following problems.

1. Due to the large amount of slag generated in a converter, the slopping phenomena during the blowing period is promoted and thus the recovery of iron is decreased. When one attempts to prevent the slopping phenomena, it is necessary to install an excessively large free-board, with the result that not only the weight of the converter vessel and amounts of refractories used are increased, but also the time required for the construction and repairing of converter vessel is increased. As a result, low productivity occurs.

2. Iron oxide in the slag is increased proportionally to the amount of slag generated, and, therefore, the recovery of iron is decreased.

3. In accordance with the increase in the amount of slag generated, heat lost as the sensible heat of slag is increased and, thus, the thermal efficiency of the steel-making refining process is decreased, which, in turn, leads to an unavoidable decrease in the ratio of scraps to be loaded to the molten pig iron.

In order to eliminate the above-mentioned problems, it is possible to pretreat molten pig iron before the converter refining so that various impurities are removed from the pig iron. Two pretreatments have been mainly developed regarding the removal of sulfur and phosphorus from the molten pig iron before it is put into the converter, so that it is not necessary to carry out these processes in the converter. The desulfurization and dephosphorization, which have been conventionally achieved in a converter, are therefore replaced by the desulfurization and dephosphorization during the pretreatment of the molten pig iron, according to recently developed steelmaking methods. In a case when the desiliconization, which has been conventionally achieved in a converter, is replaced with the desiliconization by pretreatment, it is possible to considerably decrease the amount of a slag forming agent put into the converter and, thus, the amount of the slag generated in the converter is also considerably decreased, thereby further removing the problems mentioned above.

In the most advanced multi-step steelmaking refining method at present, the steps of desiliconization, dephosphorization and decarburization are successively carried out. Desulfurization can be carried out at any time of the steelmaking refining method. For example, desulfurization can be carried out either once or twice simultaneously with the dephosphorization step, between the desiliconization and dephosphorization steps, or after the decarburization step. Even in this most advanced multi-step steelmaking refining method however, decarburization is accomplished in a conventional converter after the pretreatment of the molten pig iron for removing silicon, and phosphorus and occasionally sulfur in a ladle or torpedo car has been completed. In this case, since reloading of the melt is necessary at the time the molten pig iron is loaded into a converter and tapped from the converter, such problems as generation of dust at the reloading and lowering in the temperature due to reloading are caused, which, in turn, causes a decrease in the thermal efficiency.

In addition, a problem occurs during decarburization in a conventional converter according to the multi-step steelmaking refining method, since the amount of slag generated in the converter is drastically smaller than the slag generated during the conventional steelmaking refining method, so that when the molten pig iron, which is virtually uncovered, is subjected to the decarburization blowing, it is likely to eject upwards due to the oxygen jet. In the multistep steelmaking refining method, such oxygen-blowing as that employed for the conventional converter would result in a rather violent spitting and reduction in recovery of iron. To overcome the spitting during the decarburization step in a multi-step steelmaking refining method comprising a desiliconization step, desulfurization and dephosphorization and a step to decarburize the molten iron whose silicon, sulfur and phosphorus contents have been reduced and it is known from FR—A—2 439 821 to blow the gaseous oxygen softly onto the surface of the bath, while simultaneously a gas is blowing into the reaction vessel from the bottom in order to stir the bath of molten iron vigorously. The soft blowing can be performed by a single or a multi-aperture lance.

It is an object of the present invention to provide a multi-step steelmaking refining method, in which decarburization is carried out without causing the disadvantages in the prior art and which leads to an increase in recovery of steel.

The object of the present invention is achieved by a multi-step steelmaking refining method comprising refining steps, beginning when the molten pig iron is tapped from the blast furnace and ending when the molten steel is cast, carried out in a single reaction vessel, wherein the decarburization of molten pig iron, which has been desiliconized and dephosphorized, is carried out in the reaction vessel by means of oxygen which is softblown onto the surface of the molten pig iron by a multi-aperature lance or a plurality of lances, while a stirring fluid is blown beneath the level of the molten pig iron within said reaction vessel during step decarburization treatment, characterized by the combination of blowing with said lance or lances and stirring with a power of not less than 400 watts per ton in terms of the equation $(\varepsilon)=0.0285\ (Q\cdot T/W)\ \log\ (1+H/148)$, wherein:

Q is the flow rate of the stirring fluid in l/min,

T is the temperature of the melt in K,

W is the weight of the melt in tons, and

H is the depth of the stirring fluid blown in cm.

For the decarburization of the desiliconized and dephosphorized pig iron, no slag-forming agent is necessary, as a rule, in a reaction vessel, such as a ladle, and therefore it is possible to overcome the problems arising in the conventional converter steelmaking method.

In other words, the molten pig iron, which is the starting material of the decarburization treatment, is a pretreated molten pig iron which has been desiliconized and dephosphorized and, occasionally, has also been desulfurized to a predetermined level. The molten pig iron subjected to the pretreatment mentioned above has a silicon content of usually not less than 0.20%, and desirably only a trace, and also has a phosphorus content not exceeding the value specified regarding the finished steel. The present invention is not limited to a specific pretreatment method, and any known pretreatment method can be carried out. In addition, any known treatment of decarburization steel may be carried out in the multi-step steelmaking refining method of the present invention. This treatment, which is carried out after the decarburization treatment, is hereinafter referred to as a post treatment. Regarding sulfur, the sulfur content can be decreased to a value lower than the value specified for the finished steel by means of the following methods, which are selected depending upon the specific purpose of the steel. That is, the molten pig iron can be subjected to a desulfurization pretreatment, a desulfurization post treatment, or a combination of the desulfurization-pretreatment and post treatment, which combination is employed for producing high grade steels required to have a low sulfur content.

As described hereinabove, spitting is likely to occur when decarburization blowing is carried out when no slag, or only a small amount of slag, is present on the surface of the melt. The so-called soft blow, in which oxygen is calmly blown and transmitted to the surface of the melt, effectively suppresses spitting. Incidentally, since, in the method of the present invention, only decarburization is carried out while on a melt slag is essentially absent, direct contact of the oxygen with the molten pig iron is easy. Therefore, in an embodiment of the present invention, oxygen top blowing is carried out by a super soft blow, which cannot achieve effective decarburization in the conventional converter steelmaking method. It is also possible to drastically suppress spitting, while the decarburization reaction is effectively promoted, due to the stirring explained in detail hereinbelow.

According to the invention decarburizing is accomplished in a short period of time in carrying out oxygen top blowing by means of a multi-aperture lance and/or a plurality of lances, thereby dispersing the oxygen jet on the surface of the melt and thus decreasing the depth of the cavity formed by the oxygen jet (L) of the oxygen jet into the melt. Thus oxygen is supplied to the melt at a high rate and the advantages of the super soft blow are maintained.

In the conventional converter steelmaking method, the oxygen jet is required to have both a function of supplying oxygen to cause the refining reactions and a function of stirring the melt so as to enhance the reaction efficiency. The oxygen jet of the conventional converter steelmaking method, therefore, involves a problem in that the stirring function, which should enhance and promote the reaction, leads instead to spitting. In order to avoid such a problem, the two functions of the oxygen jet, mentioned above, are distinctly divided so that the top blowing oxygen jet is provided only to supply the oxygen and a stirring fluid is employed only to stir the melt. More specifically, the super soft blow is so inadequate for stirring molten pig iron that a large iron oxide layer tends to form on the surface of the melt, and, further, the ratio of supplied oxygen combining with the carbon during decarburization, which is referred to as the decarburization reaction ratio, is decreased. In order to maintaining the advantages of the super soft blow and simultaneously eliminate the disadvantages due to the absence of the stirring function, it is necessary to employ a stirring method apart from the top blowing of the oxygen. This is achieved by introducing a stirring fluid beneath the level of the molten pig iron in a reaction vessel.

In an embodiment of the present invention, the stirring fluid is blown through one or more immersion lances.

In an embodiment of the present invention, the stirring fluid is blown through one or more of tuyeres or gas-permeable plugs situated in the reaction vessel beneath the level of the molten pig iron.

The blowing rate of the stirring fluid must be such that a stirring state, in terms of stirring power, of at least 400 watt/ton, preferably at least 800 watt/ton, be ensured. The stirring power is calculated by the following equation

$$\dot{\varepsilon}=0.0285\ (Q\cdot T/W)\log(1+H/148),$$

wherein:

Q is the flow rate of the stirring fluid in l/min;
T is temperature of the melt in K;
W is the weight of the melt in tons; and,
H is the depth the stirring fluid is blown in cm.

It is not necessary to maintain a stirring power of at least 400 watt/ton over the entire decarburization blowing period, but it is necessary to do so at least during the initial or early stage.

The decarburization blowing, in which spitting is drastically suppressed due to the super soft blow, is advantageously achieved in the present invention, and, therefore, a considerably greater amount of molten pig iron can be loaded in a converter than that able to be loaded in a conventional converter refining method.

In an embodiment of the present invention, the reaction vessel mentioned above is a ladle for molten pig iron, which may be provided with a means for blowing the stirring fluid, and this ladle contains the molten pig iron in a filling ratio which is of a usual value. The usual amount of molten pig iron loaded in a pig iron ladle, for example from 60 to 80% based on the volume of the pig iron ladle, is considerably higher than the usual amount of molten pig iron loaded in a converter according to a conventional decarburization blowing method. Although the decarburization blowing method according to said embodiment is carried out under a high loading condition, the decarburization blowing can be carried out effectively without causing a decrease in the recovery of iron. It is therefore unnecessary according to the decarburization blowing method of the present invention, to use such an excessively large apparatus as a converter, since the steelmaking refining steps can be effectively carried out in a compact apparatus or apparatuses.

By using the single reaction vessel mentioned above, the steps starting at receiving the molten pig iron from a blast furnace and ending at the casting of the molten steel can be carried out. These steps may include successively the desiliconization step, the dephosphorization or simultaneous dephosphorization and desulfurization step, and the decarburization step. In the embodiment now described the reaction vessel, such as a molten pig iron ladle, has both a role of transporting the melt and a role of supplying a place where the refining reactions take place. It is therefore possible to continuously use the reaction vessel from a time when the reaction vessel receives the molten pig iron from the blast furnace until a time when either the continuous casting method or the usual casting method for forming ingots is carried out, without reloading the melt. Between the two times mentioned above, the treatments of desiliconization, dephosphorization, desulfurization and decarburization can be carried out by a multi-step refining method. In a steelmaking plant, in which torpedo cars are installed, the desiliconization step and the dephosphorization, or simultaneous dephosphorization and desulfurization step, can be successively carried out in the torpedo cars, and subsequently, before the initiation of the decarburization step, the molten pig iron is reloaded from the torpedo cars into a reaction vessel, which is a reaction vessel other than the torpedo cars. The decarburization blowing is then carried out in the reaction vessel. If necessary, the desulfurization and adjusting of the steel chemistry can be carried out in this reaction vessel, followed by a casting step. In the multi-step steelmaking refining method by means of torpedo cars and a reaction vessel, the melt must be reloaded once. However, this method is also advantageous, because the decarburization step is carried out according to the present invention.

Methods for decreasing the times of reloading the melt or making the reloading unnecessary are previously known. According to one of these methods, known in Japanese laid-open patent application No. 54-130420, a ladle receives the molten pig iron tapped and this molten pig iron is directly loaded in a converter without reloading of the melt. According to another known method, molten pig iron, which has been desiliconized, dephosphorized and desulfurized in one vessel, is decarburized in a converter. According to another method, known from Japanese laid-open patent application No. 51-27811, refining is continuously carried out in a transportable refining ladle. However, since in the former two methods a converter is necessary in a sequence of the refining steps, two reloading operations are necessary, i.e. at the step of reloading into the converter and at the step of reloading from the converter into a casting ladle. These two methods, therefore, still involve problems in that a large amount of heat is lost and dust is generated during the reloading operations. In addition, since the decarburization blowing of these two methods is a conventional method of decarburization, the recovery of iron is low. In the latter method, although the problems of heat loss and dust generation are solved, various problems resulting from slag, such as a large amount of the slag generated, remain unsolved because the molten pig iron is not pretreated and is subjected to the steelmaking reactions which are basically the same as the conventional ones.

In an embodiment of the present invention, the stirring fluid is at least one member selected from the group consisting of carbon dioxide gas, argon, nitrogen gas and oxygen gas. The nitrogen gas, however, should not be used for producing a grade of steel in which the nitrogen content is required to be very low. Since the oxygen may erode the refractories of the gas-permeable plugs, the cooling of such plugs is advisable.

In an embodiment of the present invention, a removable free board is installed on the reaction vessel at the decarburization period.

Several of the embodiments will now be described more quantitatively or specifically.

In the super soft blowing, a characteristic parameter of the oxygen jet (L/L_o) cannot be more than 0.3, wherein L_o is the depth of a stationary melt within a reaction vessel in mm and L is the depth of the cavity formed by the oxygen jet in mm determined by the following formulae.

$$L = L_h \cdot \exp(-0.78\ h/L_h)$$

and

$$L_h = 63.0(kFo_2/nd)^{2/3}.$$

In these formulae:

L is an infiltration depth of the oxygen jet into the melt in mm;

h is the distance between the lance(s) and the surface of the melt in mm;

Fo_2 is the flow rate of oxygen in Nm^3/h;

n is the number of apertures (nozzles) in each lance;

d is the diameter of each aperture (nozzles) in mm; and

k is the calibration coefficient depending upon the injection angle θ from the lance axis as follows.

In a case when n is 1 ($n=1$), $k=1.0$. In a case when n is 2 or more ($n \geqq 2$), $k=1.7$ at $\theta=0°$, $k=1.4$ at $\theta=6°$, and $k=1.0$ at $\theta=10°$.

In the conventional converter, the depth of a stationary melt within a converter (L_o) is, at the highest, from approximately 0.1 to 0.3 times the effective inner height of the converter (L_t), and, therefore, most of the effective inner height (L_t) of the converter is a so-called free board, where the converter wall does not come in contact with the melt. According to the present invention, in which heavy loading in the decarburization step is achieved, the ratio of L_o/L_t can be 0.6 or more ($L_o/L_t \geqq 0.6$). In this case, the maximum ratio of L_o/L_t is limited, so that height of the melt, which is stirred due to the decarburization blowing, does not exceed the height of the free board. When the maximum height of the stirred melt measured from the level of the stationary one during the decarburization blowing is expressed by L_s, the maximum ratio of L_o/L_t is limited, so that the relationship of $L_o/L_t < 1 - L_s/L_t$ is satisfied. If the heavy loading of present invention is carried out in the conventional converter steelmaking method, problems caused by swelling of the slag, slopping and spitting become serious. Therefore, in the conventional converter, the loading of pig iron is limited, so that the relationship of $L_o/D_o < 0.5$ is satisfied, wherein D_o is the effective inner diameter of the converter. Contrary to this, the decarburization blowing is possible, even in a case when $L_o/D_o \geqq 0.5$. This means that the decarburization treatment capacity of a reaction vessel having a predetermined dimension can be significantly increased, as compared with that in the conventional converter refining method, which is a commercially useful point.

In order to stir the melt, not only gas, but also liquid, such as liquid oxygen and liquid carbon dioxide, as well as mixture of a gas and a liquid can be used as the stirring fluid. The volume expansion at the gasification of the liquid is highly effective for stirring the melt.

As understood from the description hereinabove, the multi-step steelmaking refining method of the present invention comprises a novel decarburization step which does not rely at all on the conventional converter steelmaking method. Since one of the advantages of the present invention resides in a very simplified process starting at the receipt of the molten pig iron from a blast furnace and ending at the pouring and solidification of the steel, the present invention is greatly advantageous to the steelmaking industry.

The preferred embodiments of the present invention will now be described with reference to the following drawings.

Fig. 1 and Fig. 2 schematically illustrate preferred embodiments of the multi-step steel making refining method of the present invention.

Figs. 3 through 5 illustrate reaction vessels in which the decarburization blowing is being carried out.

Fig. 6 is a graph illustrating the relationship between the characteristic parameter of the oxygen jet of (L/L_o) and the decarburization ratio which defines the carbon decarburization reaction ratio, relative to the amount of oxygen supplied. In Fig. 6, the relationship is shown between the characteristic parameter of oxygen jet (L/L_o) and the amount of molten steel scattered out of a reaction vessel due to spitting, etc. In Fig. 6, the ratios of L_o/L_t according to the present invention and the conventional method are 0.7 and 0.2, respectively.

Referring to Figs. 1 and 2, it will be understood that the multi-step refining is carried out in the following sequence:

I—A reaction vessel receives molten pig iron from the blast furnace (BF).

II (Desiliconization Step) The desiliconization is carried out, for example by means of the oxygen injection method.

III (Dephosphorization and/or Desulfurization Step) For example, a method of admixing flux by means of a mechanical stirring method or an oxygen-injection method while incorporating flux is carried out.

IV (Decarburization Step) Decarburization by the super soft blow method is carried out and the melt is stirred by a stirring fluid, which is, for example, blown through an immersion lance.

V (Adjusting Step of Steel Chemistry) For example, RH degassing is carried out.

VI (Casting Step) Finished steel is cast by a continuous casting method.

VII The reaction vessel is hot-repaired and waits the tapping from the blast furnace.

It will be apparent from the above description that one reaction vessel has the roles of transporting, storing, pouring and being the place where the refining reactions take place. In Fig. 1, the stations of refining, casting and the like are arranged linearly, while in Fig. 2 these stations are arranged in a circle.

Referring to Fig. 3, a preferred embodiment of the decarburization blowing is schematically illustrated. In Fig. 1, the reaction vessel is composed of the metal shell 1a and refractory lining 1b and contains therein the melt 2.

The depth of the melt 2 is L_o when the melt is stationary. The reaction vessel has the effective inner height L_t which is shown in Fig. 3. The oxygen is blown through the top blowing lance 3 by a super soft blow. One gas-permeable refractory plug 4 is provided at the bottom of the reaction vessel 1 so as to blow the stirring fluid into the melt 2. The oxygen blown from the top blowing lance 3 makes the cavities onto the melt 2 by a depth of L. The melt 2 is basically molten pig iron, since if the slag forming agent is used, it is used only to the extent that the oxides resultant from the oxygen blowing cannot erode the refractory lining 1b. The symbols of HF and D_o in Fig. 3 denote the height of the freeboard and the effective inner diameter of the reaction vessel. If necessary, a plurality of the top blowing lances 3 and a plurality of the gas-permeable refractory plugs may be used.

Referring to Fig. 4, three top blowing lances 3 are used for blowing the oxygen and the bottom of reaction vessel 1 is provided with two blowing tuyeres 5 instead of the gas-permeable refractory plug 4 for blowing the stirring fluid. Referring to Fig. 5, two top blowing lances 3 are used for oxygen blowing and the stirring fluid is blown through the immersion lance 6. A removable side wall, i.e. free board 7, is installed on the reaction vessel, so as to form an inner space 8 defined by the inner wall of the free board 7 and thus spitting of melt 2 out of the inner space 8 is prevented.

Referring to Fig. 6, the present invention and conventional methods having different ratios of L_o/L_t different from one another are compared with one another regarding the amount of melt scattered out of the reaction vessel and the variation of the decarburization reaction ratio vary depending upon the characteristic parameter of oxygen jet (L/L_o). In Fig. 6, the ratios of L_o/L_t of the present invention and conventional methods are 0.7 and 0.2, respectively. In case of the conventional converter, the characteristic parameter of oxygen jet (L/L_o) is usually set between 0.7 and 1.0. As is apparent from Fig. 6 the super soft blow of present invention in terms of characteristic parameter of oxygen jet (L/L_o) is not more than 0.3, which is the preferable maximum value for keeping the recovery of iron, and the decarburization reaction in the conventional converter steelmaking method virtually does not take place. More specifically, the term "super soft blow" can be explained by the concept that the decarburization reaction ratio is virtually zero when the melt is not subjected to stirring by the stirring fluid blown into the melt.

As is also apparent from the lower half of Fig. 6, the decarburization reaction ratio is at the ideal level. This is because the oxygen is brought into a direct contact with the melt and the stirring mentioned above is carried out.

The present invention will now be explained by way of Examples.

Example 1

Table 1 shows the average steel chemistry of six heats, when the multi-step steelmaking method comprising the desiliconization, simultaneous dephosphorization and desulfurization, and decarburization steps were carried out. Each heat consisted of 60 ton of molten pig iron and 6 ton of scraps. An increase in the phosphorus content after the decarburization step is not considered to be the result of rephosphorization. The recovery of iron and the amount of slag generated are shown in Table 2.

TABLE 1

Steps	C%	Si%	Mn%	P%	S%	Remarks
Tapping from blast furnace	4.34	0.35	0.47	0.079	0.030	—
After desiliconization	4.20	0.10	0.25	0.079	0.031	Scraps 10% Scale 10 kg/t O_2: 5 Nm^3/t
After dephosphorization and desulfurization	4.00	tr	0.22	0.015	0.015	CaO: 15 kg/t O_2: 2 Nm^3/t Iron ore 25 kg/t
After decarburization	0.60	tr	0.22	0.017	0.015	Three lances CaO: 5 kg/t O_2: 40 Nm^3/t One immersion lance Ar: 1.5 Nm^3/min Stirring power 456 watt/t
After adjusting the steel chemistry	0.62	0.20	0.60	0.017	0.015	RH Degassing Fe—Mn: 5.6 kg/t Fe—Si: 3.0 kg/t

TABLE 2

	Conventional (A)	Invention (B)	Difference (B–A)
Recovery of iron (molten steel)	94.6%	96.3%	+1.7%
Amount of slag generated	100 kg/t	60 kg/t	−40 kg/t

The term "Conventional (A)" in Table 2 indicates a conventional converter steelmaking method.

Example 2

The procedure of Example 1 was repeated except for the decarburization step as is apparent from Table 3. The recovery of iron by the present invention is considerably higher than that of the comparative tests.

TABLE 3

	Test	Number of top-blowing lance(s)	Means for blowing stirring fluid	Stirring fluid	O_2 Amount per ton of steel (Nm^3/T)	Flow rate or stirring fluid (Nm^3/min)	Stirring power (watt/t)	Recovery of steel (molten steel) (%)
Invention	1	3	One immersion lance	Ar gas	40.3	1.4	425	96.1
	2	3	do	do	40.0	2.0	607	96.5
	3	3	Three plugs (bottom blowing)	do	39.7	3.5	1062	96.7
	4	2	do	do	41.2	2.7	820	96.3
	5	2	One immersion lance	CO_2 gas	40.5	0.9	410	96.1
	6	5	do	Ar gas	41.1	2.0	607	96.2
Comparative Example	7	3	One immersion lance	Ar gas	40.8	0.7	213	94.9
	8	3	none	none	42.5	0	0	94.0
	9	1	One immersion lance	Ar gas	43.0	1.5	456	94.8
	10	1	do	do	41.5	0.6	182	94.6
	11	1	none	none	42.0	0	0	94.5

Example 3

In the present example, the multi-step refining method comprised the desiliconization, dephosphorization, decarburization and desulfurization steps. The resultant steel chemistry and refining condition in each step are shown in Table 4, and the recovery of iron and amount of slag generated are shown in Table 5.

TABLE 4

Steps	C%	Si%	Mn%	P%	S%	Remarks	
Tapping from blast furnace	4.34	0.35	0.47	0.079	0.030	—	
After desiliconization	4.20	0.10	0.25	0.079	0.031	Scraps 10% Scale 10 kg/t	O_2: 5 Nm^3/t
After dephosphorization	4.00	tr	0.22	0.015	0.017	CaO: 12 kg/t $CaCl_2$: 1.5 kg/t	Iron oxide 20 kg/t O_2: 2 Nm^3/t
After decarburization	0.60	tr	0.22	0.015	0.017	Three lances CaO: 5 kg/t O_2: 40 Nm^3/t	One immersion lance Ar: 1.5 Nm^3/min 456 watt/t
After desulfurization	0.60	tr	0.22	0.015	0.008	CaO: 5.0 kg/t Ar: 1.4 Nm^3/t	CaO Powder injection
After adjusting the steel chemistry	0.62	0.20	0.60	0.015	0.008	RH Degassing	Fe—Mn 5.6 kg/t Fe—Si 3.0 kg/t

TABLE 5

	Conventional (A)	Invention (B)	Difference (B–A)
Recovery of iron (molten steel)	94.6%	96.5%	+1.9%
Amount of slag generated	100 kg/t	60 kg/t	−40 kg/t

Example 4

The procedure of Example 3 was repeated except for the decarburization step as apparent from Table 6.

TABLE 6

	Test No.	Number of top blowing lance(s)	Means for blowing stirring fluid	Stirring fluid	O_2 Amount per ton of steel (Nm^3/T)	Flow rate or stirring fluid (Nm^3/min)	Stirring power (watt/t)	Recovery of iron (molten steel) (%)
Invention	12	3	One immersion lance	N_2 gas	40.8	2.5	760	96.3
	13	2	One plug (bottom blowing)	O_2 gas	39.3	2.3	1047	96.6
	14	3	Three plugs (bottom blowing)	$Ar+O_2$ =4:1	40.1	1.5	501	96.2

Example 5

In the present example shown in Table 7 "Invention" indicates the decarburization blowing of the desiliconized, dephosphorized and desulfurized molten pig iron which was loaded in a reaction vessel at the ratio of L_o/L_t=0.7. In addition "Conventional" indicates a conventional converter refining of molten pig iron which was loaded in the converter at the ratio of L_o/L_t=0.2. In the method of the present invention, the amount of slag generated is very small because no auxiliary raw materials are used at all, and the recovery of iron is high.

TABLE 7

	Invention					Conventional				
L_o/L_t	0.7					0.2				
L/L_o	0.2					0.8				
Oxygen flow rate	120 $Nm^3/hr \cdot t$					130 $Nm^3/Hr \cdot t$				
Flow rate of Ar for stirring	0.19 $Nm^3/min \cdot t$					—				
Number of (oxygen) top blowing lance	3					1				
(CaO)	—					50.4 kg/t				
Auxiliary raw materials (CaF_2)	—					3.9 kg/t				
Amount of slag generated	5 kg/t					120 kg/t				
Steel chemistry (%)	C	Si	Mn	P	S	C	Si	Mn	P	S
Pig iron chemistry	3.78	tr	0.25	0.020	0.015	4.50	0.43	0.29	0.079	0.022
Analysis at the end of decarburization blowing	0.08	tr	0.16	0.020	0.015	0.08	tr	0.16	0.021	0.015
Temperature at the end of decarburization blowing	1640°C					1635°C				
Recovery of iron (molten steel)	97.1%					95.3%				

Example 6

In the present example shown in Table 8, "Invention" and "Conventional" indicate the decarburization blowing method, in which the liquid oxygen was blown as the stirring gas, and the decarburization blowing method, in which no stirring gas was blown, respectively.

TABLE 8

	Invention					Conventional				
Top blowing lance(s)	Three lances (multi-lances)					Single lance with apertures (nozzles)				
Oxygen-flow rate	46 Nm³/t					49 Nm³/t				
Flow rate of liquid oxygen through a single immersion lance	1.4 l/min					—				
L/L_o	0.15					0.88				
Time of refining period of time	18 minutes					20 minutes				
Amount of molten pig iron	60 t					60 t				
Amount of scraps	6 t					6 t				
Recovery of iron (molten steel)	97%					95%				
	C	Si	Mn	P	S	C	Si	Mn	P	S
Molten-steel chemistry	0.31	0.15	0.62	0.015	0.015	0.32	0.16	0.62	0.017	0.015

As will be understood from the description hereinabove, especially the Examples, an excessively large apparatus, such as a converter, is no longer necessary in refining pig iron and an increase in the recovery of iron can be achieved, according to the present invention. Since reloading of the melt is no longer necessary or if necessary, reloading is limited to only one or possibly two times, the generation of dust is decreased and thermal efficiency is increased. Since the amount of slag generated in accordance with the method of the present invention is considerably smaller that generated in the conventional converter steelmaking method, the slag processing apparatus can be very compact.

Furthermore, the free oxygen content of the steel at the end of the oxygen blowing process is lower as compared with that the conventional steelmaking method, which contributes to the recovery of alloying elements, as well as to the recovery of iron.

Claims

1. A multi-step steelmaking refining method comprising refining steps, beginning when the molten pig iron is tapped from the blast furnace and ending when the molten steel is cast, carried out in a single reaction vessel, wherein the decarburization of molten pig iron, which has been desiliconized and desphosphorized, is carried out in the reaction vessel by means of oxygen which is softblown onto the surface of the molten pig iron by a multi-aperture lance or a plurality of lances, while a stirring fluid is blown beneath the level of the molten pig iron within said reaction vessel during the decarburization treatment, characterized by the combination of blowing with said lance or lances and stirring with a power (ε) of not less than 400 watts per ton in terms of the equation $(\varepsilon)=0.0285\ (Q \cdot T/W) \log (1+H/148)$, wherein:
Q is the flow rate of the stirring fluid in l/min
T is the temperature of the melt in K,
W is the weight of the melt in tons, and H is the depth of the stirring fluid blown in cm.

2. A method according to claim 1, wherein said stirring fluid is blown through one or more immersion lances (6).

3. A method according to claim 1, wherein said stirring fluid is blown through one or more of tuyeres or gas-permeable plugs (5) situated in said reaction vessel (1) beneath the level of the molten pig iron (2).

4. A method according to any one of claims 1 through 3, wherein the characteristic parameter of oxygen jet (L/L_o) is not more than 0.3, wherein L_o is the depth of a stationary melt within said reaction vessel in mm and L is a depth of cavity formed by the oxygen jet in mm.

5. A method according to any one of claims 1 through 3, wherein the depth of a stationary melt within a converter (L_o) is, at the lowest, 0.6 times the effective inner height of the converter (L_t).

6. A method according to any one of claims 1 through 3, wherein the relationship of $L_o/D_o \geqq 0.5$ is satisfied, wherein D_o is the effective inner diameter of said reaction vessel.

7. A method according to claim 1, wherein said stirring power is not less than 800 watt/ton.

Patentansprüche

1. Feinungsperiode bei einem mehrstufigen Stahlerzeugungsverfahren, welches die Feinungsschritte umfaßt, beginnend, wenn das geschmolzene Roheisen von dem Hochofen abgestochen wird, und endend, wenn die Stahlschmelze gegossen ist, ausgeführt in einem einfachen Reaktionsgefäß, wobei die Entkohlung des geschmolzenen Roheisens, das endsiliciert und endphosphorisiert wurde, in dem Reaktionsgefäß mittels Sauerstoff durchgeführt wird, der weich auf die Oberfläche des geschmolzenen Roheisens durch eine Lanze mit vielen Öffnungen oder durch eine Vielzahl von Lanzen geblasen wird, während eine Rührflüssigkeit unter die Oberfläche des geschmolzenen Roheisens innerhalb des Reaktionsgefäßes während der Entkohlungsbehandlung geblasen wird, gekennzeichnet durch die Kombination des Blasens mit der Lanze oder den Lanzen und des Rührens mit einer Kraft (ε) von nicht weniger als 400 Watt/Tonne nach der Gleichung $(\varepsilon)=0.0285\ (Q \cdot T/W) \log (1+H/148)$, worin
Q die Fließgeschwindigkeit der Rührflüssigkeit in Liter/Minute,
T die Temperatur der Schmelze in °K,
W das Gewicht der Schmelze in Tonnen und
H die Tiefe der geblasenen Rührflüssigkeit in cm ist.

2. Verfahren nach Anspruch 1, worin die Rührflüssigkeit durch eine oder mehrere Eintauchlanzen (6) geblasen wird.

3. Verfahren nach Anspruch 1, worin die Rührflüssigkeit durch eine oder mehrere Düsen oder gasdurchlässige Stopfen (5) geblasen wird, die in dem Reaktionsgefäß (1) unter der Oberfläche des geschmolzenen Roheisens (2) angeordnet sind.

4. Verfahren nach einem der Ansprüche 1 bis 3, worin der charakteristische Parameter der Sauerstoffdüse (L/L_o) nicht mehr als 0,3 beträgt, wobei L_o die Tiefe einer feststehenden Schmelze innerhalb des Reaktionsgefäßes in mm und L die Tiefe des durch die Sauerstoffdüse geformten Hohlraums in mm ist.

5. Verfahren nach einem der Ansprüche 1 bis 3, worin die Tiefe einer feststehenden Schmelze innerhalb eines Konverters (L_o) beim kleinsten Wert das 0,6-fache der effektiven inneren Höhe des Konverters (L_t) beträgt.

6. Verfahren nach einem der Ansprüche 1 bis 3, worin das Verhältnis von $L_o/D_o \geqq 0{,}5$ erfüllt ist, wobei D_o der effektive innere Durchmesser des Reaktionsgefäßes ist.

7. Verfahren nach Anspruch 1, worin die Rührkraft nicht weniger als 800 Watt/Tonne beträgt.

Revendications

1. Méthode d'affinage dans un procédé multi-étapes d'élaboration d'acier, comprenant des étapes d'affinage, commençant lorsque la fonte liquide est déversée du haut fourneau et se terminant lorsque l'acier fondu est coulé, effectuée dans une seule cuve à réaction, où la décarburation de la fonte liquide qui a été désiliciée et déphosphorée est effectuée dans la cuve à réaction au moyen de l'oxygène envoyé doucement à la surface de la fonte liquide à l'aide d'une lance à ouvertures multiples ou d'un ensemble de lances, tandis qu'un fluide agitateur est injecté en-dessous de la surface de la fonte liquide à l'intérieur de la cuve à réaction pendant le traitement de décarburation, méthode caractérisée par la combinaison de l'injection par la ou les lances et de l'agitation avec une puissance (ε) inférieure à 400 watts par tonne, conformément à l'équation:

$$(\varepsilon)=0{,}0285\ (Q\cdot T/W)\ \log\ (1+H/148)$$

dans laquelle

Q est le débit du liquide agitateur en l/min,

T est la température de la masse fondue en K,

W est le poids de la masse fondue en tonnes, et H est la profondeur du fluide agitateur injecté, en cm.

2. Méthode selon la revendication 1, caractérisée en ce que le fluide agitateur est injecté à travers une ou plusieurs lacnes immergées (6).

3. Méthode selon la revendication 1, caractérisée en ce que le fluide agitateur est injecté à travers une ou plusieurs tuyères ou embouts perméables aux gaz (5) situés dans la cuve à réaction (1) en-dessous du niveau de la fonte liquide (2).

4. Méthode selon l'une des revendications 1 à 3, caractérisée en ce que la paramètre caractéristique du jet d'oxygène (L/L_o) n'est pas plus grande que 0,3, L_o étant la profondeur de la masse fondue stationnaire dans la cuve à réaction, exprimée en mm, et L est la profondeur des cavités formées par le jet d'oxygène, exprimée en mm.

5. Méthode selon l'une des revendications 1 à 3, caractérisée en ce que la profondeur de la masse fondue stationnaire à l'intérieur d'un convertisseur (L_o), est au minimum 0,6 fois la hauteur intérieure utile du convertisseur (L_t).

6. Méthode selon l'une des revendications 1 à 3, caractérisée en ce que la relation $L_o/D_o \geqslant 0{,}5$ est satisfaite, D_o étant le diamètre intérieur utile de la cuve à réaction.

7. Méthode selon la revendication 1, caractérisée en ce que la puissance d'agitation n'est pas inférieure à 800 watts/tonne.

Fig. 1

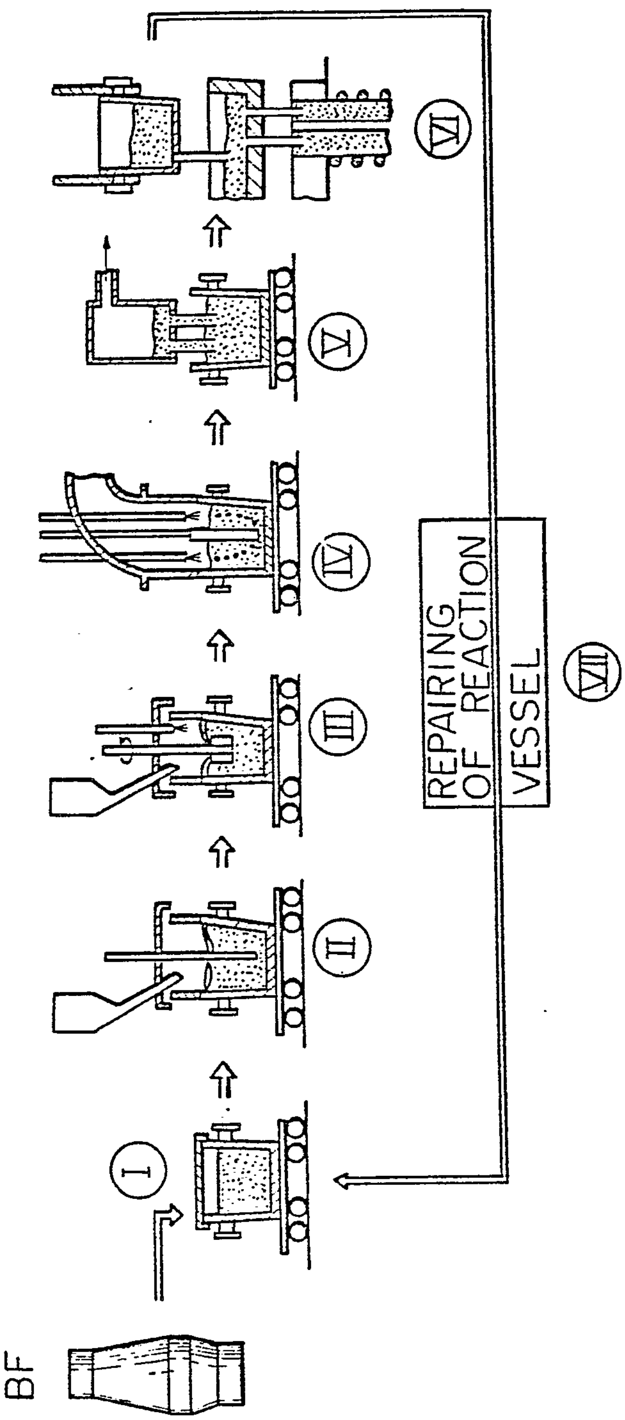


Fig. 2

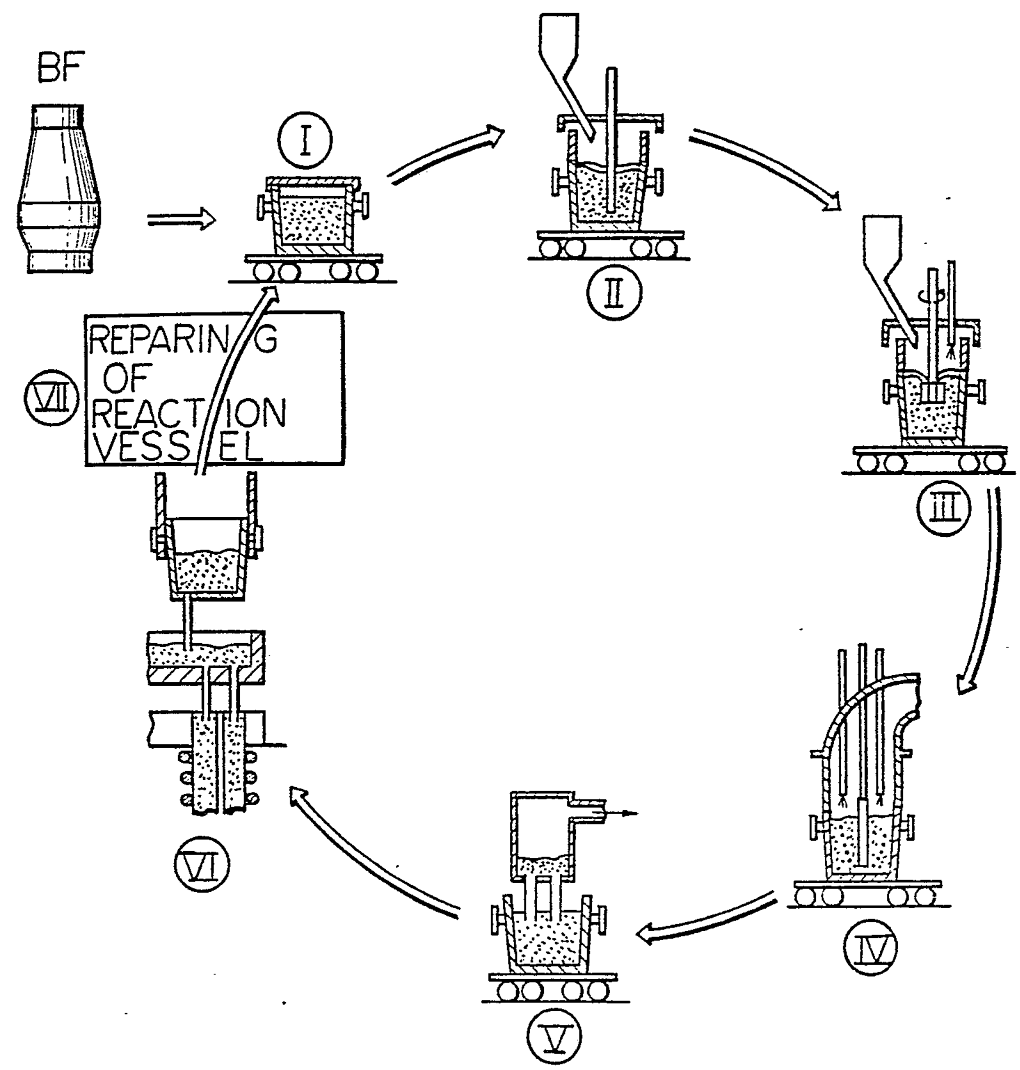


Fig. 3

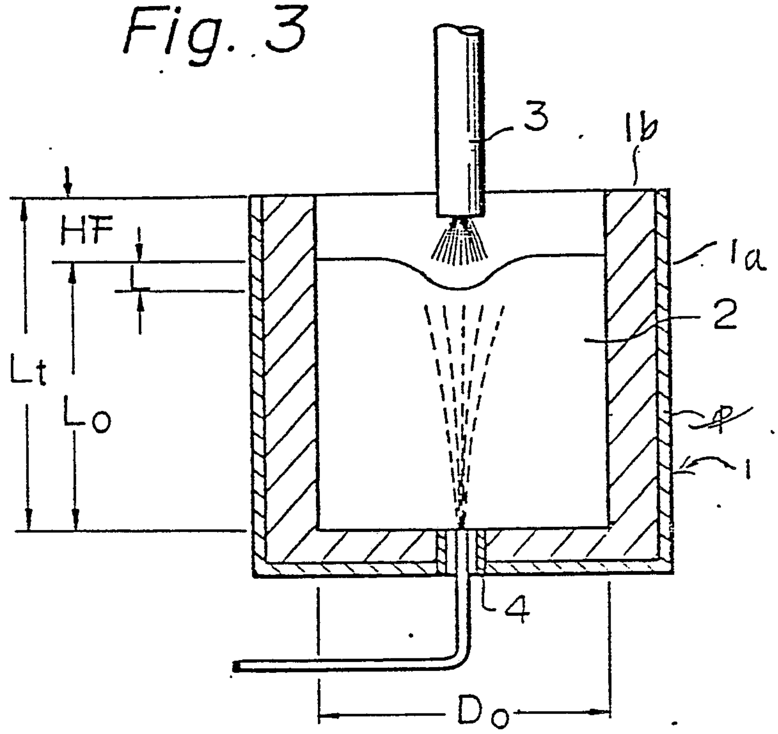


Fig. 4

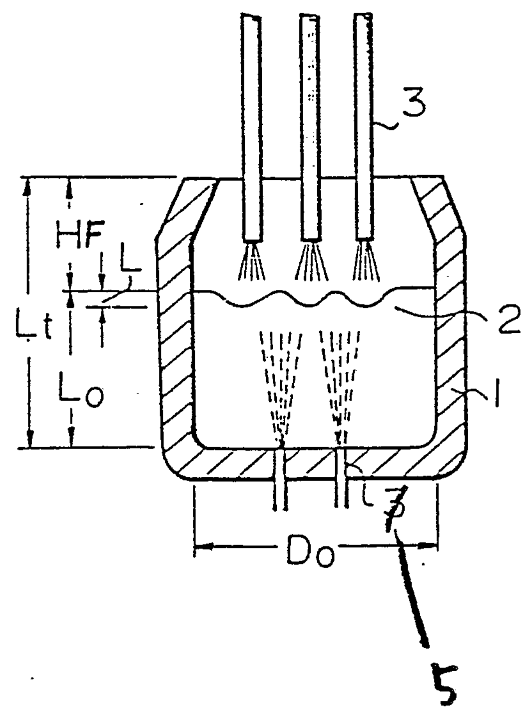


Fig. 5

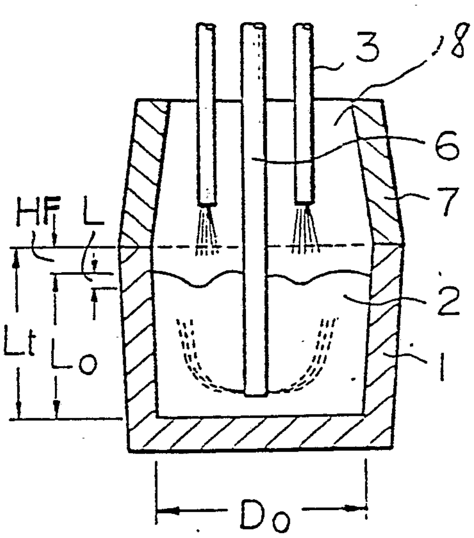
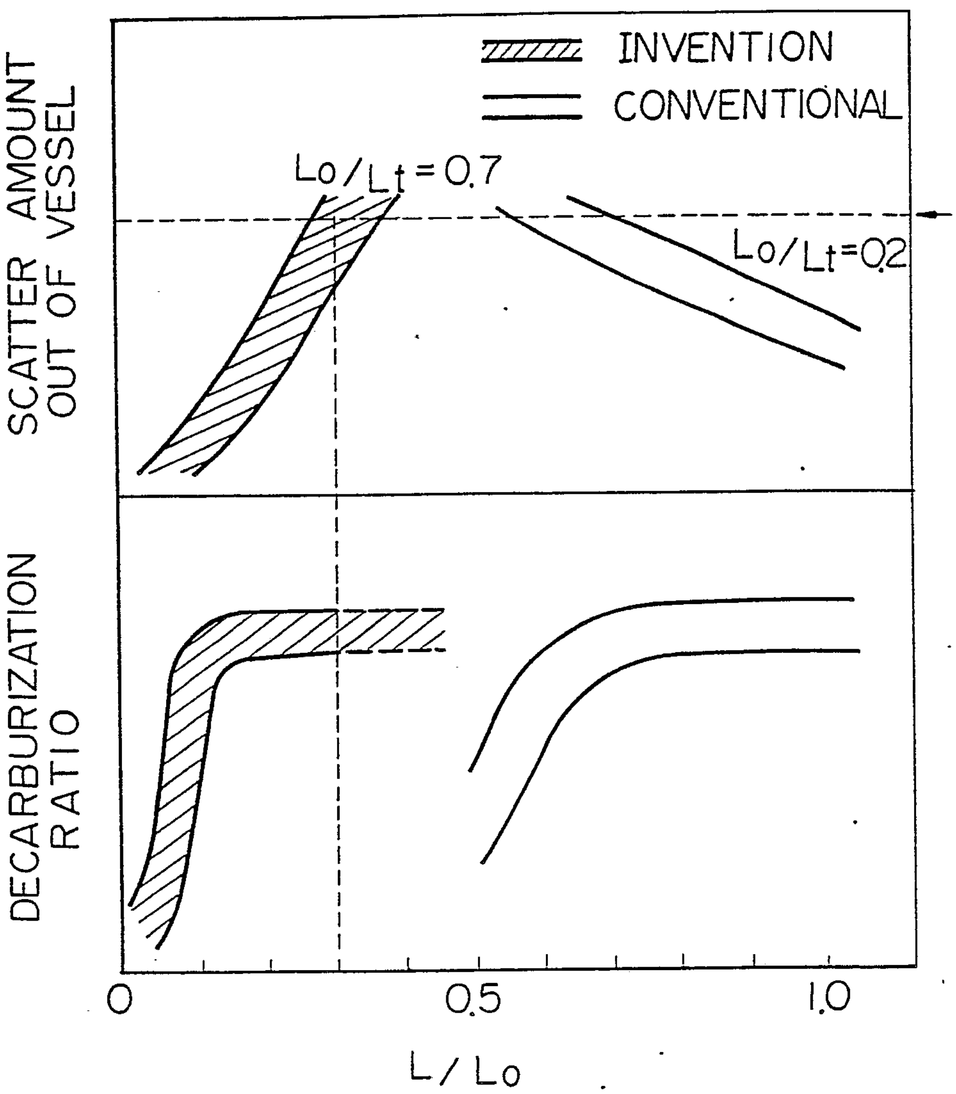


Fig. 6


INVENTION
CONVENTIONAL
Lo/Lt=0.7
Lo/Lt=0.2
SCATTER AMOUNT
OUT OF VESSEL
DECARBURIZATION
RATIO
0
0.5
1.0
L/Lo