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(54) An improved raw materials mix and process for producing self-fluxing, sintered ores, and improved self-fluxing, sintered ores.

(57) A process is disclosed for producing self-fluxing, sintered ores using a raw materials mix comprising at least 25 wt% of fine grains below 1 mm in size and not more than 5.4 wt% of SiO_2 in terms of sintered ore product. The process is characterized by control of the SiO_2 content of said fine grains to be at least 50 wt% of the total SiO_2 content of the mix, and sintering of the thus controlled mix.

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Croydon Printing Company Ltd.

Title

An Improved Raw Materials Mix And Process For Producing Self-Fluxing, Sintered Ores, And Improved Self-Fluxing, Sintered Ores

This invention relates to an improved raw materials mix for producing self-fluxing, sintered ores, and more particularly, to an improved process for producing low-slag, sintered ores which are resistant to disintegration, and the improved self-fluxing sintered ores resulting from the process. The process is based on the finding that the SiO_2 content of the fine grains of the new materials mix is important to the production of improved self-fluxing, sintered ores.

Sintereing by a common Dwight-Lloyd sinter machine generally comprises preparing a raw materilas mix of iron ore, limestone, silica, miscellaneous other materials and coke, agglomerating the mix in the presence of water, and charging the resulting agglomerate into the sinter machine. In that machine, the surface layer of the sinter bed is ignited in an ignition furnace, and suction is applied downwardly of the sinter bed for a period of about 20 minutes during which the whole thickness of the sinter bed is sintered, starting from the surface layer and ending with the bottom layer.

In the production of sintered ores which flux themselves and have a CaO/SiO_2 level in the range of from 1.0:1 to 2.0:1 generally from 1.3:1 to 1.8:1, a high productivity, a low fuel consumption and an improved quality in terms of shatter index and degradation index after reduction at 550°C (RDI) are factors always to be kept in mind. In order to improve the RDI value which expresses, as a weight percentage of grains below 3 mm in size, the ease with which the sintered ore disintegrates when subjected to a reducing atmosphere in a blast furnace at a temperature in the range of from 400 to 600°C according to the conventional technique, either the coke content of the mix or its slag content (expressed as the sum of CaO and SiO_2) is increased. The first method, i.e. increasing the coke content, is effective in improving the RDI value, but lowers the gas permeability of the sinter bed, thus decreasing the productivity and reducibility while increasing coke consumption. The second method, i.e. increasing the slag content (expressed as the sum of CaO and SiO_2), achieves the intended purpose, but calls for more slag to be charged into the blast furnace, thus increasing the blast furnace fuel consumption. Usually, blast furnaces are charged with about 300 kg of slag per ton of pig, and this amount is far greater than the amount necessary for furnace operations. As mentioned above, such excess slag is primarily due to the high content of SiO_2 carried with the furnace charge, especially its major ingredient, i.e., the sintered ore. A small SiO_2 content of sintered ore denotes a low strength and a low yield of sintered ore. To avoid this problem, it has been necessary to keep the SiO_2 content of the sintered ore in the range of from about 5.6 to about 6.0 wt%, inclusive.

Certain proposals have been made for decreasing the SiO_2 content of sintered ore without increasing the coke content.

One such proposal recommends burning a large amount of a gaseous fuel (coke oven gas) in an ignition furnace or heating furnace to replace the usual solid fuel (coke). However, the technique proposed uses essentially low firing temperatures and requires the higher range of firing temperature to be retained for a lengthy period of time; this inevitably lowers the productivity of the process. In addition, past records of the technique for reducing the SiO_2 content in terms of the sintered ore show that the SO_2 content cannot be made lower than about 5.6 wt%, and, therefore, the technique is not an effective method of lowering the SiO_2 content of the sintered ore. The high blast furnace slag volume also denotes an increased furnace fuel consumption, and, therefore, with the current concern over energy saving, a reduction in the blast furnace slag volume is an important task for the industry.

We have now surprisingly found that, in a raw materials mix for sintering which consists of coarse and fine grains, the SiO_2 content of the fine grains is critical to the production of an improved self-fluxing, sintered ore.

More specifically, the process of this invention for producing a self-fluxing sintered ore is based on the finding that SiO_2 contained in the fine grains of the raw materials mix melts easily in the sintering operation to form a melt, and that even a small amount of such SiO_2 can bind and agglomerate the coarse grains of the iron ore to give a strength which is such that the resulting sintered ore will not disintegrate under the load (the weight of furnace charge) when it is charged into a blast furnace.

According to our invention, we provide:

(1) a process for producing a self-fluxing, sintered ore using a raw material mix comprising iron ore, limestone, silica and coke, at least 25 wt% of said mix consisting of fine grains below 1 mm in size and said mix containing not more than 5.4 wt% of SiO_2 in terms of sintered ore product, i.e. sintered ore product from which coke, combined CO_2 and combined water have been removed by sintering of the mix, said process being characterized by controlling the SiO_2 content of said fine grains to be at least 50 wt% of the total SiO_2 content of the mix, and sintering the thus controlled mix;

(2) a process for producing self-fluxing sintered ores using a raw materials mix comprising iron ore, limestone, silic and return fines, at least 25 wt% of said mix consisting of fine grains below 1 mm in size and said mix containing not more than 5.4 wt% of SiO_2 in terms of sintered ore product, i.e. sintered ore product from which coke, combined CO_2 and combined water have been removed by sintering of the mix, said process being characterised by controlling the SiO_2 content of said fine grains to a value in the range of from 2.4 to 3.0 wt%, inclusive, of the mix (dry), and the basicity (CaO/SiO_2 ratio) of said fine grains to be not more than 1.3:1 and sintering the thus controlled mix (the expression "mix(dry)" refers to a raw material mix which has been dried so as to be freed of water other than combined water);

(3) a process according to (2) above wherein the sum of the CaO and SiO_2 contained in said fine grains is at least 4.0 wt% of said mix;

(4) a process according to (2) or (3) above, wherein the SiO_2 content of said fine grains minus the Al_2O_3 content of said fine grains is within the range of from 1.8 to 2.4 wt%, inclusive, based on the mix, and the weight ratio of CaO to (SiO_2-Al_2O_3) contained in said fine grains is within the range of from 0.5:1 to 2.0:1, inclusive;

(5) a process according to (4) above, wherein the weight ratio of CaO to (SiO_2-Al_2O_3) contained in said fine grains is within the range of from 1.0:1 to 1.8:1, inclusive;

(6) a composition consisting of a raw materials mix for producing a self-fluxing, sintered ore, said mix comprising iron ore, limestone, silica and coke, at least 25 wt% of said mix consisting of fine grains below 1 mm in size and said mix containing not more than 5.4 wt% of SiO_2 in terms of "sintered ore product" (said sintered ore product being a product from which coke, combined

CO_2 and combined water have been removed by sintering of the mix), said mix being characterised by an SiO_2 content of said fine grains of at least 50% of the total SiO_2 content of said mix;

(7) a composition consisting of a raw materials mix for producing a self-fluxing, sintered ore, said mix comprising iron ore, limestone, silica, coke and return fines, at least 25 wt% of said mix consisting of fine grains below 1 mm in size and said mix containing not more than 5.4 wt% of SiO_2 in terms of "sintered ore product" (as defined in (6) above), said mix being characterized by an SiO_2 content of said fine grains between 2.4 and 3.0 wt% of said mix(dry), and the basicity (CaO/SiO_2 ratio) of said fine grains being not more than 1.3:1; and a self-fluxing sintered iron ore which contains not more than 5.4 weight % of SiO_2 and in which fine grains below 1 mm in size account for at least 25% of the ore, characterized in that said fine grains have a basicity (CaO/SiO_2 ratio) below 1.3:1.

The invention defined above provides a novel process for producing a sintered ore with a reduced slag content (CaO plus SiO_2) without increasing the RDI value of the ore, such sintered ore of low slag content requiring less thermal energy for melting in a blast furnace. A further feature of the invention is that the process of the invention produces a sintered ore the SiO_2 content of which is below 5.4 wt% without adverse effects on the quality and productivity of the ore.

Reference is now made to the accompanying drawings, in which:

FIG. 1 shows the relationship of the weight percentage of CaO and SiO_2 to the basicity (CaO/SiO_2 by weight) for six ranges of grain size of a raw materials mix used in the conventional sintering process.

FIG. 2 shows the relationship of the same parameters for a raw materials mix used in the process of this invention.

FIG. 3 shows the relationship of the same parameters for another raw materials mix used in the process of this invention.

FIG. 4 shows the relationship of the RDI value and the ratio of the SiO_2 content of fine grains below 1 mm in size to the SiO_2 content of the total mix.

FIGS. 5, 7 and 9 respectively show the productivity (a), the sintering time (b), the sinter to sinter cake ratio (c), the coke consumption (d), the shatter index (e), and the RDI value (f) obtained in the practice of the process of this invention, and in various comparison examples.

FIG. 6 shows the SiO_2 content and CaO content of fine grains of the mix (of this invention) below 1 mm in size in relation to the RDI value of the resulting sintered ore.

FIG 8 shows the SiO_2 content, the Al_2O_3 content and the CaO content of fine grains of the mix (of this invention) below 1 mm in size in relation to the RDI value of the resulting sintered ore.

Preferred embodiments of the invention are now described in detail.

In general, particles of self-fluxing sintered ore having a CaO/SiO_2 level in the range of from 1.0:1 to 2.0:1, inclusive, mostly from 1.3:1 to 1.8:1, inclusive, agglomerate together by the action of "slag bond" wherein the grains of iron are bonded by means of a melt. Since the quality and productivity of the sintered ore are determined by the bond, it becomes very important to form a suitable bond. However, with the current sintering process using suction through the sinter bed as is typically performed with a Dwight-Lloyd sintering machine, the sintering reaction at high temperatures finishes so soon that it is necessary to form the required melt within a short period of time.

In accordance with this invention, we have found that the quantity and quality of the fine grains of a raw materials mix for sintering below 1 mm in size are important factors, and that the proper control of these two factors accelerates the formation of the above melt, leading to a reduction in the SiO_2 content of the resulting sintered ore.

In general, a raw materials mix for sintering is about 6% water, which accelerates the formation of pseudo-particles that increase the gas permeability of the sinter bed. Each pseudo-particle comprises a coarse grain core about 1 to 5 mm in size which is surrounded by fine grains below 1 mm in size adhering to the core. Our studies suggest that the formation of the melt in question starts at that portion of the surrounding fine grains which melts at low temperatures. The quantity of initially fused grains gradually increases by melting adjacent coarse grains, but because the sintering materials stays in a high temperature range only for a short period of time, the coarse grains do not fuse completely and the resulting melt is not a uniform mixture of fine and coarse grains but contains a higher proportion of the initially fused fine grains when it has coagulated and formed slag bonds. Therefore, to form a required amount of melt quickly, it is necessary that the fine grains below 1 mm in size surrounding a coarse grain should contain as many starting points as possible which melt at low temperatures. The melt basically consists of SiO_2, CaO and iron oxides, and, since the greater part of the sintering material is made up of iron ore as the source of iron oxides, the fine grains surrounding a coarse grain unavoidably contain a large proportion of iron oxides. Accordingly, the more SiO_2 and CaO sources which are present in the fine grains, the more easily is a melt is formed. This may be achieved by using a raw material which contains a large proportion of SiO_2 and CaO in only fine grains. However no such iron ore is found in nature, and, therefore, a practical method is to add fine grains of silica, serpentite, peridotite and Ni-slag as SiO_2 sources and fine grains of limestone as a CaO source. Other effective materials are slag from a blast furnace, slag from a converter, and returned fines which contain large proportions of SiO_2 and CaO.

1. The first embodiment of the process of this invention is a process for producing self-fluxing, sintered ores using a raw materials mix comprising at least 25 wt% of fine grains below 1 mm in size and not more than 5.4 wt% of "SiO_2 in terms of sintered ore product", as defined above, said process being characterized by controlling the SiO_2 content of said fine grains to be at least 50 wt% of the total SiO_2 content of the mix, and sintering the thus controlled mix.

The first embodiment of the process of this invention is now described in detail with reference to the accompanying drawings and the following tables. Let the mix used in the conventional sintering process (see FIG. 1 and Table 1) be compared with the mix used in the first embodiment of the process of this invention (see FIG. 2, Table 2 and FIG. 3 and Table 3). FIGS. 1, 2 and 3 each show the relationship of the weight of SiO_2 and CaO for each grain size (as percentage of the total content of each size) to the basicity (CaO/SiO_2 ratio by weight) for each grain size. The grain size scale of each figure is divided into six ranges, namely: -0.25 mm, 0.25～0.5 mm, 0.5～1 mm, 1～2 mm, 2～5 mm, and 5～10 mm. The premix has an average basicity (CaO/SiO_2) of about 1.33:1. Tables 1, 2 and 3 (below) each show the grain size distribution of the mix and the contents of CaO and SiO_2, respectively, for each grain size as percentages of the CaO and SiO_2 contents of the mix.

Table 1 - Comparative Example 1

grain size (mm) / parameter		<0.25	0.5 ~ 0.25	1.0 ~ 0.5	2.0 ~ 1.0
weight (%)	a	15.9	10.5	15.0	18.2
CaO content for each grain size (%)	b	5.5	8.5	7.4	10.3
	c	0.8745	0.8925	1.1100	1.8746
SiO_2 content for each grain size (%)	d	4.8	6.0	6.0	5.7
	e	0.7632	0.6300	0.9000	1.0374
basicity (CaO/SiO_2) for each grain size	f	1.15	1.42	1.23	1.81
CaO content as a percentage of CaO of mix (%)	g	12.7	13.0	16.2	27.4
SiO_2 content as a percentage of SiO_2 of mix (%)	h	15.0	12.3	17.6	20.3

Table 1 - Comparative Example 1 (Continued)

grain size (mm) / parameter		5.0 ~ 2.0	10.0 ~ 5.0	total average	less than 1mm
weight (%)	a	35.0	5.4	average grain size 2.074mm	41.4
CaO content for each grain size (%)	b	6.0	0	6.85	6.95
	c	2.1000	0	6.8516	28.770
SiO_2 content for each grain size (%)	d	4.7	2.5	5.11	5.34
	e	1.6450	0.1350	5.1106	2.2932
basicity (CaO/SiO_2) for each grain size	f	1.28	0	1.34	1.25
CaO content as a percentage of CaO of mix (%)	g	30.7	0	100	41.9
SiO_2 content as a percentage of SiO_2 of mix (%)	h	32.2	2.6	100	44.9

Notes: $c = a \times b/100$ $e = a \times d/100$ $f = b/d = c/e$

$g = c/6.8516 \times 100$ $h = e/5.1106 \times 100$

Table 2 - Example 1

grain size (mm) parameter		<0.25	0.5 ~ 0.25	1.0 ~ 0.5	2.0 ~ 1.0
weight (%)	a	16.4	10.7	15.0	17.9
CaO content for each grain (%)	b	5.13	8.05	7.15	10.10
	c	0.8413	0.8614	1.0725	1.8079
SiO content for each grain size (%)	d	5.66	7.07	5.96	3.87
	e	0.9282	0.7565	0.8940	0.6927
basicity (CaO/SiO_2) for each grain size	f	0.91	1.14	1.20	2.61
CaO content as a percentage of CaO of mix (%)	g	12.7	13.0	16.2	27.3
SiO content as a percentage of SiO_2 of mix (%)	h	18.9	15.4	18.2	14.1

Table 2 - Example 1 (Continued)

grain size (mm) / parameter		5.0 ~ 2.0	10.0 ~ 5.0	total average	less than 1mm
weight (%)	a	34.7	5.3	average grain size 2.05mm	42.1
CaO content for each grain (%)	b	5.88	0	6.62	6.59
	c	2.0404	0	6.6255	2.7752
SiO content for each grain size (%)	d	4.33	2.58	4.91	6.13
	e	1.5025	0.1367	4.9106	2.5787
basicity (CaO/SiO_2) for each grain size	f	1.36	0	1.35	1.05
CaO content as a percentage of CaO of mix (%)	g	30.8	0	100	41.9
SiO_2 content as a percentage of SiO_2 of mix (%)	h	30.6	2.8	100	52.5

Notes: c = a x b/100 e = a x d/100 f = b/d = c/e

g = c/6.6255 x 100 h = e/4.9106 x 100

Table 3 - Example 2

parameter \ grain size (mm)		<0.25	0.5 ~ 0.25	1.0 ~ 0.5	2.0 ~ 1.0
weight (%)	a	16.1	10.6	15.0	17.8
CaO content for each grain size (%)	b	5.1	7.8	6.9	9.8
	c	0.8211	0.8268	1.0350	1.7444
SiO_2 content for each grain size (%)	d	5.2	6.5	5.5	3.9
	e	0.8372	0.6890	0.8250	0.6942
basicity (CaO/SiO_2) for each grain size	f	0.98	1.20	1.25	2.51
CaO content as a percentage of CaO of mix (%)	g	12.7	12.9	16.1	27.2
SiO_2 content as a percentage of SiO_2 of mix (%)	h	17.9	14.7	17.6	14.8

Table 3 - Example 2 (continued)

parameter \ grain size (mm)		5.0 ~ 2.0	10.0 ~ 5.0	total average	less than 1mm
weight (%)	a	35.0	5.5	average grain size 2.08mm	41.7
CaO content for each grain size (%)	b	5.7	0	6.42	6.43
	c	1.9950	0	6.4225	2.6829
SiO_2 content for each grain size (%)	d	4.3	2.5	4.69	5.64
	e	1.5050	0.1375	4.6879	2.3512
basicity (CaO/SiO_2) for each grain size	f	1.33	0	1.37	1.14
CaO content as a percentage of CaO of mix (%)	g	31.1	0	100	41.17
SiO_2 content as a percentage of SiO_2 of mix (%)	h	32.1	2.9	100	50.2

Notes: c=a x b/100 e = a x d/100 f = b/d = c/e

g = c/6.4225 x 100 h = e/4.6879 x 100

As FIG. 1 shows, the mix for the conventional process contains more CaO in the range of from 1 to 2 mm and of from 0.25 to 0.5 mm than in the other ranges, but its SiO_2 content is unifromly distributed over the six ranges. In addition, as Table 1 (above) shows, both the CaO and SiO_2 contents, as percentages of the CaO and SiO_2 contents of the mix, are below 50% in the case of grain sizes below 1 mm. On the other hand, as FIG 2 shows, the mix for the process of this invention is characterized by a CaO distribution for grain sizes below 1 mm which is similar to that obtained with the mix of the conventional process and yet contains more SiO_2 in grains below 1 mm in size than does the conventional mix. Furthermore, the mix for the process of this invention is controlled so that is contains not more than 5.4 wt % of SiO_2 in terms of the SiO_2 content of the sintered ore product. In consequence, the grains of the mix below 1 mm in size have a low basicity (CaO/SiO_2). As Table 2 shows, the SiO_2 content for grain sizes below 1 mm, as a percentage of the total SiO_2 of the mix, is higher than 50%.

FIG. 3 illustrates another mix to be used in the process of this invention. The mix is such that the SiO_2 content of fine grains below 1 mm in size is at least 50% of the total SiO_2 content of the mix, and that the SiO_2 content of the mix is 5.2% in terms of the SiO_2 content of the sintered ore product. The mix is characterized in that grains below 1 mm in size have a higher SiO_2 content and a lower basicity (CaO/SiO_2) than grains below 1 mm in size in the conventional mix (see FIG 1). It follows that, as shows in Table 3 (above), the SiO_2 content of grains below 1 mm in size as compared with the total SiO_2 content of the mix is at least 50% as with the mix the characteristics of which are shown in Table 2 (above).

As described in the foregoing, the SiO_2 content of the mix to be used in the process of this invention is so controlled that it is not more than 5.4% as converted to a value for sintered ore product. Such conversion is necessary for determining accuratly the SiO_2 content of the mix because some portions of the mix are eliminated as gas and dust in the course of sintering. No general conversion formula can be set because the type and amount of the ingredients to be eliminated from the mix vary slightly with the composition of the mix and the sintering conditions, but it can be approximated by the following relationship:

$$Y = aX + b \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which: Y is the SiO_2 content (wt%) of the sintered ore product, X is the SiO_2 content (wt%) of the mix, and a and b are constants, generally 1.1 and not more than 0.2, respectively, which canbe determined empiracally on the basis of actual records of sintering operations.

The mix for use in the process of this invention contains at least 25%, preferably from 25 to 60%, of fine grains below 1 mm in size. If the content of fine grains below 1 mm in size is lower than 25%, not enough slag bonds are formed by sintering to provide a strong sintered ore. If the content of fine grains below 1 mm in size exceeds 60%, the gas permeability of the sinter bed is decreased but this will not sacrifice the productivity of the process of this invention if the agglomeration operation is enhanced by longer agglomeration or if a binder such as quicklime or bentonite is added.

Sintered ores were produced from themix described above with varying proportions of SiO_2 in grains below 1 mm in size relative to the total SiO_2 of the mix, and the RDI values of the products were plotted in FIG 4, from which one can understand that the RDI value is greatly and suddenly improved when the SiO_2 content of mix grains below 1 mm in size exceeds 50% of the total SiO_2 content of the mix. This is probably because an increased reactive area of the SiO_2-containing mix causes rapid and uniform formation of SiO_2 slag, the basic component of the slag bond which binds the particles or iron oxide together and governs the strength of the sintered ore product. As a result, a low-slag sintered ore containing not more than 5.4% of SiO_2 is produced.

The following are illustrative methods of controlling the SiO_2 content of the sintered ore product to be not greater than 5.4% and also of controlling the SiO_2 content of mix grains below 1 mm in size to be at least 50% of the total SiO_2 content of the mix:

(1) first controlling the SiO_2 content of the mix to be not more than 5.4% in terms of the SiO_2 content of the sintered ore product, and at the same time decreasing the CaO content of the mix so that its basicity (CaO/SiO_2) does not vary, and then decreasing the grain size of SiO_2 sources such as silica, dunnite, serptentite, Miferma and other high SiO_2 content ores to below 1 mm;

(2) second, decreasing the size of returned fines containing more SiO_2 than ordinary ores to below 1 mm; and

(3) third, using a large proportion of ores which contain more SiO_2 than ordinary ores, and which comprise many fine grains below 1 mm in size.

2. The second embodiment of the process of this invention is a process for producing a low slag-content sintered ore using a raw materials mix for a self-fluxing sintered ore comprising at least 25 weight % of fine grains below 1 mm in size, said process being characterized by lowering the SiO_2 content of the mix to not more than 5.4 wt% in terms of sintered ore product, increasing the SiO_2 content of said fine grains of the mix below 1 mm in size to be between 2.4 and 3.4 weight % of the raw material mix (dry), and controlling the weight ratio of

CaO to SiO_2 basicity of said fine grains to be below 1.5:1, and sintering the thus controlled mix.

Therefore, the sintered ore produced by the second embodiment of this invention is a self-fluxing (basic) sintered ore which contains not more than 5.4 wt% of SiO_2, and the fine grains below 1 mm in size which account for at least 25% of the ore are characterized by having a basicity (CaO/SiO_2) below 1.5:1.

Thus, the next point to be considered is the composition of the fine grains of the mix below 1 mm in size. As we have already revealed, the lower the basicity (CaO/SiO_2 ratio) of fine grains of the mix below 1 mm in size, the higher the reduction strength of the sintered ore, and this effect is particularly conspicuous when the fine grains have a basicity below 1.0:1. Accordingly, two raw materials mixes with the same average composition will provide sintered ores of different reduction strengths if the fine grains below 1 mm in size have different basicities. For example, a mix in which the fine grains below 1 mm in size have a higher basicity provides a sintered ore of higher reduction strength than a mix in which such fine grains have a lower basicity.

However, our studies have also shown that not only is the basicity of fine grains below 1 mm in size, an important factor, but also the absolute amounts of SiO_2 and CaO contained in such fine grains.

The above discussion shows that the amounts of fine grains of a mix below 1 mm in size and their constituents, especially SiO_2 and CaO, have an important effect on the quality of the sintered ore product. We have also found that most of the SiO_2 and CaO in coarse grains larger than 1 mm in size either remains unreacted or is reacted but mostly confined within the coarse particles, thus failing to perform the function of a "bond". However, CaO which forms slag more easily than SiO_2 will form some slag in the later stage of the sintering reaction. Therefore, by properly controlling the SiO_2 and CaO contents of fine grains below 1 mm in size, sintered ores can be produced without impairing their quality and productivity even if the SiO_2 and CaO contents of coarse grains larger than 1 mm in size are decreased. In other words, the necessary and sufficient requirement for high quality and productivity of sintered ore is that the proper conditions of the amount and constituents (SiO_2 and CaO) of fine grains of a raw materials mix for sintering below 1 mm in size should be satisfied. By reducing the SiO_2 and CaO contents of coarse grains more than 1 mm in size which have not been involved in the formation of a "bond", and thereby decreasing the total SiO_2 and CaO contents of the raw material, a low-slag sintered ore can be prepared which contains not more than 5.4 wt% of SiO_2 but which has previously been difficult to produce commercially due to low quality and productivity. However, it is substantially impossible in practice selectively to eliminate SiO_2 and CaO from only the coarse grains of the raw material which are more than 1 mm in size. Therefore, as a practically feasible method, the SiO_2 and CaO contents of the coarse grains are reduced not directly but indirectly by decreasing the SiO_2 and CaO contents of the total mix, and then compensating for the required amounts of SiO_2 and CaO in the fine grains below 1 mm in size. Therefore, a 40 kg-pot test was conducted to determine the quantitative relationship between the SiO_2 and CaO contents of fine grains below 1 mm in size and the quality of the sintered ore product. The results of the test are shown in FIG 6 of the drawings.

FIG 6 is a graph plotting the RDI values of sintered ore products produced by varying the SiO_2 and CaO contents of fine grains of a raw materials mix below 1 mm in size. On the x-axis, the weight of SiO_2 contained in fine grains below 1 mm in size is plotted as a percentage of the components of the mix (dry). This factor is defined by the following formula (the factor will hereunder be referred to as $[SiO_2]$in -1 mm):

$$\frac{A}{100} \times B$$

wherein A is the percentage by weight of the fine grains below 1 mm in size contained in the mix, and B is the percentage by weight of SiO_2 contained in the fine grains below 1 mm in size. On the y-axis, the weight of CaO contained in fine grains below 1 mm in size is plotted as a percentage of the components of the mix(dry). The RDI values of the resulting sintered ore products are indicated by numerals in the graph. The basicity (CaO/SiO_2 ratio) of the fine grains below 1 mm in size is shown as a solid line sloping upwards to the right, and the sum of the CaO and SiO_2 contained in the fine grins below 1 mm in size is shown as a dotted line sloping upwards to the left. As is clear from FIG 6, the area of RDI <40 is hatched and it enclosed the region where $[SiO_2]$ in -1 mm is at least 2.4 and the CaO/SiO_2 ratio of fine grains below 1 mm in size is not more than 1.3:1. In particular, the region where $[SiO_2]$ in -1 mm is at least 3.0 and the CaO/SiO_2 ratio of fine grains below 1 mm in size is not more than 1.0:1 is characterized by very desirable RDI values (<30). Therefore, to keep the RDI value of a sintered ore product within a desired range, it is necessary that the $[SiO_2]$ in -1 mm should be higher than a certain value and that the CaO/SiO_2 ratio of fine grains below 1 mm in size should not exceed a given value.

Since the sintered ore produced by the process of this invention is of low SiO_2 content, the total SiO_2 content of the mix should naturally be smaller than that of the conventional mix, and this requirement unavoidably constitutes a limit to the increase in the level of $[SiO_2]$ in – 1 mm. The region where $[SiO_2]$ in -1 mm exceeds 3.0 in FIG 6 is obtainable only in a laboratory by selecting only iron ores which are extremely low in SiO_2 content, blending them with fine powders of SiO_2 sources and sintering the resulting mix. In commercial operations where selection of such ores is difficult, there is little possibility of obtaining the stated range.

Furthermore, the strength at ordinary temperatures (shatter index) of a sintered ore is directly correlated with the sum of the CaO and SiO_2 contained in fine grains below 1 mm in size, and, therefore, the value of the sum cannot be made excessively low. With the level of $[SiO_2]$ in -1 mm of the mix being at least 2.4, if the sum of CaO and SiO_2 contained in fine grains below 1 mm in size is smaller than 4.0, the sintered ore product has a tendency to exhibit low strength at ordinary temperatures (shatter index), making it necessary to implement separate provisions for increasing the shatter index by, for instance, incorporating more coke in the mix.

The following conclusion can be drawn from the above discussion: the technique of this invention can be easily implemented within the hatched area of FIG 6 where the $[SiO_2]$ in -1 mm value is at leat 2.4 and the CaO/SiO_2 ratio of fine grains below 1 mm in size is not more than 1.3:1, especially in the dotted area where the $[SiO_2]$ in -1 mm value is between 2.4 and 3.0, the CaO/SiO_2 ratio of fine grains below 1 mm in size is not greater than 1.3:1 and the sum of CaO and SiO_2 contained in the fine grains below 1 mm in size is at least 4.0. It is to be noted again that the mix for use in the process of this invention generally contains from 25 to 60 wt% of fine grains below 1 mm in size.

It is well known that the reduction strength of a sintered ore will usually decrease with an increase in the Al_2O_3 ~~content of the ore.~~ In contrast with this statistical fact, some cases are observed in which an increase in the Al_2O_3 content does not necessarily result in a low reduction strength and, therefore, the relationship between the Al_2O_3 content and the reduction strength has not been altogether clear. On the basis of our understanding that a slag bond is formed of relatively fine grains and that most of the coarse grains remain in the unmelted ore, we have carried out experiments varying the Al_2O_3 content of fine grains only rather than the Al_2O_3 content averaged by both fine and coarse grains, and we have found that there is an inverse relationship between the Al_2O_3 content of fine grains below 1 mm in size and the reduction strength of the sintered ore product. We have also found that the inconsistency which has been observed in some cases between the average Al_2O_3 content of the sintered ore and its reduction strength can be explained by the Al_2O_3 content of fine grains below 1 mm in size. Accordingly, it is necessary to control not only the average Al_2O_3 content of a sintered ore but also the Al_2O_3 content of fine grains below 1 mm in size. What is more, a raw material for sintering should not be composed of crushed iron ores having a high Al_2O_3 content, and this is important for ensuring an acceptable reduction strength in the sintered ore.

The above discussion shows that the proportions of fine grains of a raw material for sintering which are below 1 mm in size and of their constituents, especially

SiO_2, CaO and Al_2O_3, have an important effect on the quality of the sintered ore product. We have also found that most of the SiO_2, CaO and Al_2O_3 in the coarse grains larger than 1 mm in size either remains unreacted or is reacted but mostly confined within the coarse grains, thus failing to perform the function of a"bond". However, CaO which more easily forms slag than SiO_2 and Al_2O_3 will form some slag in the later stage of the sintering reaction. Therefore, by properly controlling the SiO_2, CaO and Al_2O_3 contents of fine grains below 1 mm in size, sintered ores with quality and productivity unimpaired can be produced even if the SiO_2 and CaO contents of coarse grains larger than 1 mm in size are decreased, or even if the Al_2O_3 content of said coarse grains is increased. In other words, as stated above, the necessary and sufficient requirement for high quality and productivity of the sintered ore is that the proper conditions with respect to the amount and constituents (SiO_2, CaO and Al_2O_3) of fine grains of a raw materials mix for sintering below 1 mm in size should be satisfied. By reducing the SiO_2 and CaO contents of coarse grains larger than 1 mm in size which have not been involved in the formation of a "bond", and therby decreasing the total SiO_2 and CaO contents of the raw material, a low-slag sintered ore can be prepared which contains not more than 5.4 wt% of SiO_2 but which has previously been difficult to produce commercially due to low quality and producivity. However, it is substantially impossible in practice selectively to eliminate SiO_2 and CaO from only the coarse grains of the raw material below 1 mm in size. Therefore, as a practically feasible method, the SiO_2 and CaO contents of the coarse grains are reduced not directly but indirectly by decreasing the SiO_2 and CaO contents of the total raw material, and then compensating for the required amounts of SiO_2 and CaO in the fine grains below 1 mm in size. Accordingly, a 40 kg-pot test was conducted to determine the quantitative relationship between the SiO_2, CaO and Al_2O_3 contents of fine grains below 1 mm in size and the quality of the sintered ore product. The results of the test are shown in FIG 8 of the accompanying drawings.

FIG 8 is a graph plotting the RDI values of sintered ore products produced by varying the SiO_2, CaO and Al_2O_3 contents of fine grains of a raw materials mix which are below 1 mm in size. We have plotted on the x-axis the weight of the SiO_2 contained in fine grains below 1 mm in size minus the weight of Al_2O_3 contained in the fine grains as a percentage of the components of the mix(dry). This factor is defined by the following formula (the factor will hereunder be referred to as $[SiO_2 - Al_2O_3]$ in -1 mm):

$$\frac{A}{100} \times (B - C)$$

wherein A is the precentage by weight of the fine grains below 1 mm in size contained in the mix, B is the percentage by weight of SiO_2 contained in the fine grains below 1 mm in size, and C is the percentage by weight of Al_2O_3 contained in the fine grains below 1 mm in size.

On the y-axis, we have plotted the weight of the CaO content of the fine grains below 1 mm in size as a percentage of the components of the mix (dry). The RDI values of the resulting sintered ore products are indicated by numerals in the graph of Fig 8. The $CaO/(SiO_2 - Al_2O_3)$ values for fine grains below 1 mm in size are shown as dotted lines. As is clear from FIG 8, the area of RDI 40 is hatched and it encloses the region where $[SiO_2 - Al_2O_3]$ in -1 mm is at least 1 .8 and the $CaO/(SiO_2 - Al_2O_3)$ ratio of fine grains below 1 mm in size is not greater than 2.0:1. In particular the region where the [SiO_2 -Al_2O_3] in -1mm value is at least 2.4 and the $CaO/(SiO_2 - Al_2O_3)$ ratio of fine grains below 1 mm in size is not greater than 1.8:1 is characterized by very desirable RDI values (<30). Therefore, to keep the RDI value of a sintered ore product within a desired range, it is necessary that the [SiO_2 - Al_2O_3] in — 1 mm value should be higher than a certain level and that the $CaO/(SiO_2 - Al_2O_3)$ ratio of fine grains below 1 mm in size should not exceed a given value.

Now, the change in the Al_2O_3 content of a raw material for sintering is generally smaller than that in the SiO_2 content, and furthermore, in practice iron ores having an extremely low content of Al_2O_3 are not generally available in large quantities. Therefore, it is unavoidable that the level of [SiO_2 - Al_2O_3] in -1 mm must be increased by increasing the SiO_2 content of fine grains below 1 mm in size. However, since the sintered ore produced by the process of this invention is of low SiO_2 content, the total SiO_2 content of the raw materials mix should naturally be smaller than that of the conventional mix, and this requirement unavoidably constitutes a limit to the available increase in the level of [SiO_2 - Al_2O_3] in -1 mm. The region where [SiO_2 - Al_2O_3] in -1 mm exceeds 2.4 in FIG 8 is obtainable only in a laboratory by selecting only iron ores which are extremely low in SiO_2 and Al_2O_3 contents, blending them with fine powders of SiO_2 sources and sintering the resulting mix. In commercial operations where selection of such iron ores is difficult, there is little possiblity of obtaining the stated range.

Furthermore, the strength at ordinary temperatures (shatter index) of the sintered ore is directly correlated with the sum of CaO and SiO_2 contained in fine grains below 1 mm in size, and, therefore, the value of the sum cannot be made excessivley low. With the level of [SiO_2 - Al_2O_3] in -1 mm of a raw materials mix being at least 1.8, if the value of the $CaO/(SiO_2 - Al_2O_3)$ ratio of the fine grains below 1 mm in size is smaller than 1.0:1, the sum of the CaO and SiO_2 contained in said fine grains decreases, and the sintered ore product has a tendency to exhibit a low strength at ordinary temperatures (shatter index), making it necessary to implement separate provisions for increasing the shatter index by, for instance, incorporating more coke in the mix. It is to be mentioned here that the level of the $CaO/(SiO_2 - Al_2O_3)$ ratio of fine grains below 1 mm in size should not be below 0.5:1 because, otherwise, sintered ore which is very low in strength at ordinary temperatues is produced.

The following conclusion can be drawn from the above discussion: the technique of this invention can be easily implemented within the hatched area of FIG 8 where the [SiO_2 - Al_2O_3] in -1 mm values are at least 1.8 and the $CaO/(Sio_2 - Al_2O_3)$ ratio of fine grains below 1 mm in size are not greater than 2.0:1 especially in the dotted area where the [SiO_2 - Al_2O_3] in -1 mm values are between 1.8 and 2.4 and the $CaO/(SiO_2 - Al_2O_3)$ rates between 0.5:1 preferably 1.0:1 and 2.0:1.

Preferred embodiments of the process of this invention are described hereunder in greater detail with reference to the following examples.

Three different raw materials mixes each comprising iron ores, limestone, silica, coke and return fines were agglomerated in the presence of water, and the resulting agglomerates were charged into a 40 kg test pot at a negative pressure of 1700 mm H_2O to produce three different sintered ores. The description of the ingredients of each mix and the grain size distribution of each ingredient are shown in Table 4 (for Comparative Example 1), Table 5 (for Example 1) and Table 6 (for

Example 2). The average basicity (CaO/SiO_2) of each raw materials mix was about 1.55:1. The raw materials mix used in Example 1 according to one embodiment of the process of this invention incorporated fine grains (below 1 mm in size) of silica containing at least 90% of SiO_2 so that the SiO_2 content of the mix was not more than 5.4% in terms of sintered ore product. The raw materials mix used in Example 2 according to another embodiment of this invention likewise incorporated fine grains (below 1 mm in size) of silica containing at least 90% of SiO_2, but it contained a smaller amount of silica and limestone so that the SiO_2 content of the mix was not more than 5.2% in terms of sintered ore product. Tables 4,5 and 6 are keyed to Tables 1, 2 and 3, respectively. The compositions of the principal ingredients of each mix are identified in Table 8 below.

Table 4 (Comparative Example 1)

Description and Proportions of Ingredients

Description of Ingredients	Proportions (%)	grain size (mm)					
		10~5	5~2	2~1	1~0.5	0.5~0.25	-0.25
M B R	45	5%	30%	15%	15%	10%	25%
Mt. Newman	24.5	10	30	15	15	15	15
Robe River	15	10	30	20	20	10	10
scale	3	17	32	20	16	8	7
silica	1.7	-	13	27	25	15	20
limestone	10.8	-	20	30	18	16	16
total of new materials (N)	100	-	-	-	-	-	-
return fines (R)	20	-	60	20	20	5	5
coke breeze (C)	3.4	-	30	20	15	12	25

CaO in — 1 mm	41.9%
SiO_2 in — 1 mm	44.9%
(SiO_2 content of sintered ore	5.6%)

$$\text{proportion of return fines} = \frac{R}{N + R} \times 100$$

$$\text{proportion of coke breeze} = \frac{C}{N + R + C} \times 100$$

Table 5 (Example 1)

Description and Proportions of Ingredients

Description of Ingredients	Proportions (%)	grain size (mm)					
		10~5	5~2	2~1	1~0.5	0.5~0.25	-0.25
M B R	45	5%	30%	15%	15%	10%	25%
Mt. Newman	25.2	10	30	15	15	15	15
Robe River	15	10	30	20	20	10	10
scale	3	17	32	20	16	8	7
silica	1.4	-	-	-	30	30	40
limestone	10.4	-	20	30	18	16	16
total of new materials (N)	100	-	-	-	-	-	-
return fines (R)	20	-	60	20	10	5	5
coke breeze (C)	3.4	-	30	20	15	12	23

CaO in -1 mm 41.9%

SiO_2 in – 1 mm 52.5%

(SiO_2 content of sintered ore 5.4%

$$\text{proportion of return fines} = \frac{R}{N + R} \times 100$$

$$\text{proportion of coke breeze} = \frac{C}{N + R + C} \times 100$$

Table 6 (Example 2)

Description and Proportions of Ingredients

Description of Ingredients	Proportions (%)	grain size (mm)					
		10~5	5~2	2~1	1~0.5	0.5~0.25	-0.25
M B R	45	5%	30%	15%	15%	10%	25%
Mt Newman	26.0	10	30	15	15	15	15
Robe River	15	10	20	20	20	10	10
scale	3	17	32	20	16	8	7
silica	1.1	-	-	-	30	30	40
limestone	9.9	-	20	30	18	16	16
total of new materials (X)	100	-	-	-	-	-	-
return fines (R)	20	-	60	20	10	5	5
coke breeze (C)	3.4	-	30	20	15	12	23

CaO in -1 mm 41.7%

SiO_2 in -1 mm 50.2%

(SiO_2 content of sintered ore 5.2%

$$\text{Proportion of return fines} = \frac{R}{X + R} \times 100$$

$$\text{proportion of coke breeze} = \frac{C}{X + R + C} \times 100$$

The test results are shown in Table 7 (below) and FIG 3 of the drawings. The process of this invention (Examples 1 and 2) was slightly more productive than the conventional process (Comparative Example 1) due to a shorter sintering period and a higher ratio of sinter to sinter cake. The process of this invention consumed slightly less coke than the conventional process. This means that, although the process of this invention achieved almost the same results of sintering as in the conventional technique with respect to moisture content, coke content, productivity, sintering time, sinter to sinter cake ratio, coke consumption and shatter index, it greatly reduced the RDI value of the sintered ore product (as in Example 1), or reduced the SiO_2 content of the sintered ore product to less than 3.2% without greatly increasing its RDI value (as in Example 2).

Table 7 - Test Results

	moisture (%)	coke (%)	productivity (t/H.m^2)	sintering time (min)	sinter to sinter cake ratio (%)
Comp Ex 1	6.0	3.4	1.32	22.5	80.4
Ex 1	6.0	3.4	1.39	21.0	80.9
Ex 2	6.0	3.4	1.39	21.5	81.5

Table 7 - Test Results (Continued)

	coke consumption (kg/t-s)	shatter index (%)	RDI (%)	symbols used in FIG 5
Comp Ex 1	47.1	86.6	32.1	X
Ex 1	46.9	86.9	30.8	O
Ex 2	46.3	87.5	32.9	●

Table 8

unit : wt%

composition		T.Fe	FeO	Fe_2O_3	SiO_2	Al_2O_3
ore	*1 M B R	67.77	0.34	96.51	1.53	0.69
	*2 Mt. N	61.28	0.07	87.51	6.10	2.88
	*3 R R	57.34	0.17	81.79	5.70	2.56
scale (mill scale)		72.84	67.18	29.48	0.73	0.23
silica		0.94	-	1.34	93.00	1.92
limestone		0.17	-	-	0.63	0.08

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Table 8 (Continued) unit : wt%

composition		CaO	MgO	CW^{*4}
ore	*1 M B R	0.14	0.04	0.42
	*2 Mt N	0.06	0.05	2.64
	*3 R R	0.15	0.12	8.58
scale (mill scale)		0.09	0.59	0.03
silica		0.19	0.45	0.94
limestone		54.66	0.56	0.14

*1 Minerações Brasileiras Reunidas S.A. (Brazil)
*2 Mt. Newman Min. Co. Pty. Ltd. (Australia)
*3 Robe River (Australia)
*4 combined water

As described in the foregoing, the process of this invention is comparable with, or even superior to, the conventional sintering process with respect to productivity, coke consumption, shatter index and other factors while it can greatly reduce the RDI value of the sintered product, or reduce the SiO_2 content of the sintered product to below 5.4% without greatly increasing its RDI value.

Comparative Examples 2 and 3 and Examples 3 to 7 of this invention are described hereunder. Seven different raw materials mixes each comprising iron ores, limestone, silica, coke and return fines were aggolomerated in the presence of water, and the resulting agglomerates were charged into a 40 kg test pot at a negative pressure of 1700 mmH_2O to produce seven different sintered ores. The description of the ingredients of each mix and the composition of each ingredient are shown in Tables 9 to 12 (Comparison Example 2 and Examples 3 to 5) and Tables 19 to 22 (Comparison Example 3 and Examples 6 and 7). The proportions of the ingredients of the mixes are indicated in Table 13 (Comparison Example 2 and Examples 3 to 5) and in Table 23 (Comparison Example 3 and Examples 6 and 7). Tables 14 to 17 are keyed to the data on the proportions of ingredients set forth in Table 13 for Comparative Example 2 and Examples 3 to 5, respectively, and each table shows the SiO_2 and CaO contents of the raw materials mix and the sintered ore product. In each of Tables 14 to 17, the data on the SiO_2 content, the CaO content and the CaO/SiO_2 ratio of the mix are classified under coarse grains largerthan 1 mm in size and fine grains below 1 mm in size.

Tables 24 to 26 are keyed to the data on the proportions of ingredients set forth in Table 23 for Comparative Example 3 and Examples 6 and 7, respectively, and each table shows the SiO_2, CaO and Al_2O_3 contents and the CaO/SiO_2 ratios of the raw materials mix and sintered ore product, and the (SiO_2 - Al_2O_3) contents and $CaO/(SiO_2 - Al_2O_3)$ ratios of fine grains (below 1 mm in size) of the mix. In each of Tables 24 to 26, the data on the SiO_2 content, CaO content and Al_2O_3 content of the mix are classified under "coarse grains" (above 1 mm in size) and "fine grains" (below 1 mm in size), respectively.

As mentioned above in connection with the raw material mix to be used in the process of this invention, the relationship between Y which is the SiO_2 content (wt%)

of the sintered ore product and X which is the SiO_2 content (wt%) of the raw materials mix can be approximated by the following formula:

$$Y = aX + b \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

wherein a and b are constants, generally 1.1 and not more than 0.2, respectively, which can be determined empirically on the basis of actual records of sintering operations.

As Tables 13 and 14 show, the raw materials mix prepared in Comparative Example 2 is such that the amount of silica containing at least 90% of SiO_2 is simply decreased to lower the SiO_2 content in terms of sintered ore product from the ordinary range of 5.6 to 6.0 wt% down to 5.4 wt%. As a result, the level of $[SiO_2]$ in -1 mm of the mix is 2.25 and the CaO/SiO_2 ratio of fine grains below 1 mm in size is 1.20:1. Therefore, a simple reduction of the SiO_2 content gives a level of $[SiO_2]$ in -1 mm which is below 2.4.

As shown in Tables 13 and 15, the raw materials mix prepared in Example 3 is such that not only is the amount of silica which is added lowered but the grain size is also decreased to below 1 mm so as thereby to decrease the SiO_2 content in terms of sintered ore product down to 5.4 wt%. As a result, the $[SiO_2]$ in - 1 mm value is increased to 2.77 and the CaO/SiO_2 ratio of fine grains below 1 mm in size is decreased to 0.95:1.

In Example 4 (shown in Tables 13 and 16), the raw materials mix contains both return fines a part of which is crushed to a size below 1 mm and relatively coarse grains of other iron ores, so that the SiO_2 content in terms of sintered ore product is decreased to 5.4 wt%. The mix is characterized by an $[SiO_2]$ in -1 mm value which is as high as 2.97 and a CaO/SiO_2 ratio of fine grains below 1 mm in size as high as 1.25:1.

In Example 5 (illustrated in Tables 13 and 17), the raw materials mix is such that not only is the amount of silica added decreased to 0.8 wt% but also the grain size is decreased to below 1 mm and also it incorporates partially crushed iron ores containing a higher proportion of SiO_2 than for the mix as a whole, so that the SiO_2 content in terms of sintered ore is decreased to 5.0 wt%. In consequence, the $[SiO_2]$ in - 1 mm of the mix is 2.55 and the CaO/SiO_2 ratio of fine grain below 1 mm in size is 1.12:1. The results obtained by sintering the raw material mixes prepared in Comparative Example 2 and Examples 3 to 5, respectively, are shown in Table 18 and illustrated in the graph of FIG. 7.

As shown in Table 18 and FIG 7, the raw material mix of Comparative Example 2, which was prepared by simply reducing the SiO_2 content, provided a sintered ore having an excessively high RDI value which could only be produced after an extended sintering period and in a low sinter to sinter cake rato. The mix consumed a large amount of coke as it was sintered. In contrast, the raw materials mix of Example 3, which was prepared by not only decreasing the amount of silica added but also by reducing its grain size to below 1 mm, provided a sintered ore having a desired RDI value (below 40), which could be produced with high productivity and in a short sintering period, consuming less coke, although the sintered ore product contained 5.4 wt% of SiO_2 which was less than the ordinary values between 5.6 and 6.0 wt%.

The raw materials mix of Example 4, which contained return fines with somewhat more SiO_2 than the intended sintered ore product and part of which was crushed to a size below 1 mm, provided a sintered ore having a high shatter index and an RDI value below 40. Such ore could be produced in a high sinter to sinter cake ratio, consuming a small amount of coke.

The raw materials mix of Example 5, prepared by not only decreasing the amount of silica added to 0.8 wt% but also by reducing its grain size to below 1 mm and by incorporating partially crushed iron ores which were relatively high in SiO_2 content, provided a sintered ore having a desired value of RDI below 40 without sacrificing the productivity and sinter to sinter cake ratio and without increasing the coke consumption, although the resulting sintered ore had its SiO_2 content decreased to 5.0 wt%.

Table 9 unit : wt%

composition / ore	T.Fe	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	CW*6
M B R *1	67.62	0.35	96.21	1.61	0.67	0.10	0.04	0.39
RD CF *2	65.01	0.09	92.77	4.25	1.25	0.10	0.09	1.00
Mt. N. *3	61.12	0.07	87.24	6.13	2.99	0.05	0.06	2.72
Ham. *4	61.98	0.10	88.43	4.44	2.78	0.09	0.05	2.33
R.R. *5	57.35	0.20	81.70	5.50	2.51	0.15	0.14	8.40

*1 Mineracoes Brasileiras Reunidas S.A. (Brazil)
*2 Rio Doce common fine (Brazil)
*3 Mt. Newman Min. Co. Pty. Lt (Australia)
*4 Hamersley (Australia)
*5 Robe River (")
*5 combined water

Table 10 unit : wt%

composition	T.Fe	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	CW
(mill scale)	73.33	68.29	28.89	0.70	0.13	0.10	0.02	0.03

Table 11

unit : wt%

	T.Fe	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	CW
silica	0.94	1.34	93.00	1.92	0.19	0.45	0.94

Table 12

unit : wt%

	T.Fe	SiO_2	Al_2O_3	CaO	MgO	CW
limestone	0.17	0.66	0.07	55.01	0.55	0.29

Table 13

Ingredients description	proportions (wt%)							
	Com. Ex. 2		Ex. 3		Ex. 4		Ex. 5	
	new material	total	new material	total	new material	total	new material	total
M B R	32	77.1	32	77.1	40	77.1	40	77.1
Rio Doce CF	9.7		14.7		6.7		8.6	
Mt. Newman	10		10		22		22	
Hamersley	23		18		6		6	
Robe River	10		10		10		10	
scale	3		3		3		3	
silica	1.4		1.4		1.4		0.8	
limestone	10.9		10.9		10.9		9.6	
total of new materials	100		100		100		100	
return fines	19.5		19.5		19.5		19.5	
coke breeze	3.4		3.4		3.4		3.4	

Table 14 Com. Ex. 2

	raw material mix			sintered ore
	≥1 mm	<1 mm	total	
Proportion by weight (%)	59.9	40.1	100.0	-
SiO_2 (%)	2.55	2.25	4.80	5.40
CaO (%)	4.26	2.70	6.96	7.83
CaO/SiO_2	1.67	1.20	1.45	1.45

Table 15 Ex. 3

	raw material mix			sintered ore
	≥1 mm	<1 mm	total	
Proportion by weight (%)	57.0	43.0	100.0	-
SiO_2 (%)	2.03	2.77	4.80	5.40
CaO (%)	4.33	2.63	6.96	7.83
CaO/SiO_2	2.13	0.95	1.45	1.45

Table 16 Ex. 4

	raw material mix			sintered ore
	≥1 mm	<1 mm	total	
Proportion by weight (%)	51.2	48.8	100.0	-
SiO_2 (%)	1.83	2.97	4.80	5.40
CaO (%)	3.25	3.71	6.96	7.83
CaO/SiO_2	1.78	1.25	1.45	1.45

Table 17 Ex. 5

	raw material mix			sintered ore
	≥1 mm	<1 mm	total	
Proportion by weight (%)	56.2	43.8	100.0	-
SiO_2 (%)	1.95	2.55	4.50	5.00
CaO (%)	3.66	2.86	6.52	7.25
CaO/SiO_2	1.88	1.12	1.45	1.45

TABLE 1-

parameter / Run No.	moisture (%)	coke content (%)	productivity (t/H. m^2)	sintering time (min)
Com. Ex. 2	6.0	3.4	1.33	24.0
Ex. 3	6.0	3.4	1.47	22.2
Ex. 4	6.0	3.4	1.40	23.7
Ex. 5	6.0	3.4	1.39	23.8

parameter / Run No.	sinter to sinter cake ratio (%)	coke consumption (Kg/t-s)	shatter index (+10 mm%)	R D I (%)	SiO$_2$ in sintered ore (%)
Com. Ex. 2	73.7	47.3	88.1	49.1	3.4
Ex. 3	77.7	46.1	87.2	36.0	3.4
Ex. 4	79.1	43.3	88.3	33.9	3.4
Ex. 5	77.4	46.8	87.1	37.1	3.0

As Tables 23 and 24 show, the raw materials mix prepared in Comparative Example 3 is such that the amount of silica containing at least 90% of SiO_2 is simply decreased to lower the SiO_2 content in terms of sintered ore product from the ordinary range of 5.6 to 6.0 wt% down to 5.4 wt%. As a result the level of $[SiO_2 - Al_2O_3]$ in -1 mm of the mix is 1.64 and the weight ratio of $CaO/(SiO_2 - Al_2O_3)$ of fine grains below 1 mm in size is 1.54:1. Therefore, a simple decrease in the SiO_2 content gives a level of $[SiO_2 - Al_2O_3]$ in -1 mm which is below 1.8.

As shown in Tables 23 and 25, the raw materials mix prepared in Example 6 contains both return fines, part of which is crushed to a size below 1 mm, and relatively coarse grains of other ores so that the SiO_2 content in terms of sintered ore product is decreased to 5.4 wt%. The mix is characterized by an $[SiO_2 - Al_2O_3]$ in -1 mm value which is as high as 2.03 and a weight ratio of $CaO/(SiO_2 - Al_2O_3)$ of fine grains below 1 mm in size which is as high as 1.85:1.

In Example 7 illustrated in Tables 23 and 26, the raw materials mix is such that not only is the amount of silica added decreased to 0.7 wt% but also its grain size is lowered to below 1 mm and further it incorporates partially crushed iron ores containing a higher proportion of SiO_2 than for the mix as a whole, so that the SiO_2 content in terms of sintered ore is decreased to 5.0 wt%. In consequence, the $[SiO_2 - Al_2O_3]$ in -1 mm of the mix is 1.83 and the weight ratio of $CaO/(SiO_2 - Al_2O_3)$ of fine grains below 1 mm in size is 1.29:1.

The results obtained by sintering the raw materials mix prepared in Comparative Example 3 and Examples 6 and 7 are shown in Table 27 and illustrated in the graph of FIG 9. As is clear from Table 27 and FIG 9, the raw materials mix of Comparative Example 3, which was prepared by simply lowering the SiO_2 content, provided a sintered ore having a relatively high RDI value which could only be produced after extended sintering and in a low sinter to sinter cake ratio. The mix consumed a large amount of coke as it was sintered.

Table 27 Test Results

Run No. \ parameter	moisture (%)	coke content (%)	productivity (t/hr. m^2)	sintering time (min)
Com.Ex 5.	6.0	5.4	1.28	24.0
Ex.6	6.0	5.4	1.55	25.5
Ex.7	6.0	5.4	1.52	25.7

Run No. \ parameter	sinter to sinter cake ratio (%)	coke comsumption (Kg/t-s)	shatter index (+10 mm%)	R D I (%)	SiO_2 in sintered ore (%)
Com. Ex 5	75.7	47.2	86.0	49.1	5.4
Ex. 6	79.0	45.6	86.1	58.1	5.4
Ex. 7	77.2	46.7	84.9	58.5	5.0

The raws materials mix of Example 6, which contained return fines having somewhat more SiO_2 than the intended sintered ore product and part of which was crushed to a size below 1 mm provided a sintered ore having a high shatter index and an RDI value below 40. Such ore could be produced in a high sinter to sinter cake ratio, consuming a small amount of coke.

The raw material mix of Example 7 prepared by both lowering the amount of silica added to 0.7 wt% and decreasing its grain size to below 1 mm, and also by incorporating into the mix partially crushed iron ores which were relatively high in SiO_2 content provided a sintered ore having a desired value of RDI below 40 without sacrificing the productivity and sinter to sinter cake ratio, and without increasing the coke consumption, although the resulting sintered ore had its SiO_2 content decreased to 5.0 wt%.

TABLE 19 unit : wt%

composition ore	T.Fe	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	CW*6
M B R *1	67.77	0.34	96.51	1.53	0.69	0.14	0.04	0.42
RD CF *2	64.97	0.11	92.76	4.21	1.51	0.10	0.08	1.12
Mt. N. *3	61.28	0.07	87.51	6.10	2.88	0.06	0.05	2.64
Ham. *4	62.05	0.08	88.63	4.53	2.80	0.08	0.07	2.43
R. R. *5	57.34	0.17	81.79	5.70	2.36	0.15	0.12	8.38

*1 Mineracoes Brasileiras Reunidas S.A. (Brazil)

*2 Rio Doce common fine (Brazil)

*3 Mt. Newman Min. Co. Pty. Ltd. (Australia)

*4 Hamersley (Australia)

*5 Robe River (Australia) *6 Combined water

Table 20 unit : wt%

	T.Fe	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	CW
scale (mill scale)	72.84	67.18	29.48	0.73	0.23	0.09	0.59	0.05

Table 21 unit : wt%

	T.Fe	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	CW
silica	0.94	1.34	93.00	1.92	0.19	0.45	0.94

Table 22 unit : wt%

	T.Fe	SiO_2	Al_2O_3	CaO	MgO	CW
limestone	0.17	0.65	0.08	54.66	0.56	0.14

Table 23

Ingredients description	proportions (wt%)					
	Com. Ex. 3		Ex. 6		Ex. 7	
	new material	total	new material	total	new material	total
M B R	30	77.3	45	77.3	37	77.3
Rio Doce CF	15.5		0		15.3	
Mt. Newman	0		25.5		20	
Hamersley	25		0		0	
Robe River	15		15		15	
scale	3		3		3	
silica	1.4		1.4		0.7	
limestone	10.1		10.1		9.0	
tot. of new materials	100		100		100	
return fines	19.3		19.3		19.3	
coke breeze	3.4		3.4		3.4	

Table 24 Com. Ex. 3

	≥1 mm	<1 mm	total in raw material	sintered ore
Proportion by weight (%)	59.6	40.4	100.0	-
SiO_2 (%)	2.51	2.29	4.80	5.40
CaO (%)	3.95	2.53	6.48	7.29
Al_2O_3 (%)	0.95	0.65	1.60	1.80
CaO/SiO_2 (%)	1.57	1.10	1.35	1.35
$SiO_2 - Al_2O_3$ (%)	-	1.64	-	-
$\frac{CaO}{SiO_2 - Al_2O_3}$	-	1.54	-	-

Table 25 Ex. 6

	≥1 mm	<1 mm	total in raw material	sintered ore
Proportion by weight (%)	52.5	47.5	100.0	-
SiO_2 (%)	1.86	2.94	4.80	5.40
CaO (%)	2.72	3.76	6.48	7.29
Al_2O_3 (%)	0.69	0.91	1.60	1.80
CaO/SiO_2 (%)	1.46	1.28	1.35	1.35
$SiO_2 - Al_2O_3$ (%)	-	2.03	-	-
$\frac{CaO}{(SiO_2 - Al_2O_3)}$	-	1.85	-	-

Table 26 Ex. 7

	≥1 mm	<1 mm	total in raw material	sintered ore
Proportion by weight (%)	56.9	43.1	100.0	-
SiO_2 (%)	1.97	2.53	4.5	5.00
CaO (%)	3.72	2.36	6.08	6.75
Al_2O_3 (%)	0.92	0.70	1.62	1.80
CaO/SiO_2 (%)	1.89	0.93	1.35	1.35
$SiO_2 - Al_2O_3$ (%)	-	1.83	-	-
$\frac{CaO}{(SiO_2 - Al_2O_3)}$	-	1.29	-	-

As described in the foregoing, the process of this invention is comparable with, or even superior to, the conventional sintering technique with respect to productivity, coke consumption, shatter index and other factors, while it can lower the SiO_2 content of the sintered ore to below 5.4 wt% and decrease the slag content (SiO_2 plus CaO) of the ore without greatly increasing the level of RDI. Accordingly, the process can greatly curtail the amount of slag charged into a blast furnace, yielding an appreciable decrease in the blast furnace fuel consumption.

CLAIMS

1. A process for producing a self-fluxing sintered ore using a raw materials mix comprising iron, ore, limestone, silica and coke, at least 25 wt% of said mix consisting of fine grains below 1 mm in size and said mix containing not more than 5.4 wt% of SiO_2 in terms of "sintered ore product" (said sintered ore product being a product from which coke, combined CO_2 and combined water have been removed by sintering of the mix), said process being characterized by controlling the SiO_2 content of said fine grains to be at least 50 wt% of the total SiO_2 content of the raw materials mix, and sintering the thus controlled mix.

2. A process for producing a self-fluxing sintered ore using a raw materials mix comprising iron ore, silica, limestone, coke and return fines, at least 25 wt% of said mix consisting of fine grains below 1 mm in size and said mix containing not more than 5.4 wt% of SiO_2 in terms of "sintered ore product" (as defined in Claim 1 above), said process being characterized by controlling the SiO_2 content of said fine grains to be between 2.4 and 3.0 wt% of the raw materials mix (dry) and the basicity (CaO/SiO_2 ratio) of said fine grains to be not more than 1.3:1, and sintering the thus controlled mix.

3. A process according to Claim 2, wherein the sum of the CaO and SiO_2 contained in said fine grains is at least 4.0 wt% of said mix.

4. A process according to Claim 2 or Claim 3, wherein the SiO_2 content of said fine grains minus the Al_2O_3 content of said fine grains is between 1.8 and 2.4 wt% of the raw materials mix, and the weight ratio of CaO to (SiO_2 - Al_2O_3) contained in said fine grains is between 0.5:1 and 2.0:1.

5. A process according to Claim 4, wherein the weight ratio of CaO to (SiO_2 - Al_2O_3) contained in said fine grains is between 1.0:1 and 1.8:1.

6. A composition consisting of a raw materials mix for producing a self-fluxing, sintered ore said mix comprising iron ore, limestone, silica and coke, at least 25 wt% of said mix consisting of fine grains below 1 mm in size and said mix containing not more than 5.4 wt% of SiO_2 in terms of "sintered ore product" (said sintered ore product being a product from which coke, combined CO_2 and combined water have been removed by sintering of the mix), said mix being characterized by an SiO_2 content of said fine grains of at least 50% of the total SiO_2 content of said mix.

7. A composition consisting of a raw materials mix for producing a self-fluxing, sintered ore, said mix comprising iron ore, limestone, silica, coke and return fines, at least 25 wt% of said mix consisting of fine grains below 1 mm in size, and not more than 5.4 wt% of SiO_2 in terms of "sintered ore product" (as defined in Claim 6 above), said mix being characterized by an SiO_2 content of said fine grains between 2.4 and 3.0 wt% of said mix (dry), and the basicity (CaO/SiO_2 ratio) of said fine grains being not more than 1.5:1.

8. A self-fluxing sintered iron ore which contains not more than 5.4 weight % of SiO_2 and in which fine grains below 1 mm in size account for at least 25% of the ore, characterized in that said fine grains have a basicity (CaO/SiO_2 ratio) below 1.5:1.

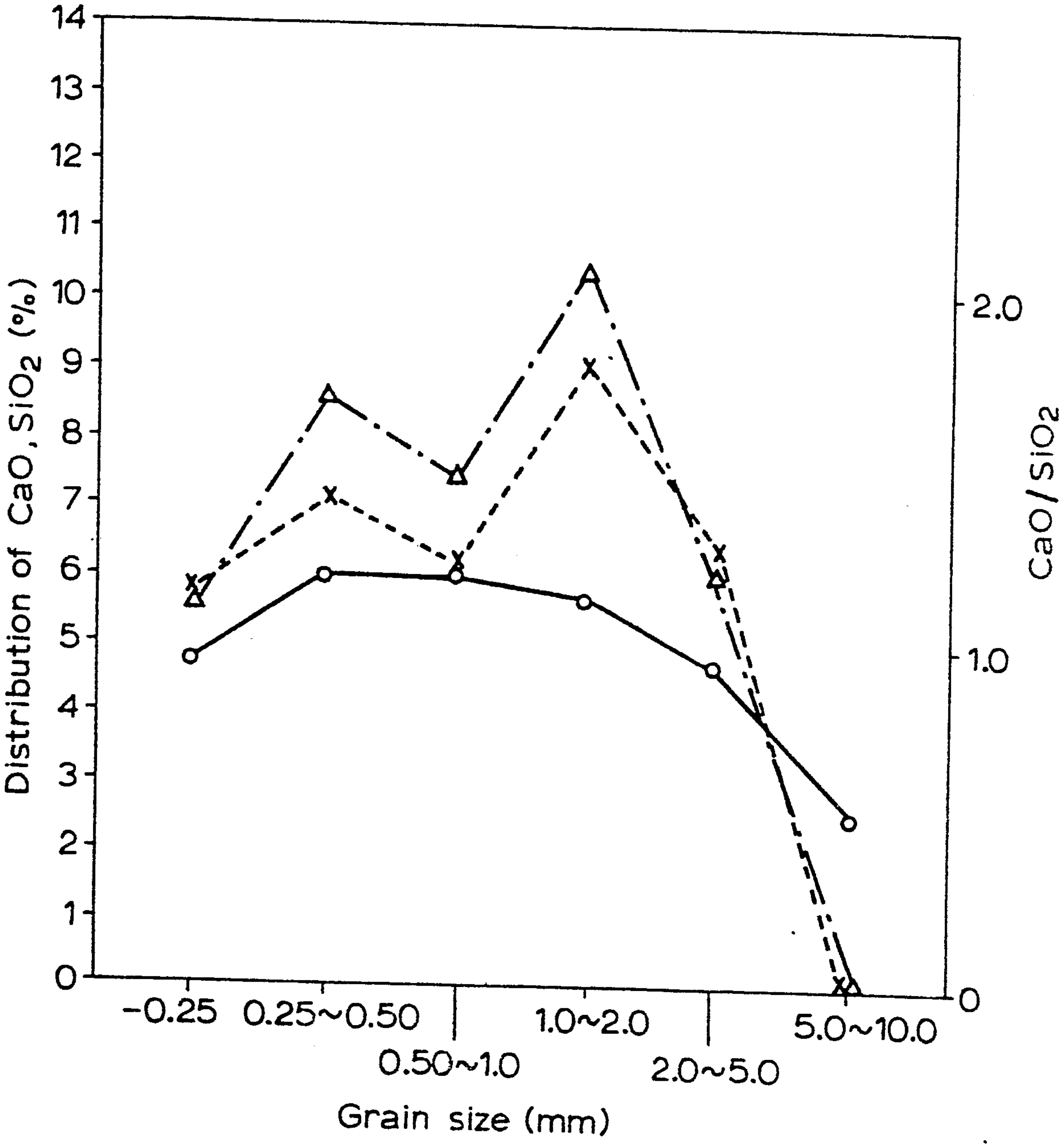
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Distribution of CaO, SiO_2 (%)
2.0
1.0
0
CaO/SiO_2
-0.25
0.25~0.50
0.50~1.0
1.0~2.0
2.0~5.0
5.0~10.0
Grain size (mm)
△ CaO
○ SiO_2
x CaO/SiO_2

Fig.1

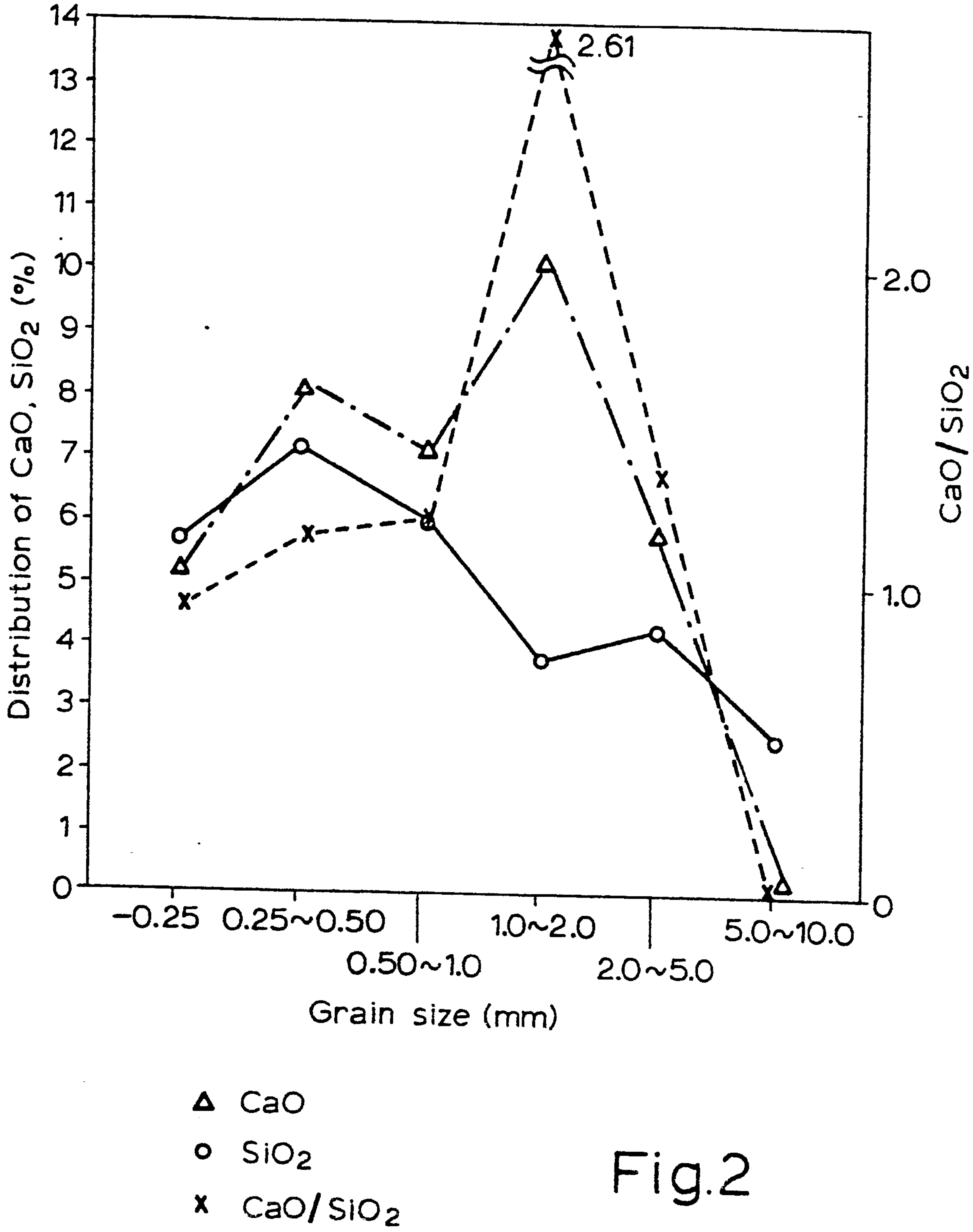
Distribution of CaO, SiO₂ (%)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
2.61
CaO/SiO₂
0
1.0
2.0
-0.25
0.25~0.50
0.50~1.0
1.0~2.0
2.0~5.0
5.0~10.0
Grain size (mm)
△ CaO
○ SiO₂
x CaO/SiO₂

Fig.2

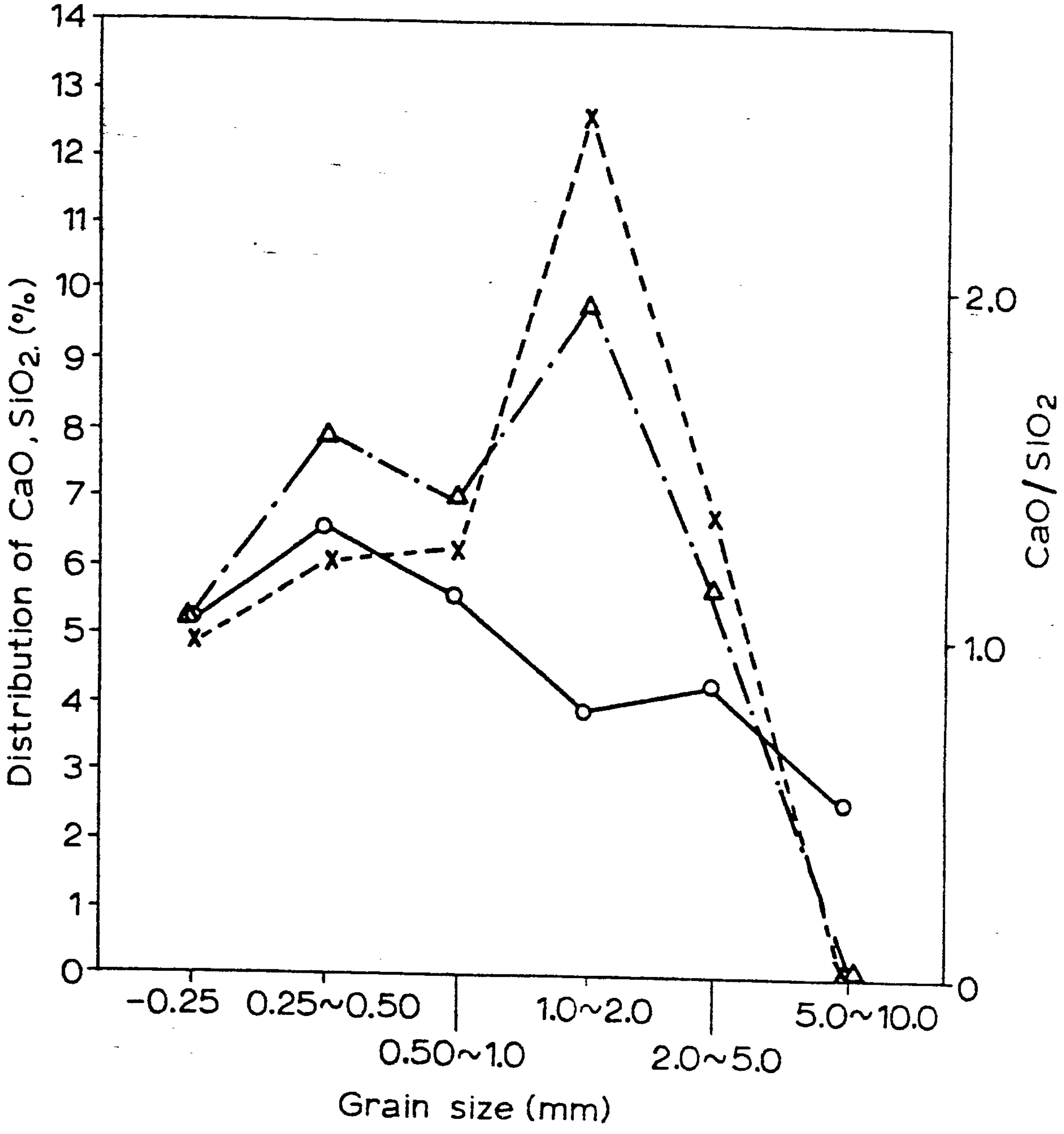
Distribution of CaO, SiO₂ (%)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
CaO/SiO₂
2.0
1.0
0
-0.25
0.25~0.50
0.50~1.0
1.0~2.0
2.0~5.0
5.0~10.0
Grain size (mm)
△ CaO
○ SiO₂
x CaO/SiO₂

Fig.3

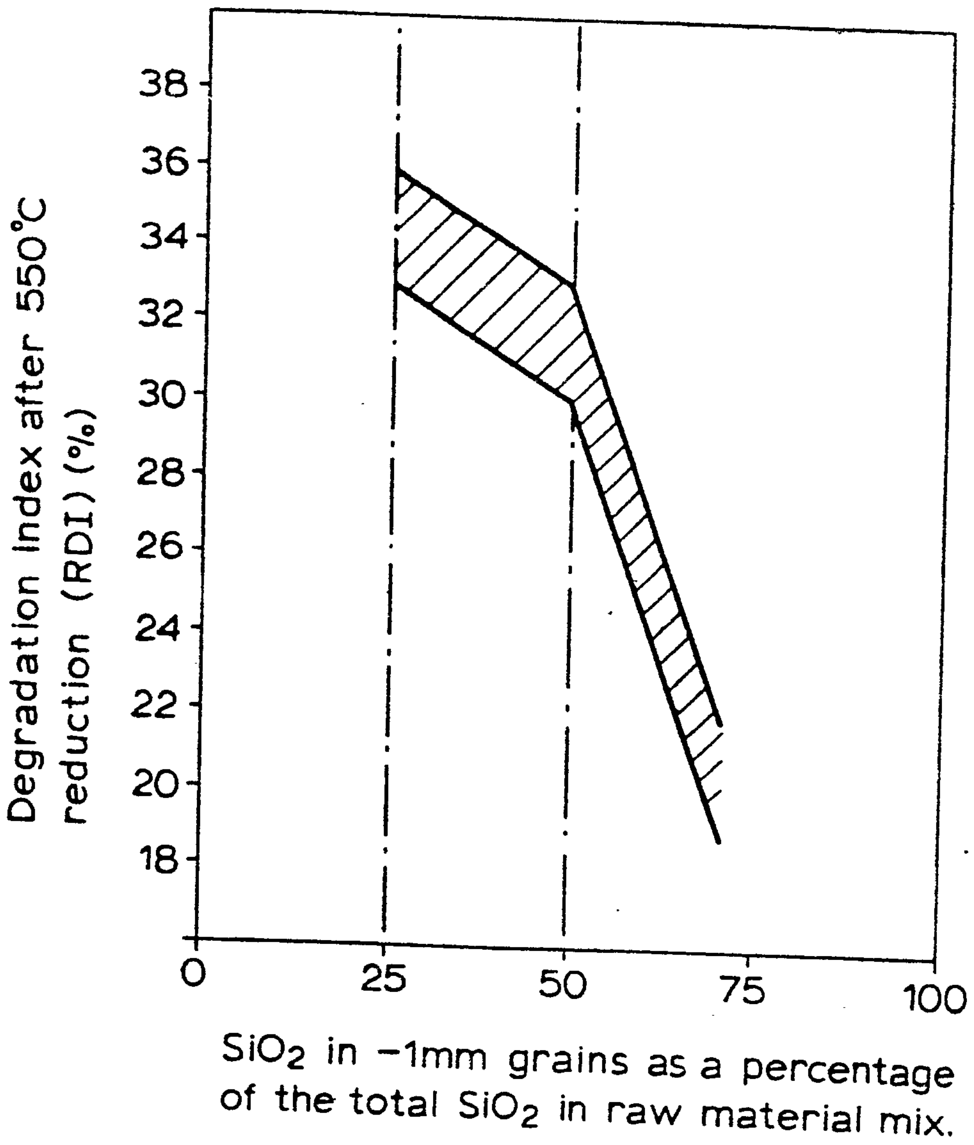
Degradation Index after 550°C reduction (RDI) (%)
38
36
34
32
30
28
26
24
22
20
18
0
25
50
75
100
SiO2 in −1mm grains as a percentage of the total SiO2 in raw material mix.

Fig. 4

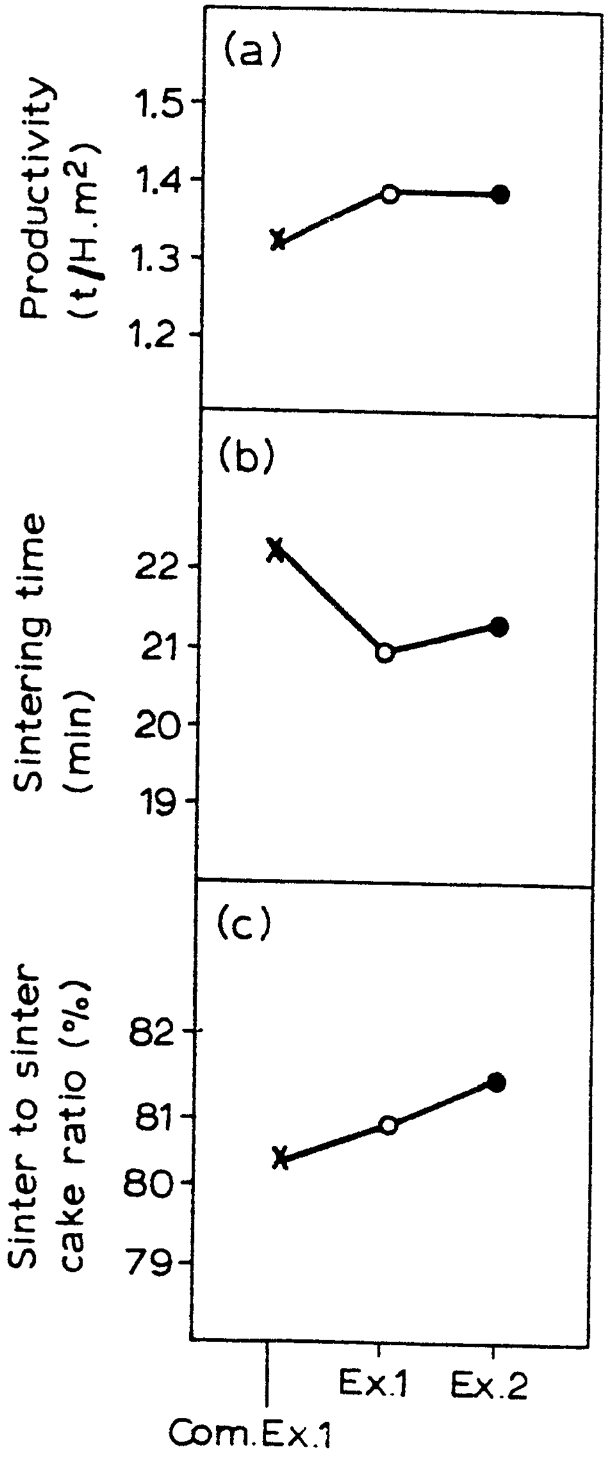
(a)
Productivity (t/H.m²)
1.5
1.4
1.3
1.2
(b)
Sintering time (min)
22
21
20
19
(c)
Sinter to sinter cake ratio (%)
82
81
80
79
Com.Ex.1
Ex.1
Ex.2

Fig.5

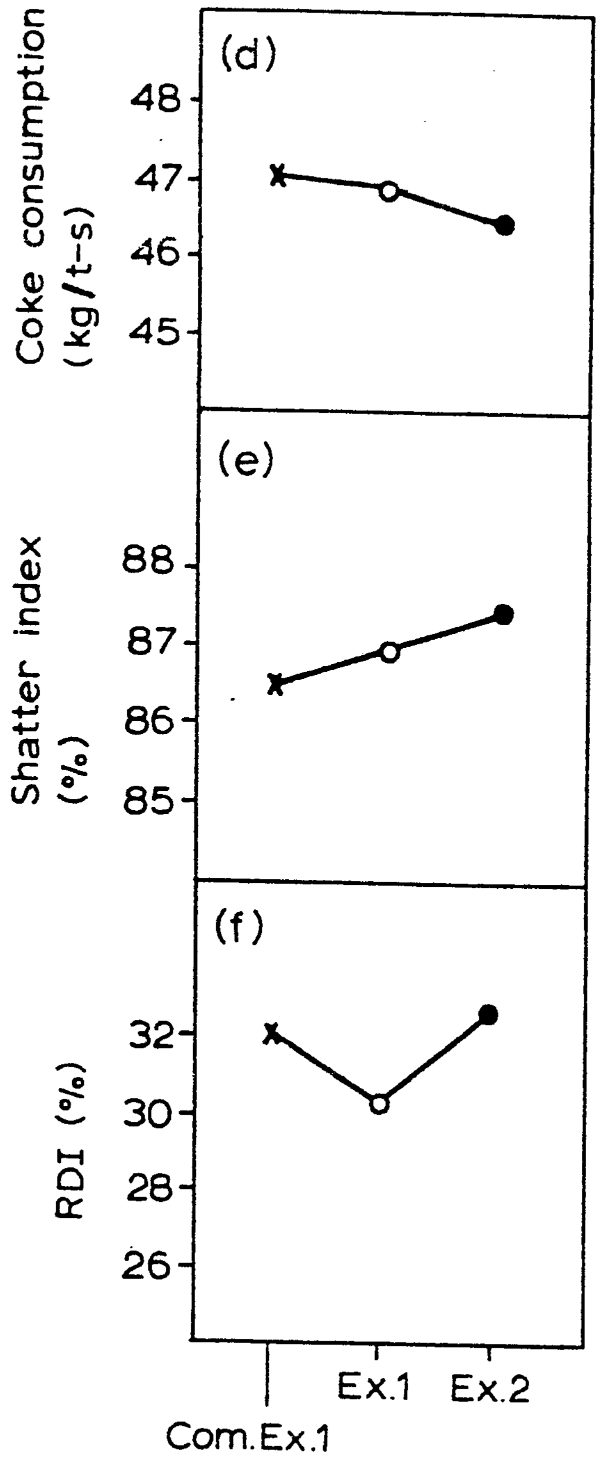
(d)
Coke consumption (kg/t-s)
48
47
46
45
(e)
Shatter index (%)
88
87
86
85
(f)
RDI (%)
32
30
28
26
Com.Ex.1
Ex.1
Ex.2

Fig.5

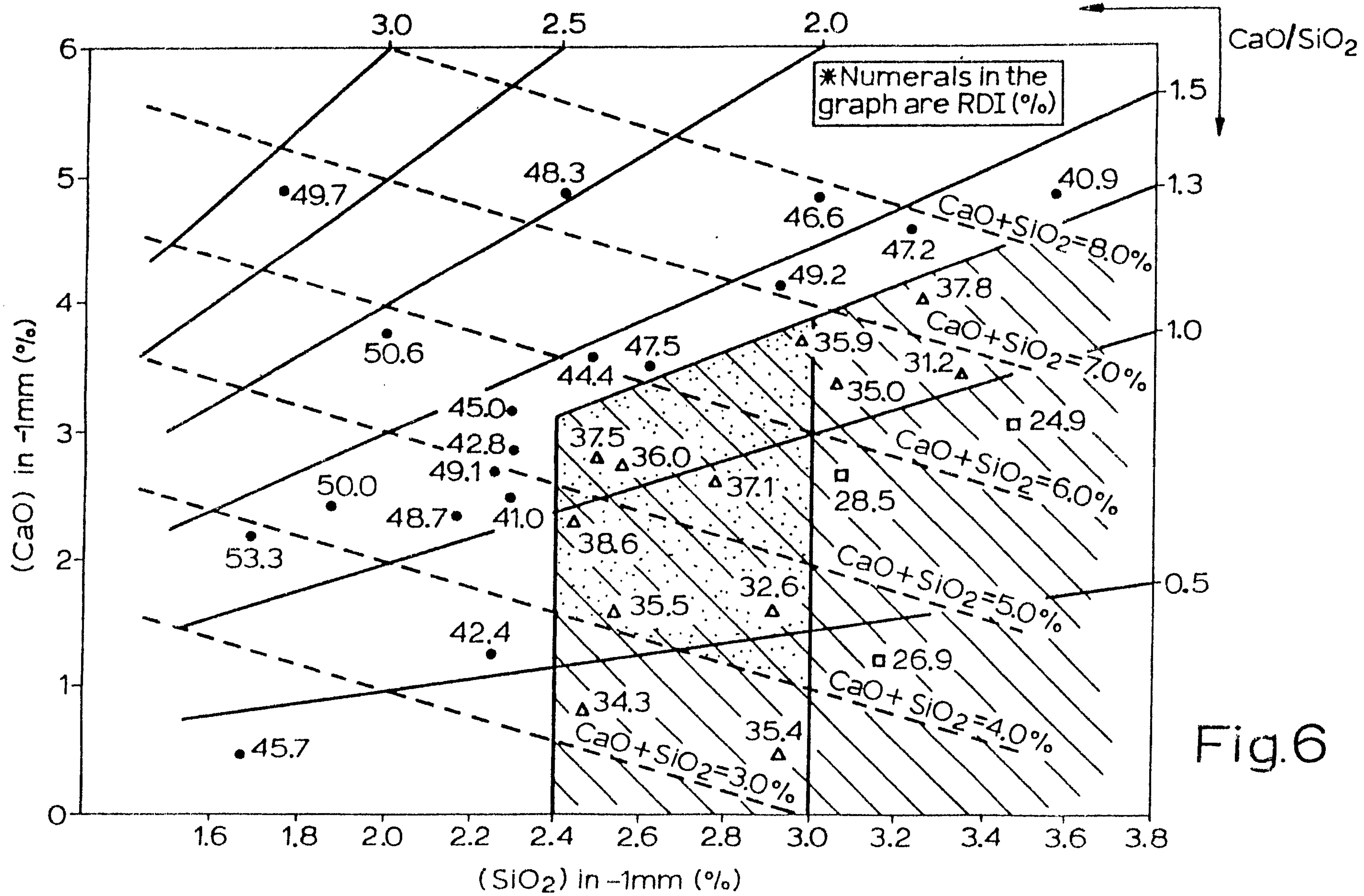
CaO/SiO$_2$
3.0
2.5
2.0
1.5
1.3
1.0
0.5
*Numerals in the graph are RDI (%)
(CaO) in -1mm (%)
0
1
2
3
4
5
6
(SiO$_2$) in -1mm (%)
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
CaO+SiO$_2$=8.0%
CaO+SiO$_2$=7.0%
CaO+SiO$_2$=6.0%
CaO+SiO$_2$=5.0%
CaO+SiO$_2$=4.0%
CaO+SiO$_2$=3.0%
49.7
48.3
46.6
40.9
47.2
49.2
37.8
50.6
47.5
44.4
35.9
31.2
35.0
45.0
24.9
42.8
37.5
36.0
49.1
50.0
37.1
28.5
48.7
41.0
53.3
38.6
32.6
35.5
42.4
26.9
34.3
35.4
45.7

Fig.6

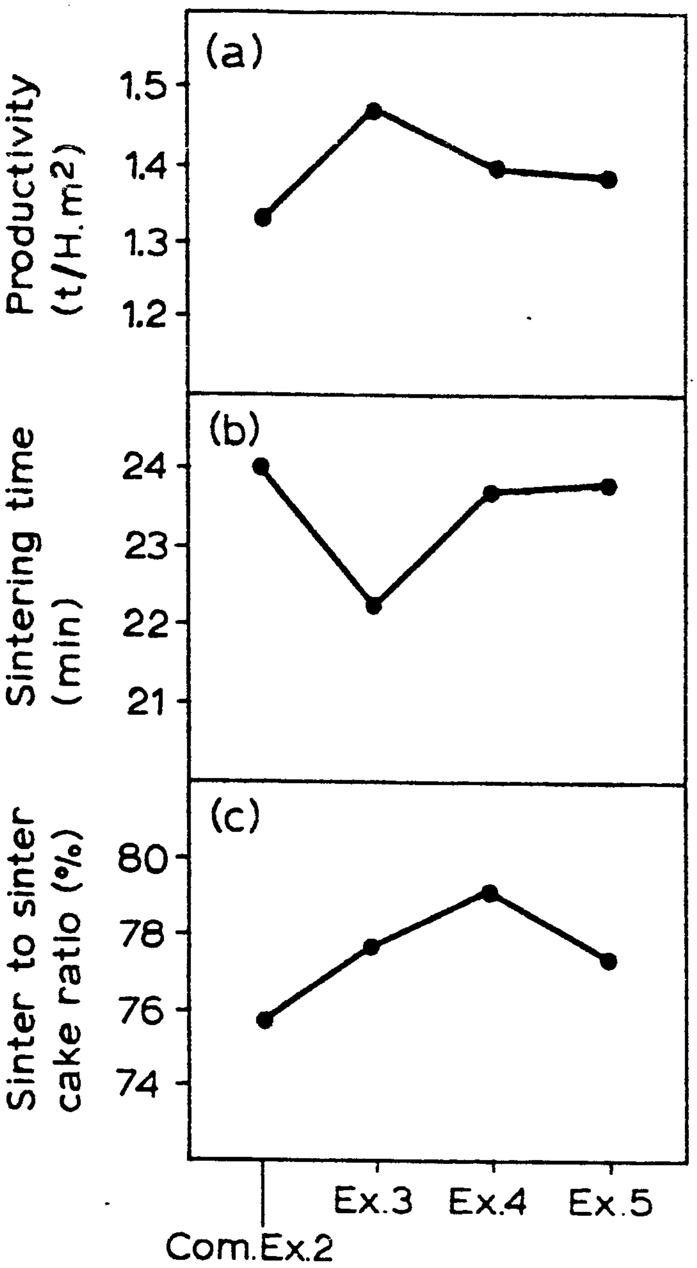
(a)
Productivity (t/H.m²)
1.5
1.4
1.3
1.2
(b)
Sintering time (min)
24
23
22
21
(c)
Sinter to sinter cake ratio (%)
80
78
76
74
Com.Ex.2
Ex.3
Ex.4
Ex.5

Fig. 7

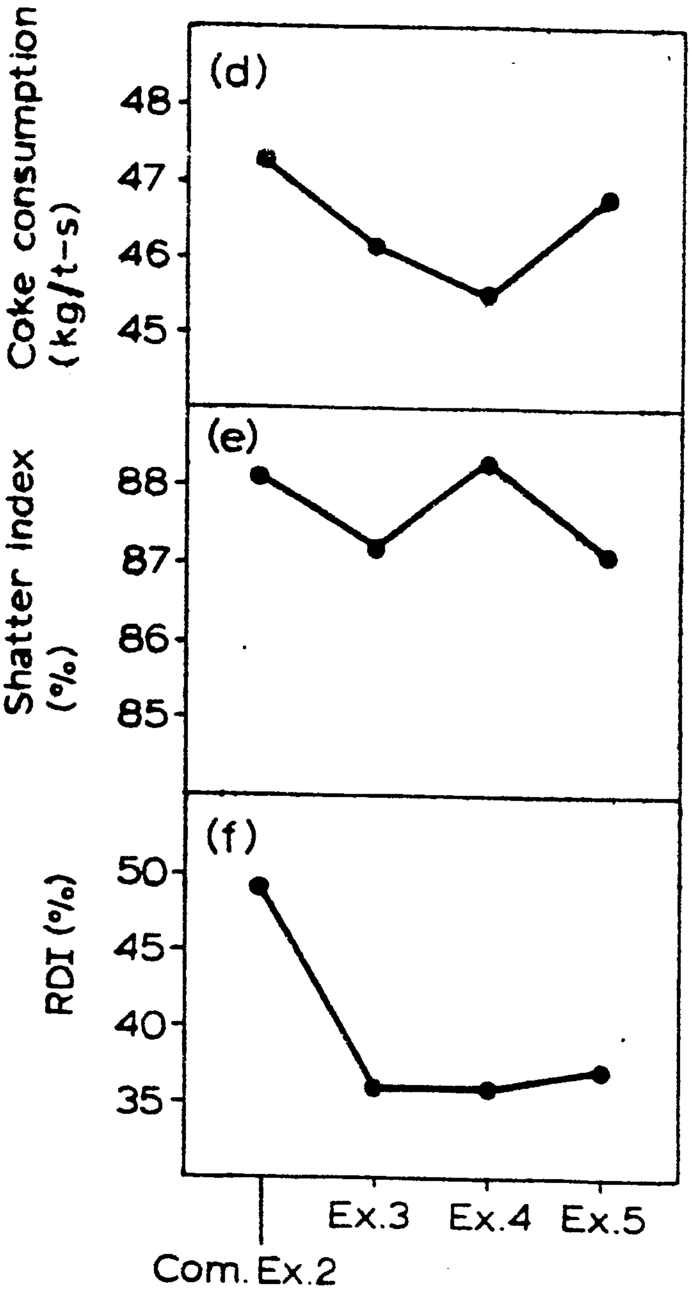
(d)
Coke consumption (kg/t-s)
48
47
46
45
(e)
Shatter Index (%)
88
87
86
85
(f)
RDI (%)
50
45
40
35
Com. Ex.2
Ex.3
Ex.4
Ex.5

Fig.7

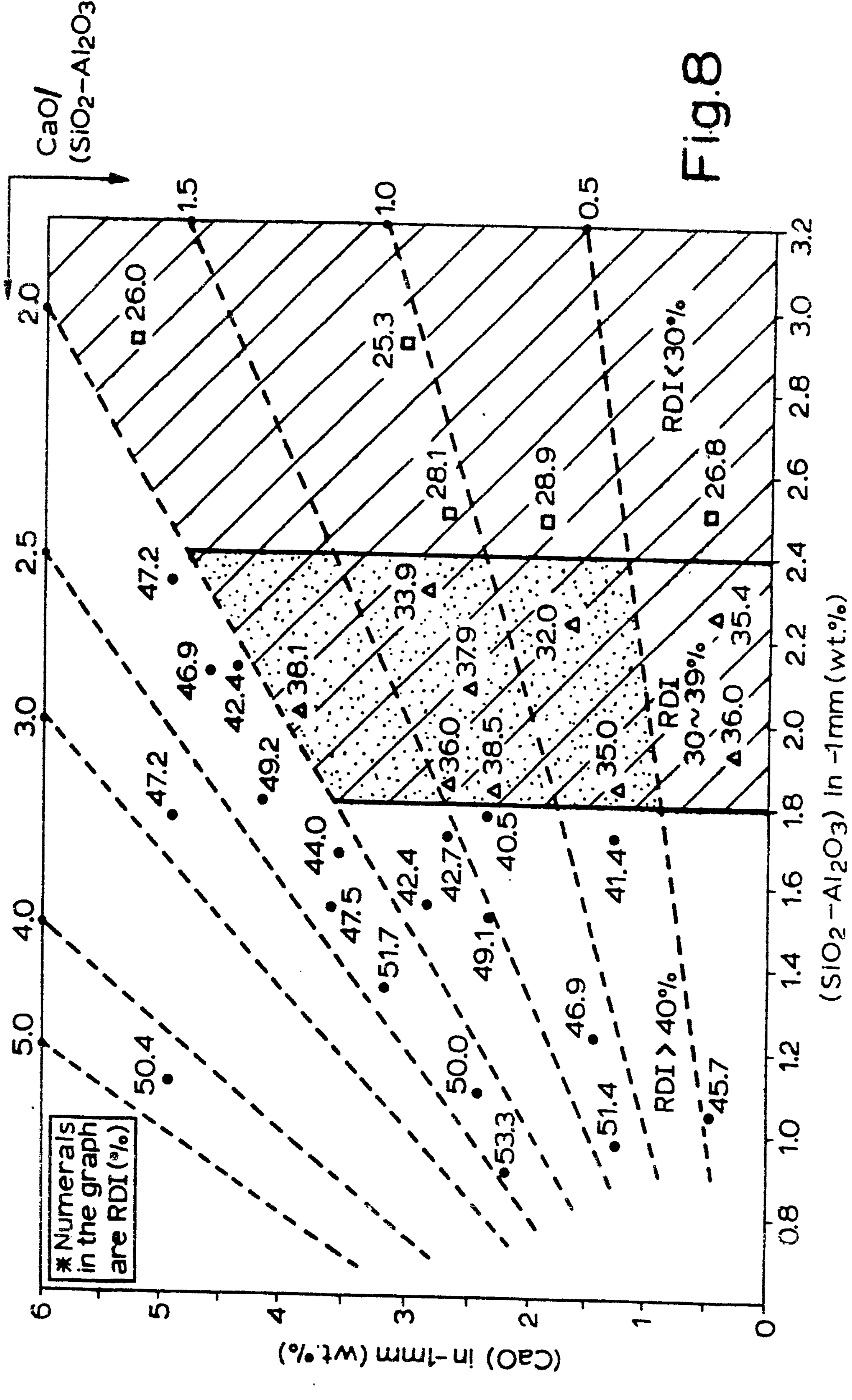
CaO/ (SiO2−Al2O3)
2.0
2.5
3.0
4.0
5.0
1.5
1.0
0.5
* Numerals in the graph are RDI (%)
26.0
25.3
28.1
28.9
26.8
RDI<30%
47.2
46.9
42.4
33.9
38.1
37.9
32.0
49.2
36.0
38.5
35.0
RDI 30~39%
35.4
36.0
47.2
44.0
47.5
42.4
42.7
40.5
41.4
51.7
49.1
46.9
RDI>40%
50.4
50.0
53.3
51.4
45.7
6
5
4
3
2
1
0
(CaO) in −1mm (wt.%)
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
(SiO2−Al2O3) In −1mm (wt.%)

Fig.8

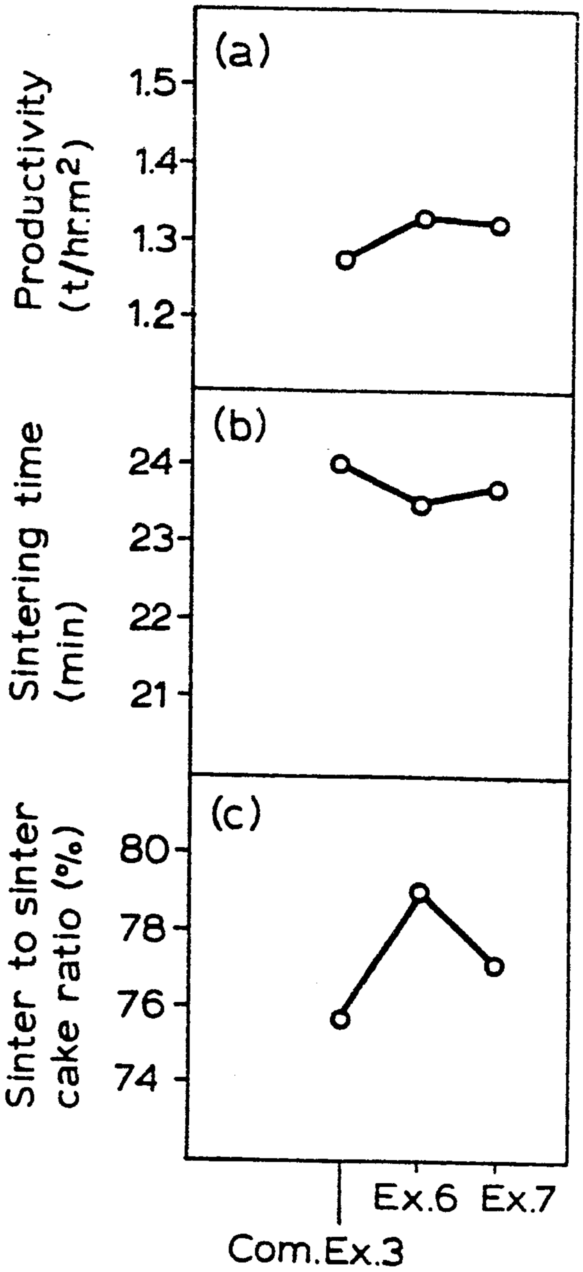
(a)
Productivity (t/hr.m²)
1.5
1.4
1.3
1.2
(b)
Sintering time (min)
24
23
22
21
(c)
Sinter to sinter cake ratio (%)
80
78
76
74
Com.Ex.3
Ex.6
Ex.7

Fig.9

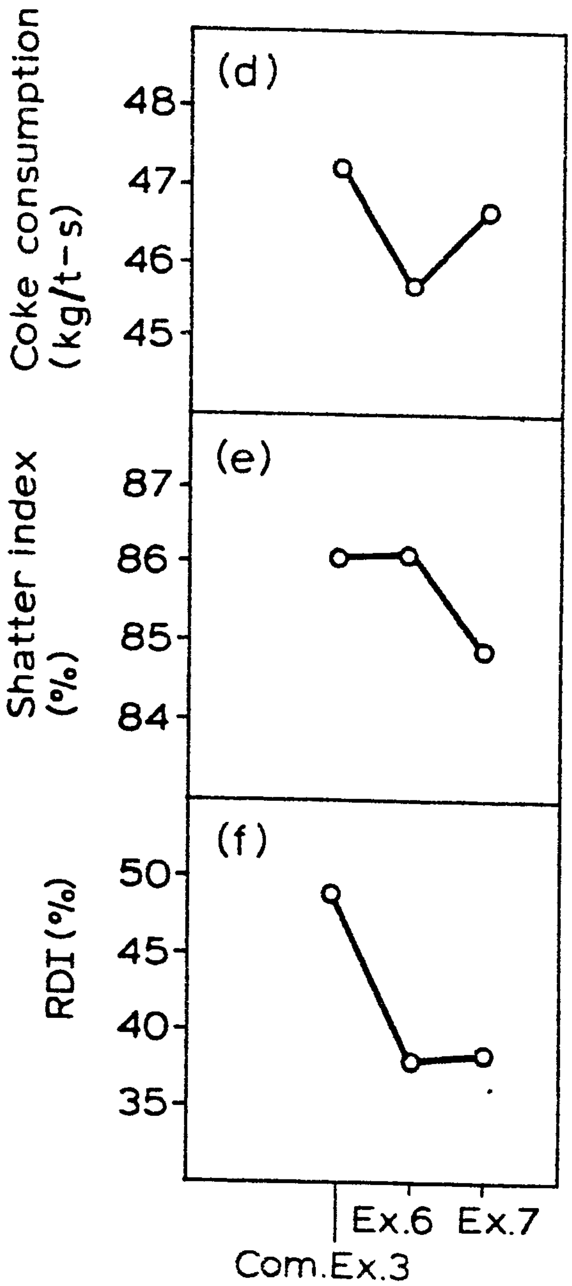
Coke consumption (kg/t-s)
(d)
48
47
46
45
Shatter index (%)
(e)
87
86
85
84
RDI (%)
(f)
50
45
40
35
Com.Ex.3
Ex.6
Ex.7

Fig.9

0015085

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 80 30 0299

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
A,P P	Patents Abstracts of Japan Vol. 3, No. 91, 3 August 1979, page 146C54 & JP - A - 54 - 71004 --	
A	US - A - 3 519 386 (REPUBLIC STEEL) --	
A	AUFBEREITUNGS-TECHNIK, Nr. 12, 1975 Wiesbaden O. BURGHARDT et al. "Qualitätsmerkmale von Sinter unter Beeinflussung der verschiedenen basischen Zuschläge" pages 631 to 634 --	
A	STAHL UND EISEN, Vol. 81, No. 1,1961 Düsseldorf L. v. BOGDANDY "Herstellung und Verarbeitung von Erzsinter mit höheren Basengraden im Hochofen" pages 12 to 22 --	
A	GMELIN-DURRER "Metallurgie des Eisens" 4th edition, Vol. 1a 1964, VERLAG CHEMIE, Weinheim pages 425a to 447a ----	

CLASSIFICATION OF THE APPLICATION (Int. Cl.3)

C 22 B 1/16

TECHNICAL FIELDS SEARCHED (Int.Cl.3)

C 22 B 1/16

CATEGORY OF CITED DOCUMENTS

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E: conflicting application
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L: citation for other reasons

&: member of the same patent family, corresponding document

☒ The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	21-05-1980	SUTOR