

- 1 -

Process and Plant for Producing Titania Slag from Ilmenite

Technical Field

5 The present invention relates to a process for producing titania slag from ilmenite, and to a corresponding plant.

Ilmenite, which beside titanium dioxide contains large amounts of iron oxides ($x \cdot \text{TiO}_2 + y \cdot \text{FeO} + z \cdot \text{Fe}_2\text{O}_3$), is one of the most important starting materials, apart
10 from rutile, for recovering metallic titanium and titanium compounds, such as titanium dioxide used for pigment production. Separating the iron from the ore usually is effected by electric melting of ilmenite in a metallurgical furnace, the iron oxides being reduced to metallic iron, which is precipitated from the slag containing titanium dioxide. However, a disadvantage of this process is the very high demand for
15 electric energy, which is about 2,200 kWh per ton of titania slag and represents the main part of the production costs.

From U.S. 3,765,868 there is known a process for producing titania slag from ilmenite, in which the crude ore first of all is partially reduced in a rotary kiln and is
20 subsequently cooled to a temperature of at least 150°C, before the magnetic fraction containing titanium dioxide is separated from the non-magnetic ash and char by means of a magnetic separator and is finally molten in an electric furnace. This process is also characterized by a high demand for energy. Another disadvantage of the aforementioned process is the fact that before the reduction the
25 ilmenite used must first be pelletized.

Description of the Invention

Therefore, it is the object underlying the present invention to provide a process for
30 producing titania slag, which with at least the same quality of the titania slag produced has a rather low demand for energy.

CONFIRMATION COPY

- 2 -

In accordance with the invention, this object is solved by a process and a plant with the features of claims 1 and 17, respectively. Advantageous aspects of the invention are evident from the dependent claims.

5 In accordance with the present invention, it could surprisingly be found that the demand for energy for producing titania slag from ilmenite can be reduced by 40 to 50% as compared with the processes known so far, when the ilmenite is prerduced prior to electric melting and is introduced into the electric furnace in the hot condition, i.e. without cooling or upon being cooled only little after the
10 partial reduction. Another advantage of this procedure consists in the increase of the magnetic susceptibility of the ilmenite with respect to the impurities, such as chromium, contained in the starting ore, so that in the case of a magnetic separation a reliable separation between fractions containing titanium dioxide and fractions free from titanium can be achieved.

15 In principle, the partial reduction a) can be effected in any apparatus known to those skilled in the art for this purpose, for instance in a rotary kiln. Particularly good results are obtained, however, when the partial reduction a) of the ilmenite is performed in a fluidized bed, preferably in a circulating fluidized bed, namely either
20 in a one-stage or multi-stage operation. Due to the high mass and heat transfer in fluidized beds, a uniform reduction of the material used is thereby achieved with a minimum expenditure of energy.

25 Preferably, the grain size of the granular ilmenite used is less than 1 mm and particularly preferably less than 400 μm .

30 As reducing agent for the partial reduction a) of the ilmenite, all substances known to those skilled in the art for this purpose can be used in principle, and in particular coal, char, molecular hydrogen, gas mixtures containing molecular hydrogen, carbon monoxide and gas mixtures containing carbon monoxide, for instance reformed gas, turned out to be useful. As reducing agent, there is preferably used a gas mixture containing carbon monoxide and molecular hydrogen, particularly preferably a gas mixture of 60 to 80 vol-% carbon monoxide and 40 to 20 vol-% molecular hydrogen, and quite particularly preferably a gas mixture of 70 vol-%

- 3 -

carbon monoxide and 30 vol-% hydrogen in combination with char. If the partial reduction is performed in a circulating fluidized bed, this can for instance easily be realized in that ilmenite to be partially reduced and char are continuously supplied to the fluidized-bed reactor via a solids supply conduit, and the solids in the reactor
5 are fluidized by a gas mixture containing carbon monoxide and molecular hydrogen.

For the partial reduction a), the process conditions preferably are adjusted such that the degree of metallization of the product obtained by this process step is 50
10 to 95% and particularly preferably 70 to 80%, based on its iron content.

To further reduce the energy demand of the process, it is proposed in accordance with a development of the invention to first of all preheat the ilmenite before the partial reduction a) in one or more heat exchangers to a temperature of 500 to
15 900°C, particularly preferably 600 to 850°C, and quite particularly preferably about 800°C, and subsequently heat the preheated material in a calcining reactor upstream of the reduction reactor, preferably a reactor with stationary fluidized bed, to a temperature of more than 900°C and particularly preferably more than 1,000°C.

20 In accordance with a particular embodiment of the present invention, the production of the char used as reducing agent is effected in one process step with the heating of the ilmenite in a stationary fluidized-bed reactor. For this purpose, the preheated ilmenite together with coal, preferably coal with a grain size of less than
25 5 mm, and molecular oxygen or a gas mixture containing molecular oxygen, is introduced into a fluidized-bed reactor and heated there to a temperature of preferably more than 900°C and particularly preferably more than 1,000°C. By means of this comparatively high carbonization temperature, the formation of hydrocarbons, e.g. tar, which will disturb in the succeeding process steps, can reliably be
30 prevented. The fluidization of the solids preferably is effected by means of the gas mixture used as reducing agent in the succeeding step of partial reduction, the degree of carbonization being adjustable by adjusting the retention time to a suitable value.

- 4 -

To achieve a particularly efficient procedure, it is proposed in accordance with a development of the invention to circulate the fluidizing gas. This can for instance be effected such that the off gas from the reduction reactor is passed through the heat exchanger(s) used for preheating the ilmenite, subsequently the off gas possibly is passed through a waste heat boiler by generating steam, in which steam is generated, before dust is removed from the cooled waste gas and the same possibly is further cooled, in a CO₂ absorber possibly is separated from the carbon dioxide obtained during the partial reduction of ilmenite, is heated in a succeeding gas heater and finally again supplied to the reduction reactor and possibly the carbonization reactor as fluidizing gas.

If the crude ilmenite used has a comparatively high content of FeO, it was found to be expedient to subject the same to an oxidative pretreatment prior to the partial reduction a), in order to rather completely oxidize the FeO to obtain Fe₂O₃. This is advantageous because FeO is present in a crystal lattice structure, which largely resists the attack of reducing gases, whereas the lattice structure of Fe₂O₃ resulting from the oxidation of FeO allows an efficient diffusion of gas into the pores of the material. Preferably, the oxidation is performed such that the FeO content of the treated material after the oxidation is less than 5 wt-%, and particularly preferably less than 3 wt-%.

In accordance with a development of the invention it is proposed to perform the oxidation of the crude ilmenite as well as the partial reduction in a circulating fluidized bed, preferably at a temperature between 600 and 1000°C.

In particular when ilmenite containing chromite is used as starting material or coal and/or char is used as reducing agent, it turned out to be advantageous to subject the partially reduced ilmenite to a magnetic separation before charging the same into the electric furnace, in order to separate the magnetic fraction rich in titanium dioxide from a non-magnetic fraction, which substantially contains chromite, ash and, if used as reducing agent, char, and to only transfer the magnetic fraction obtained thereby into the electric furnace. In this case, the temperature of the partially reduced material used during the magnetic separation preferably is at least 600°C, particularly preferably at least 675°C, and quite particularly preferably

- 5 -

about 700°C. Particularly preferably, the magnetic fraction subsequently is transferred into the electric furnace without cooling or heating. The energy required for cooling the partially reduced material after the partial reduction on the one hand and the energy required for heating the material supplied to the electric furnace to the operating temperatures in the furnace on the other hand thus is minimized without a substantial reoxidation of the partially reduced material taking place before entrance into the electric furnace. The non magnetic fraction can be further processed and the char in this non magnetic fraction can be reused in the process, e.g. as a feed material.

Preferably, the titania slag withdrawn from the electric furnace contains 75 to 90 wt-% and particularly preferably about 85 wt-% titanium dioxide, and the liquid pig iron contains more than 94 wt-% metallic iron.

A plant in accordance with the invention, which can be used in particular for performing the process described above, comprises a carbonization reactor constituting a stationary fluidized-bed reactor for carbonizing coal by heating ilmenite at the same time, a reduction reactor constituting a circulating fluidized-bed reactor for the partial reduction of ilmenite, and an electric furnace.

Preferably, the carbonization reactor is connected with the reduction reactor via a connecting passage such that the solids/gas suspension can pass from the upper part of the carbonization reactor into the lower part of the reduction reactor, and downstream of the reduction reactor a cyclone is provided for separating the solids from the solids/gas suspension, a solids return conduit extending from the cyclone to the carbonization reactor.

In accordance with an embodiment of the invention it is proposed to provide at least one preheating stage including a solids/gas suspension heat exchanger and a downstream cyclone upstream of the carbonization reactor, in which the ilmenite is preheated to temperatures of 500 to 900°C, particularly preferably 600 to 850°C and quite particularly preferably about 800°C, before being charged into the carbonization reactor.

- 6 -

In accordance with an embodiment of the invention it is proposed to provide a means for circulating the fluidizing gas in the plant.

5 In accordance with a particular embodiment of the present invention, the plant in addition comprises a magnetic separator.

10 The invention will subsequently be described in detail with reference to embodiments and the drawing. All features described and/or illustrated in the drawing form the subject-matter of the invention per se or in any combination, independent of their inclusion in the claims or their back-reference.

Brief Description of the Drawing

15 Fig. 1 shows a process diagram of a process and a plant in accordance with a first embodiment of the present invention; and

Fig. 2 shows a process diagram of a process and a plant in accordance with a second embodiment of the present invention.

20 Description of the Preferred Embodiments

25 In the process for producing titania slag from ilmenite as shown in Fig. 1, a mixture of char and ilmenite, which previously were withdrawn from the bins 2, 3 and were mixed with each other in the mixing tank 4, is continuously charged via the solids supply conduit 1 into the suspension heat exchanger 5 of a first preheating stage, in which the material preferably is suspended and preheated by the off gas withdrawn from a second preheating stage. Subsequently, the suspension is conducted by the gas stream into a cyclone 6, in which the solids are separated from the gas. The separated solids then are delivered through conduit 7 into a second
30 Venturi-type suspension heat exchanger 8, where they are further preheated to a temperature of about 800°C, and in a downstream cyclone 9 are again separated from the gas stream.

- 7 -

The ore thus preheated is delivered through the solids conduit 7' into the carbonization reactor 10, to which coal with a grain size of less than 5 mm as well as oxygen are supplied via the solids conduit 7". Furthermore, a fluidizing gas consisting of 70 vol-% carbon monoxide and 30 vol-% molecular hydrogen with a temperature of about 600°C is supplied to the carbonization reactor 10 via the gas conduit 11 for fluidizing the solids in the reactor 10 by forming a stationary fluidized bed. The oxygen and fluidizing gas supply rate as well as the retention time of the solids in the carbonization reactor 10 are adjusted such that a temperature of about 1,050°C is obtained in the fluidized bed and a sufficient carbonization of the coal is achieved. The coal supplied in conduit 7" can be externally predried and/or precarbonized before entering the reactor 10.

The gas-solids mixture is continuously passed from the carbonization reactor 10 via the connecting passage 12 into the reduction reactor 13, in which the solids are fluidized by the fluidizing gas supplied via the gas conduit 11' by forming a circulating fluidized bed, and the ilmenite is reduced by the reducing agents, in particular by carbon monoxide, to a degree of metallization of about 70%, based on its iron content.

Subsequently, the suspension is conducted by the gas stream into the cyclone 14 downstream of the reduction reactor 13, in which cyclone the solids are separated from the gas. Thereupon, the separated solids are recirculated through the return conduit 15 into the carbonization reactor 10, whereas the off gas containing CO, H₂ and CO₂ with a temperature of about 1,000°C is transferred via the gas conduit 16 first into the suspension heat exchanger 8 of the second preheating stage and from there via the cyclone 9 and the gas conduit 16' into the suspension heat exchanger 5 of the first preheating stage, in which the same is cooled to about 500°C. Via the gas conduit 16", the off gas separated in the cyclone 6 downstream of the suspension heat exchanger 5 is first conducted through a waste heat boiler (not shown), in which the off gas is cooled to approximately 200°C by generating steam (4 bar), before it is separated from dust in a scrubber 17 and cooled further to about 30°C. The solid/sludge outlet of the scrubber (fines of ore and carbon) can be further used in the process, e.g. after pelletizing as feed material to mixing

- 8 -

tank 4 and/or to the reactor 10 and/or 13 and/or furnace 22. Subsequently, carbon dioxide is removed from the off gas in the CO₂ absorber 18, and the gas mixture thus purified can be preheated in a heat exchanger, e.g. with the gas from conduit 16", and is heated to about 600°C in the gas heater 19, before it is recirculated as fluidizing gas into the carbonization reactor 10 and the reduction reactor 13 via the conduits 11, 11'. Furthermore, the value of hydrogen and/or water and/or water vapour in the circulating gas flow may be controlled e.g. by a hydrogen permeable membrane or a water condenser/absorber or water evaporator.

10 From the reduction reactor 13, a mixture of partially reduced ilmenite and char with a temperature of about 1,000°C is continuously withdrawn via the pneumatic product discharge conduit 20, is cooled to about 700°C in a heat exchanger (not shown), and with this temperature is charged to the magnetic separator 21, where a fraction rich in titanium dioxide is separated as magnetic product from a non-magnetic fraction, which substantially comprises chromite, ash and char, before the magnetic fraction is charged into the electric furnace 22.

In the electric furnace operated at about 1,600°C, titania slag with 75 to 90 wt-% titanium dioxide and liquid pig iron with more than 94 wt-% metallic iron are obtained as products. The off gas from the electric furnace contains more than 90 vol-% carbon monoxide and, after dedusting, is burnt in an afterburning chamber (not shown), and the hot flue gas is supplied to the gas heater 19 for heating the fluidizing gas. Also a part of the circulation gas flow can be burnt and supplied to the gas heater 19.

25 In contrast to the plant described above, the plant shown in Fig. 2 additionally includes an oxidation reactor 23 upstream of the carbonization reactor 10. Ore preheated in the suspension heat exchangers 5, 8 is introduced into the oxidation reactor 23 via the solids conduit 7' and is fluidized with fluidizing gas supplied via the gas conduit 11", which before was preheated in the heat exchanger 24 with the waste gas from the cyclone 14 downstream of the reduction reactor 13, by forming a circulating fluidized bed. Furthermore, fuel is supplied to the oxidation

reactor 23 via conduit 16". The suspension is conducted by the gas stream into the cyclone 25 downstream of the oxidation reactor 23, in which the solids are separated from the gas. One part of the solids is recirculated to the oxidation reactor 23, while the other part is introduced into the carbonization reactor 10 via the solids conduit 7". Off gas withdrawn from the cyclone 25 is transferred via the gas conduit 26 into the suspension heat exchanger of the second preheating stage 8 and from there via the cyclone 9, the suspension heat exchanger of the first preheating stage 5 and the cyclone 6 to a waste gas cleaning unit (not shown).

The invention will be explained below with reference to an example which demonstrates the invention, but does not restrict the same.

Example

In a plant corresponding to Fig. 2, the suspension heat exchanger 5 was charged via the solids supply conduit 1 with raw ilmenite (12 kg/h) having a grain size of less than 1 mm with the following composition:

	TiO ₂	50.04 wt-%
20	Fe ₂ O ₃	13.44 wt-%
	FeO	32.79 wt-%
	MnO	0.58 wt-%
	SiO ₂	0.62 wt-%
	Al ₂ O ₃	0.53 wt-%
25	MgO	0.68 wt-%
	CaO	0.05 wt-%
	S	0 wt-%
	C	0 wt-%
	Others	0.37 wt-%
30	Loss on Ignition (LOI)	0.90 wt-%
	Total	100.00 wt-%
	Ti _{total}	30 wt-%
	Fe _{total}	34.90 wt-%

- 10 -

After passage through the first and second preheating stages, the preheated ore was introduced into the oxidation reactor 23 via conduit 7', in order to almost completely oxidize the FeO to form Fe₂O₃. Furthermore, fuel and fluidizing gas were supplied to the oxidation reactor 23 via conduit 11". After separating the solids from the gas in the cyclone 25 downstream of the oxidation reactor 23, the solids were introduced into the carbonization reactor 10 via the solids conduit 7". The oxygen content of the waste gas from the cyclone 25 was 6 vol-%. Furthermore, oxygen and 7.5 kg/h coal (Blair Athol, C_{fix}: 62%) corresponding to a ratio Fe:C_{fix} of 1 were supplied to the carbonization reactor 10 via the solids conduit 7", and in the reactor 10 the solids were fluidized with a gas mixture of 70 vol-% carbon monoxide and 30 vol-% hydrogen by forming a stationary fluidized bed.

From the carbonization reactor 10, the gas-solids mixture was continuously introduced into the reduction reactor 13 via the connecting passage 12, and the oxidized ilmenite was partially reduced to a degree of metallization of 70%, based on its iron content.

Solids withdrawn from the reduction reactor 13 via conduit 20 were first of all separated magnetically in the magnetic separator 21, and the magnetic fraction obtained thereby was charged into an electric furnace 22. The installed transformer capacity of the furnace 22 was 2 MVA. The titania slag was tapped every 2 hours, and the sponge iron was tapped twice per day.

In accordance with a chemical analysis, the titania slag and the sponge iron thus obtained had the compositions as shown in Table 1. The calculated electric energy consumption for the process was 1.004 kWh per ton of slag.

Comparative Example

For comparison, crude ilmenite with the composition as stated above, which was subjected neither to an oxidation nor to a partial reduction, was charged into the electric furnace 22 described in the above example instead of prereduced ilmenite, and molten.

The compositions of the titania slag and the sponge iron thus obtained are set forth in Table 1. The calculated electric energy consumption for the process was 2,050 kWh per ton of slag.

Table 1

Chemical composition of the titania slag and the sponge iron obtained in the Example and in the Comparative Example, respectively.

	Example prereduced ilmenite	Comparative Example crude ilmenite
Fe _{met} in the charge	70 wt-%	0 wt-%
Titania slag		
TiO ₂	88.5 wt-%	87.9 wt-%
FeO	8.1 wt-%	8.8 wt-%
Sponge iron		
Fe	95.5 wt-%	95.2 wt-%
Si	0.61 wt-%	0.60 wt-%
FeS	0.68 wt-%	0.71 wt-%
C	3.00 wt-%	2.90 wt-%
Mn	0.12 wt-%	0.12 wt-%
Consumption of electric energy (calculated)	<u>1,004</u> kWh/t _{slag}	<u>2,050</u> kWh/t _{slag}

List of Reference Numerals

	1	solids supply conduit
5	2	reservoir for char
	3	reservoir for ilmenite
	4	mixing tank
	5	suspension heat exchanger of the first preheating stage
	6	cyclone of the first preheating stage
10	7,7',7",7"	solids conduit
	8	suspension heat exchanger of the second preheating stage
	9	cyclone of the second preheating stage
	10	(carbonization) reactor
	11,11',11"	gas conduit for fluidizing gas
15	12	connecting passage
	13	reduction reactor
	14	cyclone of the reduction reactor
	15	solids return conduit
	16,16',16",16"	gas conduit
20	17	scrubber
	18	CO ₂ absorber
	19	gas heater
	20	product discharge conduit
	21	magnetic separator
25	22	electric furnace
	23	oxidation reactor
	24	heat exchanger
	25	cyclone of the oxidation reactor
	26	waste gas discharge conduit

Claims:

1. A process for producing titania slag from ilmenite, comprising the steps of:
- 5 a) partial reduction of granular ilmenite with a reducing agent in a reduction reactor (13) at a temperature of at least 900°C,
- b) transfer of the partially reduced hot ilmenite obtained in step a) into an electric furnace (22), wherein the inlet temperature of the ilmenite entering the furnace (22) is at least 550°C,
- 10 c) melting the ilmenite in the electric furnace in the presence of a reducing agent by forming liquid pig iron and titania slag, and
- d) withdrawing the titania slag from the electric furnace (22).
- 15 2. The process as claimed in claim 1, **characterized in that** the partial reduction a) of the ilmenite is performed in a circulating fluidized bed (13).
3. The process as claimed in claim 1 or 2, **characterized in that** the grain size of the ilmenite used for partial reduction is less than 1 mm and particularly preferably less than 400 µm.
- 20 4. The process as claimed in any of the preceding claims, **characterized in that** coal, char, molecular hydrogen, a gas mixture containing molecular hydrogen, carbon monoxide and/or a gas mixture containing carbon monoxide is used as reducing agent for the partial reduction a).
- 25 5. The process as claimed in claim 4, **characterized in that** char as well as a gas mixture containing 60 to 80 vol-% carbon monoxide and 20 to 40 vol-% molecular hydrogen is used as reducing agent.
- 30 6. The process as claimed in any of the preceding claims, **characterized in that** after the partial reduction a) the degree of metallization of the ilmenite is 50 to 95% and particularly preferably 70 to 80%, based on the iron content.

- 14 -

7. The process as claimed in any of the preceding claims, **characterized in that** before the partial reduction a) the ilmenite is first preheated in one or more heat exchangers (5, 8) and subsequently heated to a temperature of more than 900°C in a reactor (10) with stationary fluidized bed.

5

8. The process as claimed in claim 7, **characterized in that** coal with a grain size of less than 5 mm and oxygen are supplied to the stationary fluidized-bed reactor (10) for producing char.

10

9. The process as claimed in any of the preceding claims, **characterized in that** a gas mixture containing molecular hydrogen and carbon monoxide is supplied to the stationary fluidized-bed reactor (10) and/or the reduction reactor (13) as fluidizing gas.

15

10. The process as claimed in any of the preceding claims, **characterized in that** the fluidizing gas of the fluidized-bed reactors (10, 13) is circulated.

11. The process as claimed in claim 10, **characterized in that** the off gas from the circulating fluidized-bed reactor (13) is passed through one or more heat exchangers (5, 8) for preheating ilmenite and is subsequently introduced into a waste heat boiler for generating steam, before it is passed through a carbon dioxide absorber (18) and, after heating, is recirculated to the circulating fluidized-bed reactor (13) as fluidizing gas.

25

12. The process as claimed in any of the preceding claims, **characterized in that** the ilmenite is oxidized before the partial reduction a).

13. The process as claimed in claim 12, **characterized in that** after the oxidation the FeO content of the ilmenite is less than 5 wt-% and particularly preferably less than 3 wt-%.

30

14. The process as claimed in claim 12 or 13, characterized in that the oxidation in the circulating fluidized bed (23) is effected at a temperature between 600 and 1000°C.

- 15 -

15. The process as claimed in any of the preceding claims, **characterized in that** before being transferred into the electric furnace (22), the partially reduced hot ilmenite is subjected to a magnetic separation and only the magnetic fraction
5 obtained thereby is charged into the electric furnace (22).

16. The process as claimed in claim 15, **characterized in that** during the magnetic separation the material has a temperature of at least 600°C, particularly preferably at least 675°C and quite particularly preferably about 700°C, and the
10 magnetic fraction subsequently is transferred into the electric furnace (22) without cooling or heating.

17. The process as claimed in any of the preceding claims, **characterized in that** the titania slag withdrawn from the electric furnace contains 75 to 90 wt-% and particularly preferably about 85 wt-% titanium dioxide, and the liquid pig iron
15 contains more than 94 wt-% metallic iron.

18. A plant for producing titania slag from ilmenite, in particular for performing a process as claimed in any of claims 1 to 17, **characterized in that** the same comprises a carbonization reactor (10) constituting a stationary fluidized-bed reactor for carbonizing coal by heating ilmenite at the same time, a reduction reactor (13) constituting a circulating fluidized-bed reactor for the partial reduction of ilmenite, and an electric furnace (22).
20

25 19. The plant as claimed in claim 18, **characterized in that** the carbonization reactor (10) is connected with the reduction reactor (13) via a connecting passage (12) such that the solids/gas suspension can pass from the upper part of the carbonization reactor (10) into the lower part of the reduction reactor (13) and downstream of the reduction reactor (13) a cyclone (14) is provided for separating the
30 solids from the gas, from which cyclone a solids return conduit (15) leads to the carbonization reactor (10).

– 16 –

20. The plant as claimed in claim 18 or 19, **characterized in that** upstream of the carbonization reactor (10) at least one preheating stage is provided, which comprises a suspension heat exchanger (5, 8) and a downstream cyclone (6, 9).
- 5 21. The plant as claimed in any of the preceding claims, **characterized in that** the same comprises a means for circulating the fluidizing gas.
22. The plant as claimed in any of the preceding claims, **characterized in that** the same furthermore comprises a magnetic separator (21).

Fig.1

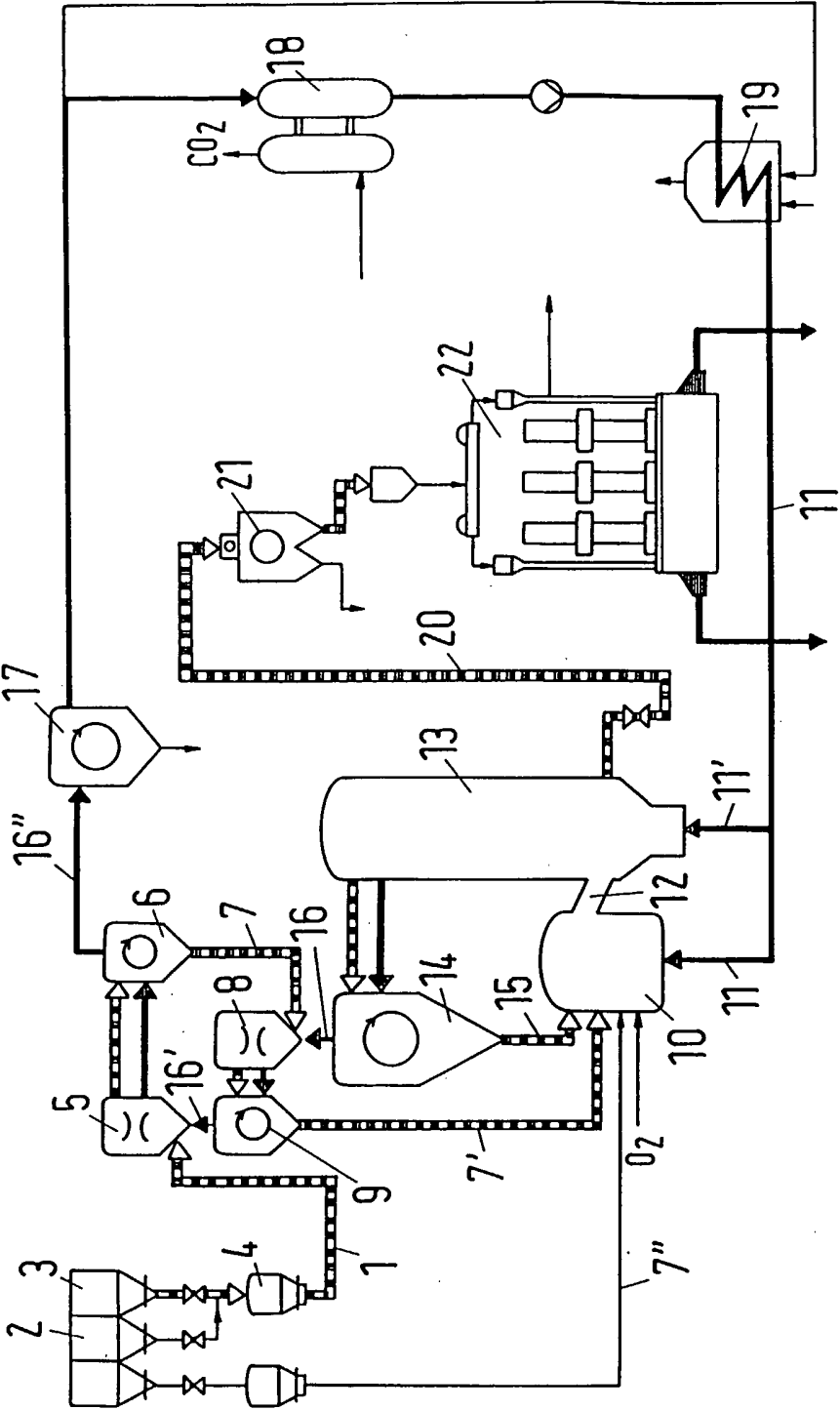
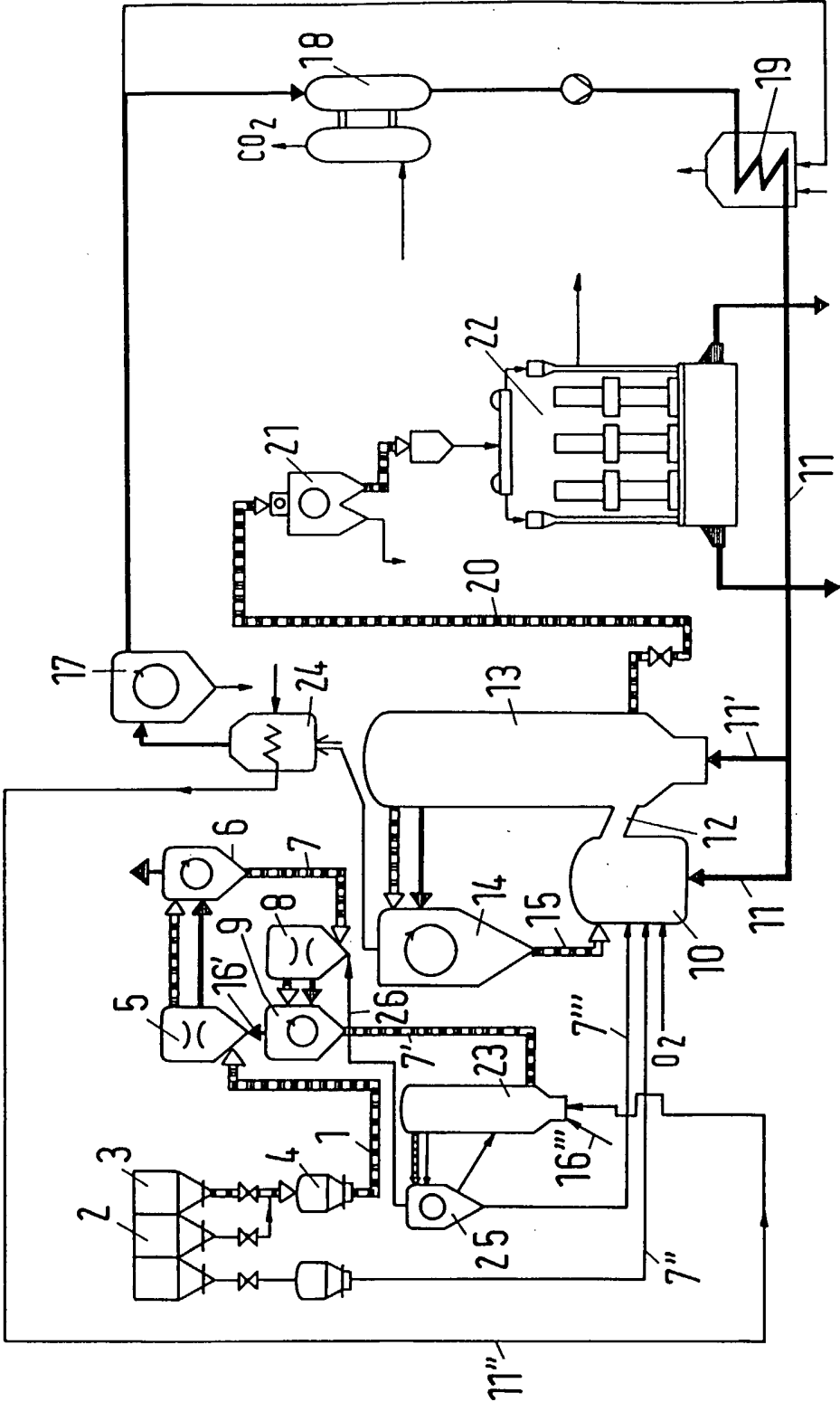


Fig.2



INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2005/011761

A. CLASSIFICATION OF SUBJECT MATTER
C22B34/12 C22B5/14

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)
C22B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 765 868 A (MOKLEBUST O,US ET AL) 16 October 1973 (1973-10-16) cited in the application column 5, lines 18-25 and 46-52 -----	1,3-6
A	VIJAY P L ET AL: "PREOXIDATION AND HYDROGEN REDUCTION OF ILMENITE IN A FLUIDIZED BED REACTOR" METALLURGICAL AND MATERIALS TRANSACTIONS B: PROCESS METALLURGY & MATERIALS PROCESSING SCIENCE, TMS, WARRENDALE, PA, US, vol. 27B, no. 5, October 1996 (1996-10), pages 731-738, XP000632260 ISSN: 1073-5623 pages 731 and 732; Figure 1 ----- -/--	1-22

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Z document member of the same patent family

Date of the actual completion of the international search

24 January 2006

Date of mailing of the international search report

02/02/2006

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Bjoerk, P

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2005/011761

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 102 60 737 A1 (OUTOKUMPU OYJ, ESPOO) 15 July 2004 (2004-07-15) Beispiel 1 -----	1-22
A	US 3 713 781 A (DUNN W, AU) 30 January 1973 (1973-01-30) claim 1; figures -----	1-22
A	US 4 359 212 A (BENGTSSON ET AL) 16 November 1982 (1982-11-16) abstract; figures -----	1-22
A	DATABASE WPI Section Ch, Week 197545 Derwent Publications Ltd., London, GB; Class M24, AN 1975-74991W XP002364193 & JP 50 031526 B (AGENCY OF IND SCI & TECHNOLOGY) 13 October 1975 (1975-10-13) abstract -----	1-22

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP2005/011761

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3765868	A	16-10-1973	NO 130827 B	11-11-1974
DE 10260737	A1	15-07-2004	AU 2003293817 A1 BR 0317636 A CA 2510926 A1 WO 2004057040 A1	14-07-2004 29-11-2005 08-07-2004 08-07-2004
US 3713781	A	30-01-1973	NO 129503 B ZA 7106957 A	22-04-1974 27-12-1972
US 4359212	A	16-11-1982	AU 542015 B2 BR 8008891 A DE 3063284 D1 EP 0022098 A1 JP 56500739 T SE 419129 B SE 7904689 A WO 8002652 A1	31-01-1985 11-08-1981 07-07-1983 07-01-1981 04-06-1981 13-07-1981 30-11-1980 11-12-1980
JP 50031526	B	13-10-1975	NONE	