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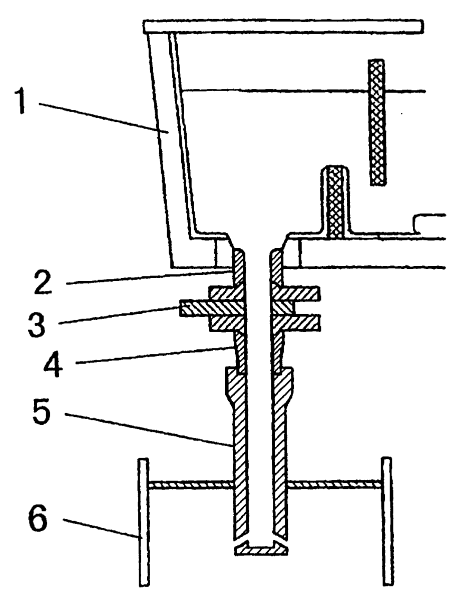
(54) NOZZLE FOR CONTINUOUS CASTING OF ALUMINUM KILLED STEEL AND CONTINUOUS CASTING METHOD

(57) The present invention provides a technique of applying a CaO-containing material to a nozzle unit for casting of aluminum-killed steel, in such a manner that the amount of large-size alumina inclusions in slabs can be reduced irrespective of nozzle type, such as single-part type or multi-part type. The amount of large-size alumina inclusions in slabs obtained using a single-part type or multi-part type nozzle unit, which has an inner hole to be used for pouring molten steel from a tundish to a mold therethrough and CaO-containing refractories applied to a surface of the inner hole, has a strong correlation with the entire surface area of the inner hole of the nozzle unit and the amount of CaO contained in the employed refractories. According to the present invention, 50% or more of the entire surface area of the inner hole of the nozzle unit is formed of refractories containing 20 mass % or more of CaO to allow the amount of large-size alumina inclusions to be reduced.

FIG. 1



EP 1 504 831 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a nozzle unit for continuous casting of aluminum-killed steel, and the use of the nozzle unit.

BACKGROUND ART

[0002] In a process for casting of aluminum-killed steel, alumina inclusions are attached to the surface of an inner hole of a nozzle unit for use in casting (hereinafter referred to as "nozzle unit" for brevity), and agglomerated to form a large-size alumina particles. The agglomerated alumina particles are mixed in the molten steel flow, and incorporated into slabs as large-size inclusions to cause defect or deteriorated quality in the slabs.

[0003] In particular, as to aluminum-killed steel which is molded as high-grade steel, such as thin sheets, it has been recently required to strictly control the quality of steel products. To meet this requirement, a good deal of effort has been made to prevent alumina from being attached onto the surface of an inner hole of a nozzle unit for use in pouring molten steel from a tundish (hereinafter referred to as "TD") into a mold in a continuous casting process.

[0004] As one of measures against the attachment of alumina, there has been known a method comprising injecting argon gas from the inner surface of a nozzle unit into molten steel to physically prevent the attachment of alumina. In this method, if the argon gas is injected at an excessive amount, bubbles of the injected argon gas will be incorporated into molten steel to form pinholes in slabs or cause defect thereof. Thus, due to the restriction in the allowable injection amount of argon gas, this method cannot be exactly used as a sufficient measure for preventing the attachment of alumina.

[0005] As another measure, there has also been known a method intended to provide a function of preventing the attachment of alumina, to a refractory material itself constituting a nozzle unit. This method is directed to prepare a refractory brick containing CaO and induce the reaction between the CaO and alumina attached onto the brick to form a low-melting-point compound so as to prevent the attachment of alumina from further increasing. For example, Japanese Patent Publication No. 61-44836 discloses a casting nozzle unit using refractories which comprise a primary component consisting of a combination of graphite, and sintered or fused calcia or another ceramic engineering material containing a CaO component.

[0006] Generally, a nozzle unit for use in pouring molten steel from a TD to a mold during casting of steel includes a multi-part type nozzle unit constructed by combining a plurality of segmental nozzles as shown in FIG. 1, and a single-part type nozzle unit consisting of only a single-piece nozzle as shown in FIG. 2.

[0007] The multi-part type nozzle unit is constructed by combining an upper nozzle 2 which is attached to an opening formed in the bottom wall of a tundish 1, a sliding nozzle 3, a lower nozzle 4, and a submerged or immersion nozzle 5 immersed in a mold 6. The flow rate of molten steel to the mold 6 is controlled by adjusting the opening area of the sliding nozzle 3. The multi-part type nozzle unit has an excellent flow-rate control function, and can stably maintain the level of molten steel. Thus, the multi-part type nozzle unit is widely used in view of stable casting performance under constant conditions and excellent safety.

[0008] The single-part type nozzle unit is comprised of a single elongated immersion nozzle defining a flow path which extends from the bottom opening of the tundish 1 to the mold 6. The flow rate of molten steel to the mold 6 is controlled by adjusting the area of the bottom opening of the tundish 1 using a long stopper 7 disposed in the tundish 1.

[0009] In experimental tests using the above two types of nozzle units each of which has an inner hole whose surface is formed of the aforementioned material containing CaO, the single-part type nozzle unit as shown in FIG. 2 actually exhibited an effect of reducing the attachment of alumina to the inner hole surface thereof and reducing large-side alumina inclusions. On the other hand, it was proven that when the CaO-containing material is applied to only a part of the segmental nozzles of the multi-part type nozzle unit as shown in FIG. 1, large-size alumina inclusions in slabs tend to be formed at a larger amount that that in the single-part type nozzle unit.

[0010] In a casting process using the single-part type nozzle unit, molten steel passing through the nozzle unit has substantially no contact with outside air. By contrast, in a casting process using the multi-part type nozzle unit, outside air enters in the inner hole through joints between the segmental nozzles. In particular, outside air inevitably inflows through the joint surface between the sliding nozzle (hereinafter referred to as "SN") and the associated segmental nozzle, because it is difficult to completely seal the joint surface with the SN to be slidingly moved during use.

[0011] The molten steel for aluminuni-killed steel contains aluminum dissolved therein. When the aluminum comes into contact with air, it is oxidized to create alumina. Then, the created alumina becomes incorporated into slabs as alumina inclusions. In the multi-part type nozzle unit composed of the plurality of segmental nozzles, even if the CaO-containing refractories are applied to a part of segmental nozzles, alumina will be attached to the remaining segmental nozzles having no CaO-containing refractories, and then large-sized alumina due to agglomeration will be incorporated into slabs.

DISCLOSURE OF INVENTION

[0012] It is therefore an object of the present invention to provide a nozzle unit for casting of aluminum-killed steel, which employs a CaO-containing material in such a manner that the amount of large-size alumina inclusions in slabs can be reduced irrespective of nozzle type, such as single-part type or multi-part type.

[0013] It is another object of the present invention to provide a method for casting of aluminum-killed steel, capable of significantly reducing the amount of large-size alumina inclusions in slabs to achieve a reduced quality-defect rate.

[0014] Through various research on the amount of large-size aluminum inclusions in slabs obtained using a single-part type or multi-part type nozzle unit which has an inner hole to be used for pouring molten steel from a tundish to a mold therethrough and CaO-containing refractories applied to a surface of the inner hole, it was found that the amount of large-size aluminum inclusions in slabs has a strong correlation with the entire surface area of the inner hole of the nozzle unit and the amount of CaO contained in the employed refractories. Based on this knowledge and obtained specific numerical requirements, the present invention has been accomplished.

[0015] Specifically, according to the present invention, 50 % or more of the entire surface area of an inner hole of a nozzle unit to be used for pouring molten steel from a tundish to a mold is formed of refractories containing 20 mass% or more of CaO.

[0016] In the multi-part type nozzle unit as shown in FIG. 1, even if CaO-containing refractories are applied to a part of the segmental nozzles or to define a portion of the entire surface area of the inner hole, alumina will be attached onto the inner hole surface of the remaining segmental nozzles having no CaO-containing refractories, and large-sized alumina due to agglomeration will be undesirably incorporated into slabs.

[0017] When the refractories containing 20 mass% or more of CaO are applied to the inner hole of the nozzle unit for allowing molten steel to flow down therethrough, in such a manner that the CaO-containing refractories occupy 50 % or more of the entire surface area of the inner hole, the amount of large-size alumina inclusions in obtained slabs is drastically reduced. This effect is derived from a synergistic effect of the actions, of which the CaO-containing refractories act to absorb alumina, a low-melting-point compound created through the reaction between CaO and alumina in the form of a liquid phase acts to smooth the inner hole surface, as well as prevention of the attachment of alumina and prevention of the agglomeration of alumina.

[0018] Such a synergistic effect can be obtained only if the CaO-containing refractories are applied to the surface of the inner hole of the nozzle unit, in such a manner that they occupy 50 % or more of the entire surface area of the inner hole. If the ratio is less than 50 %, the action of reducing the amount of alumina flowing into the mold is deteriorated to provide only an insufficient effect of reducing the amount of large-size alumina inclusions in the slabs. The ratio should preferably be set at 60 % or more. While 100 % of the entire surface area of the inner hole of the nozzle unit may be formed of the CaO-containing refractories, the CaO-containing refractories should be selectively applied to an appropriate region of the nozzle unit in consideration of its use conditions. For example, if a certain region has the risk of causing a problem, such as fusion damage or abrasion, in conjunction with the use of the CaO-containing refractories, suitable conventional refractories for such a region should be used.

[0019] The present invention can be applied to any multi-part type nozzle unit composed of either one of a combination of an upper nozzle and an immersion nozzle, a combination of a SN and an immersion nozzle, a combination of an upper nozzle, a SN and an immersion nozzle, and a combination of an upper nozzle, a SN, an lower nozzle and an immersion nozzle as shown in FIG. 1, and to any single-part type nozzle unit composed of a single-piece immersion nozzle as shown in FIG. 2, in such a manner that the CaO-containing refractories occupy 50 % or more of the entire surface area of the inner hole of the nozzle unit. Further, the present invention can also be applied to a multi-part type nozzle unit in which a SN is integrated with an upper or lower nozzle in a single piece. Even in case where the CaO-containing refractories are applied to only a portion of the surface of the inner hole of the single-part type nozzle unit, if they are applied to occupy or define 50 % or more of the entire surface area of the inner hole of the nozzle unit, the quality of slabs can be significantly improved.

[0020] If the amount of CaO to be contained in the refractories for defining a surface of the inner hole is less than 20 mass%, the refractories have deteriorated abilities of absorbing alumina and preventing the attachment of alumina to provide only an insufficient effect of reducing the amount of large-size alumina inclusions in slabs. Thus, the amount of CaO must be 20 mass% or more.

[0021] While there is no upper limit of the amount of CaO to be contained in the refractories in terms of the effect of reducing the amount of large-size inclusions in slabs, a large amount of CaO is likely to cause the increased risk of fusion damage or wearing. Thus, the upper limit of the amount of CaO should be appropriately adjusted depending on its use conditions. In usual casting conditions, the amount of CaO may be set at about 60 mass% to obtained sufficient effects.

[0022] The refractories may include MgO-CaO based refractories, MgO-CaO-C based refractories, ZrO_2-CaO based refractories, and ZrO_2-CaO-C based refractories. In particular, the MgO-CaO based refractories and MgO-CaO-C based refractories are preferable in view of their excellent ability of absorbing alumina.

[0023] In the single-part type or multi-part type nozzle unit, the CaO-containing refractories are essentially applied to at least a surface of the inner hole to be in contact with molten steel. Any region of the nozzle unit other than the inner hole surface may be made of the same material as that of the inner hole surface, or may be made of any suitable refractories used in a conventional nozzle unit.

BRIEF DESCRIPTION OF DRAWINGS

[0024]

FIG. 1 is a schematic sectional view showing a multi-part type nozzle unit composed of a plurality of segmental nozzles including a SN, which is one example of a nozzle unit to which the present invention is applicable.
FIG. 2 is a schematic sectional view showing a single-part type nozzle unit which is another example of a nozzle unit to which the present invention is applicable.
FIG. 3 is a graph showing the relationship between the ratio of a surface area of an inner hole of a nozzle unit to be defined by CaO-containing refractories to the entire surface area of the inner hole, and large-size alumina inclusions in obtained slabs.
FIG. 4 is a graph showing the relationship between the average amount of CaO in refractories defining a surface area of an inner hole of a nozzle unit, and large-size alumina inclusions in obtained slabs.

BEST MODE FOR CARRYING OUT THE INVENTION

[0025] The present invention will be described in conjunction with one embodiment in which the present invention is applied to the multi-part type nozzle unit as shown in FIG. 1.

Table 1

Material		A	B	C	D
Composition (mass%)	CaO	40	50	-	-
	MgO	30	46	-	-
	Al_2O_3	-	-	70	96
	C	30	4	30	4

[0026] In the above Table 1, the respective compositions of materials applied to the segmental nozzles of the multi-part type nozzle in FIG. 1. Each of the materials A and B in Table 1 is a CaO-containing material according to the present invention, and each of the materials C and D is a comparative example containing no CaO.

[0027] Each of the materials A to D was shaped, burnt and machined to prepare sleeve-shaped refractories having a thickness of 10 mm. The sleeve-shaped refractories were inserted into the respective inner holes of the segmental nozzles, and bonded thereto with mortar to form the segmental nozzles as shown in FIG. 1. The refractories made of the material A or C were applied to the immersion nozzle, and the refractories made of the material B or D were applied to the upper nozzle, the sliding nozzle (SN) and the lower nozzle.

[0028] Table 2 shows a surface area of the inner hole of each of the segmental nozzles having the CaO-containing refractories applied thereto.

Table 2

	Surface Area of Inner Hole (cm^2)
Upper Nozzle	393
Sliding Nozzle	438
Lower Nozzle	368
Immersion Nozzle	915

[0029] A plurality of multi-part type continuous casting nozzle units were prepared by variously combining the prepared segmental nozzles serving as the upper nozzle 2, SN 3, lower nozzle 4 and immersion nozzle in FIG. 1.

[0030] The influence of the materials used in the nozzle unit on the quality of slabs was experimentally checked to clarify effects derived from the use of the CaO-containing refractories. In the experimental tests, the casting of aluminum-killed steel was performed while changing a combination of the segmental nozzles under the casting conditions of a ladle volume: 250 ton, a TD volume: 45 ton, and a drawing speed of slabs: 1.0 to 1.3 m/min, and the effects were checked in accordance with the number per area of large-size alumina inclusions having a particle size of 50 μm or more, which were contained in obtained slabs.

Table 3

		Comparative Example							Inventive Example						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Material applied to Inner Hole	Upper nozzle	D	B	D	D	D	B	D	B	D	D	B	B	B	B
	Sliding nozzle	D	D	B	D	D	B	B	D	B	B	B	B	D	B
	Lower nozzle	D	D	D	B	D	D	B	D	D	B	B	D	B	B
	Immersion nozzle	C	C	C	C	A	C	C	A	A	A	C	A	A	A
Ratio of CaO in inner hole surface Area (%) *1		0	19	21	17	43	39	38	62	64	61	57	83	79	100
Number of inclusions *2		100	90	87	92	75	80	82	15	13	16	22	6	7	3

*1 The ratio of a surface area of the inner hole defined by the CaO-containing material to the entire surface area of the inner hole

*2 The number of large-size alumina inclusions (Index Number on the basis that the number of large-size alumina inclusions in Comparative Example 1 is 100)

[0031] Table 3 shows the test result. In Table 3, the number of large-size alumina inclusions in each example is shown by an index number on the basis that the number of large-size alumina inclusions in slabs obtained using the multi-part type nozzle unit in Comparative Example 1 is 100. This means that the nozzle unit having a smaller index number can provide slabs having better quality or a smaller number of large-size alumina inclusions.

[0032] FIG. 3 diagrammatically shows the result in Table 3 in the form of the relationship between the ratio of a surface area of the inner hole defined by the CaO-containing material to the entire surface area of the inner hole, and the number of large-size alumina inclusions.

[0033] As seen in FIG. 3, when the ratio of a surface area of the inner hole defined by the CaO-containing refractories to the entire surface area of the inner hole of the nozzle unit is increased up to 50% or more, the number of large-size alumina inclusions is sharply reduced to improve the quality of slabs. Then, the quality of slabs is further improved as the ratio is increased, and the best quality can be obtained when the CaO-containing refractories are applied to the entire surface area of the inner hole of the nozzle unit.

[0034] Further, in the nozzle unit as shown in FIG. 1, the influence of the amount of CaO in the CaO-containing refractories on the quality of slabs was experimentally checked.

Table 4

Material		A	B	E	F	G	H	I	J	K	L
Composition (mass%)	CaO	40	50	10	15	20	30	10	15	20	30
	MgO	30	46	60	55	50	40	76	71	66	56
	C	30	4	30	30	30	30	4	4	4	4

[0035] As an example, Table 4 shows CaO-containing refractories having compositions E to L in addition to the compositions A and B in Table 1. As with the materials in Table 1, each of these CaO-containing refractories were shaped, burnt and machined to form sleeve-shaped refractories having a thickness of 10 mm. The sleeve-shaped refractories were inserted into the respective inner holes of the segmental nozzles, and bonded thereto with mortar to form segmental nozzles for test. The refractories made of the material A, E, F, G or H were applied to the immersion nozzle 5 in FIG. 1, and the refractories made of the material B, I, J, K or L were applied to the upper nozzle 2, the SN 3, and the lower nozzle 4 in FIG. 1.

[0036] A surface area of the inner hole of each of the segmental nozzles is the same as that shown in Table 2.

[0037] In the experimental tests, the casting was performed using each of multi-part type nozzle units prepared by variously combining these segmental nozzles in the structure as shown in FIG. 1, under the same casting conditions as those described above to check the quality of slabs. The test results are shown in Table 5. The quality of slabs was evaluated in the same manner as in Table 3.

Table 5

		Comparative Example		Inventive Example		
		8	9	8	9	10
Material applied to Inner Hole	Upper nozzle	I	J	K	L	B
	Sliding nozzle	I	J	K	L	B
	Lower nozzle	I	J	K	L	B
	Immersion nozzle	E	F	G	H	A
Number of inclusions*1		80	65	20	14	3

*1 The number of large-size alumina inclusions (Index Number on the basis that the number of large-size alumina inclusions in Comparative Example 1 is 100)

[0038] The results in Table 5 are summarized in FIG. 4 in the form of the relationship between the average amount of CaO in the refractories applied to the inner hole of the nozzle unit, and the number of large-size alumina inclusions. As seen in FIG. 4, when the average amount of CaO in the refractories applied to the inner hole of the nozzle unit is increased up to 20 mass% or more, the quality of slabs is significantly improved.

INDUSTRIAL APPLICABILITY

[0039] The present invention can significantly reduce the amount of large-size inclusions in slabs during casting of aluminum-killed steel, and can be applied to various nozzle units irrespective of nozzle type, such as multi-part type and single-part type.

Claims

1. A nozzle unit for continuous casting of aluminum-killed steel, having an inner hole to be essentially used for pouring molten steel from a tundish to a mold therethrough, wherein 50% or more of the entire surface area of said inner hole is formed of refractories containing 20 mass% or more of CaO.

2. The nozzle unit as defined in claim 1, wherein said refractories are sleeve-shaped sintered refractories which are inserted into said nozzle unit to define said inner hole.

3. The nozzle unit as defined in claim 1, which is a multi-part type nozzle unit or a single-part type nozzle unit.

4. A method of continuous casting of aluminum-killed steel, wherein the amount of CaO to be contained in CaO-containing refractories applied to a surface of an inner hole of a continuous casting nozzle unit and the ratio of a surface area of said inner hole to be defined by said CaO-containing refractories to the entire surface area of said inner hole are adjusted to reduce large-size inclusions in slabs obtained by pouring molten steel from a tundish to a mold through said inner hole.

5. The method as defined in claim 4, wherein said amount of CaO to be contained in said CaO-containing refractories is adjusted at 20 mass% or more, and said ratio of a surface area of said inner hole to be defined by said CaO-containing refractories to the entire surface area of said inner hole is adjusted at 50% or more.

FIG. 1

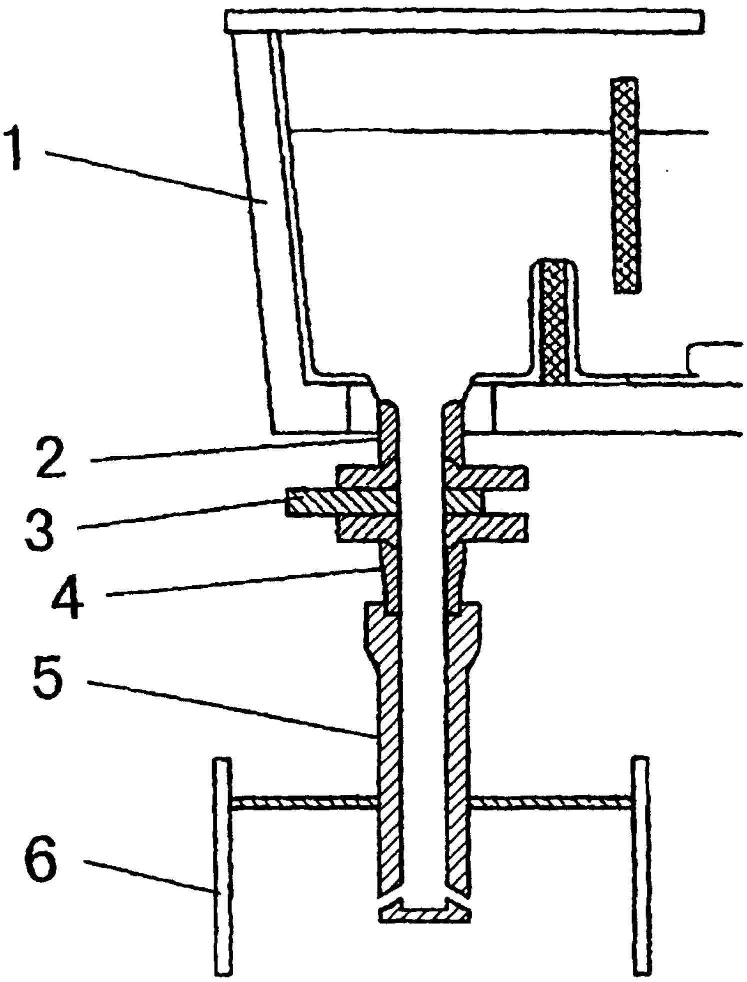


FIG. 2

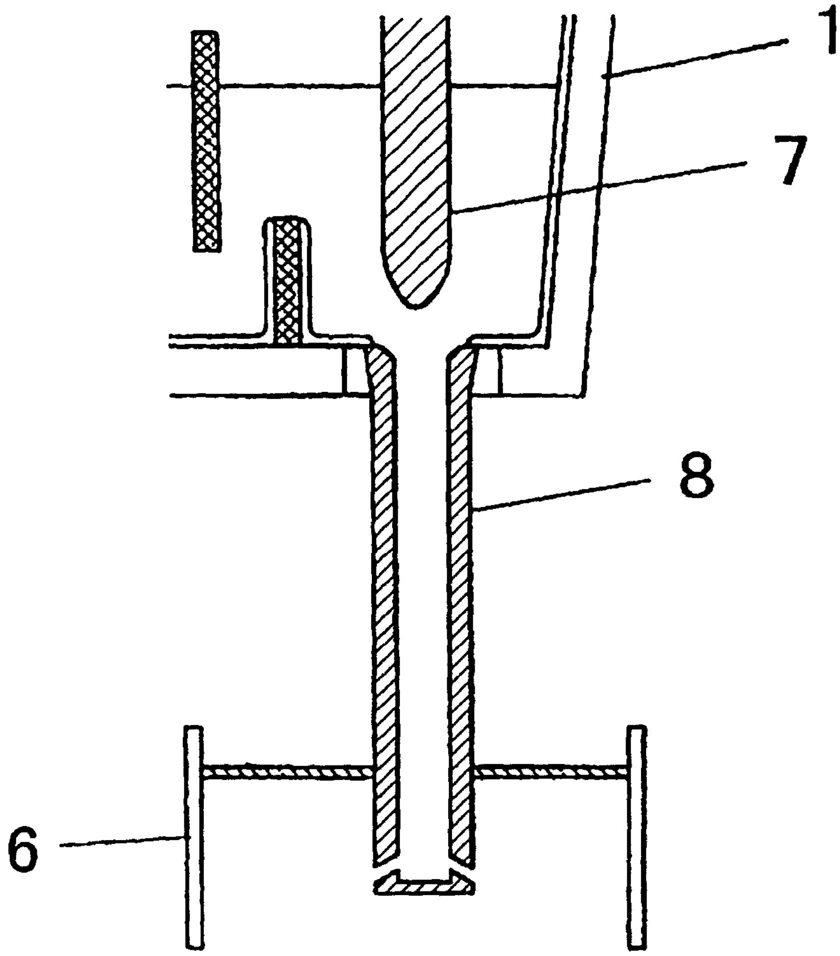


FIG. 3

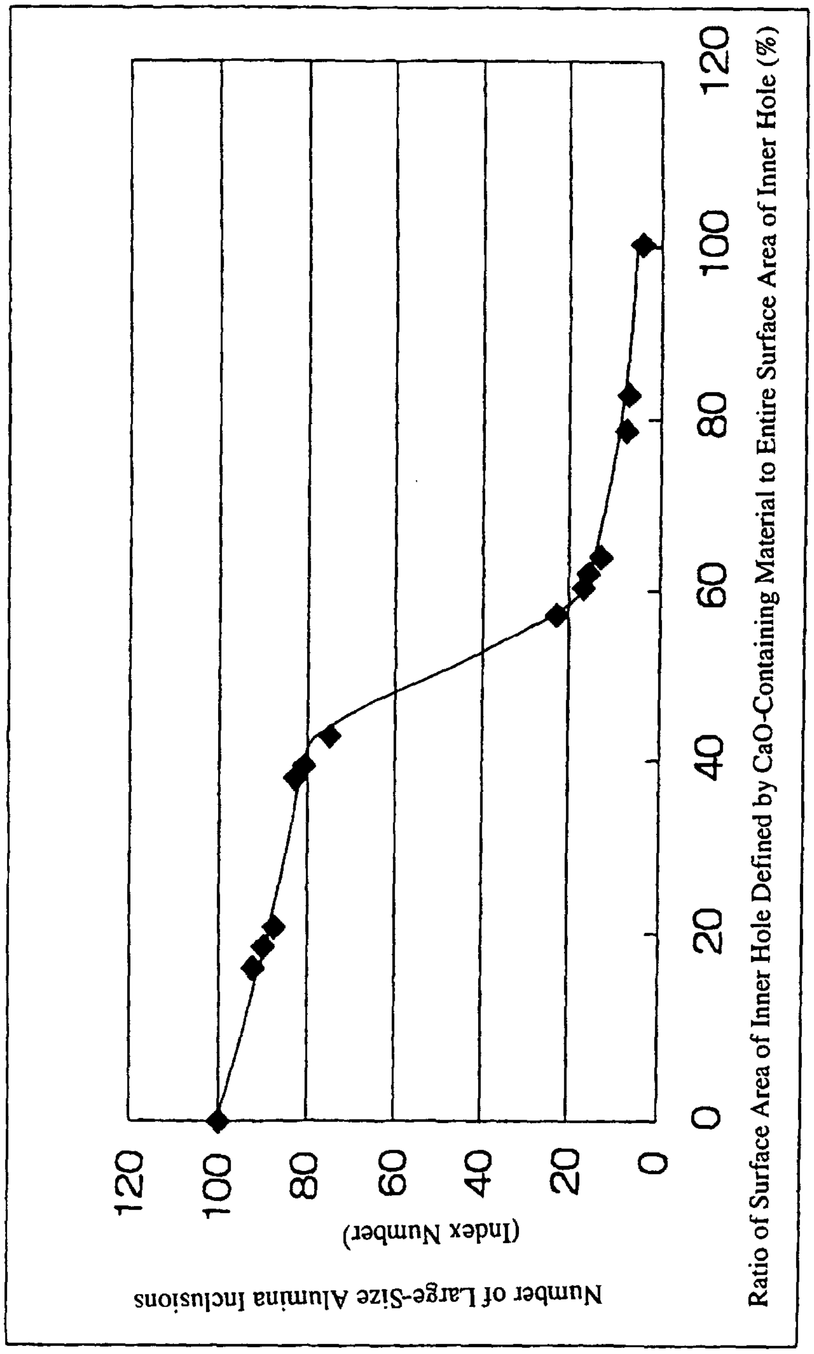
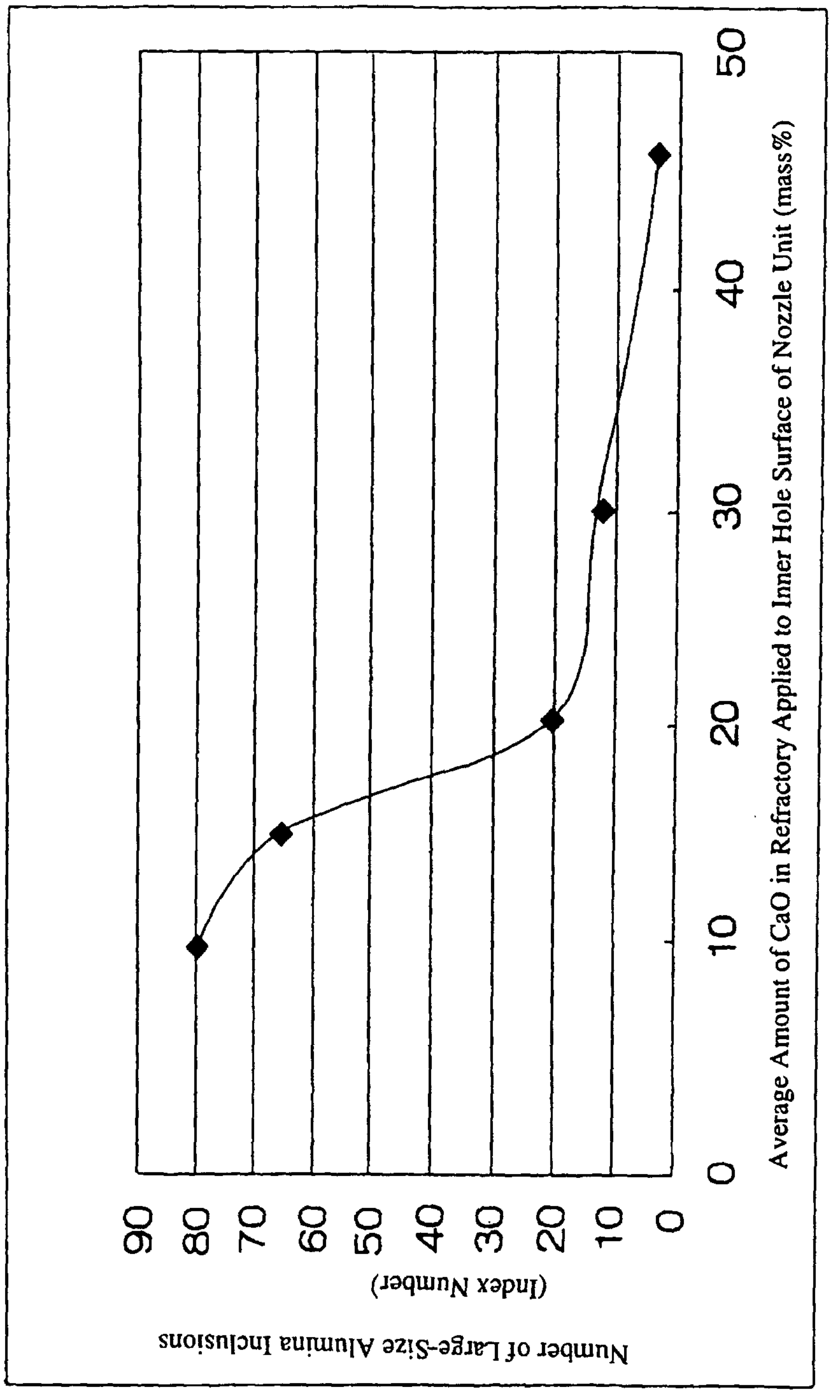

Number of Large-Size Alumina Inclusions
(Index Number)
0
20
40
60
80
100
120
Ratio of Surface Area of Inner Hole Defined by CaO-Containing Material to Entire Surface Area of Inner Hole (%)

FIG. 4


Number of Large-Size Alumina Inclusions
(Index Number)
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
Average Amount of CaO in Refractory Applied to Inner Hole Surface of Nozzle Unit (mass%)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/05558

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] B22D11/00, B22D11/10, B22D41/54

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)
Int.Cl[7] B22D11/00, B22D11/10, B22D41/54

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

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2003
Kokai Jitsuyo Shinan Koho	1971-2003	Jitsuyo Shinan Toroku Koho	1996-2003

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 5-285612 A (Kurosaki Corp.), 02 November, 1993 (02.11.93), Par. Nos. [0006], [0012], [0019], [0026] to [0027]; Figs. 1(c), (d), (g), (h) (Family: none)	1-5
X	JP 8-39214 A (Kurosaki Corp.), 13 February, 1996 (13.02.96), Par. Nos. [0002] to [0005], [0013] to [0019], [0027] to [0031]; Figs. 1 to 3 (Family: none)	1,3-5
X	JP 5-154627 A (Shinagawa Refractories Co., Ltd.), 22 June, 1993 (22.06.93), Par. Nos. [0004], [0010] to [0020], [0028] to [0029]; Figs. 1, 3 (Family: none)	1,3-5

☒ 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
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"&" document member of the same patent family

Date of the actual completion of the international search 06 August, 2003 (06.08.03)	Date of mailing of the international search report 19 August, 2003 (19.08.03)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/05558

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	JP 2003-40672 A (Shinagawa Refractories Co., Ltd.), 13 February, 2003 (13.02.03), Full text; all drawings (Family: none)	1-5

Form PCT/ISA/210 (continuation of second sheet) (July 1998)