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(54) **PROCESS FOR EXTRACTION OF SULPHUR AND METALS, IN OXIDE FORM, USABLE IN THE WAELTZ PROCESS, FROM MUDS CONTAINING COMPOUNDS OF SULPHUR AND SAID METALS**

IN EINEM WÄLZPROZESS ANWENDBARES VERFAHREN ZUR EXTRAKTION VON SCHWEFEL UND METALLEN IN OXIDFORM AUS SCHLÄMMEN MIT SCHWEFELVERBINDUNGEN UND DIESEN METALLEN

PROCÉDÉ D'EXTRACTION DE SOUFRE ET DE MÉTAUX, SOUS FORME D'OXYDE, UTILISABLES DANS LE PROCÉDÉ DE WAELTZ, À PARTIR DE BOUES CONTENANT DU SOUFRE ET LESDITS MÉTAUX

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Description

[0001] The present invention refers to the technical field of the recovery of sulphur. Particularly the subject of the present invention is the extraction of sulphur and metals, in oxide form, usable in the Waeltz process, from muds containing compounds of sulphur and said metals, for example from muds of substances chemically similar to goethite and jarosite.

[0002] As it is known, the industry for the production of zinc and lead, due to the extraction yield of the typical processes of these activities, generates wastes still having remarkable contents of compounds containing zinc, lead and various valuable and precious metals (for example copper and silver), together with significant amounts of compounds containing iron. Resulting from wet extraction/separation cycles, these residues generally are in form of semisolid mud, with content of imbibition water of about 35 - 40% by weight.

[0003] These residues could be treated as by-products and designed for further extraction processes, however this route today is technically viable (by means of various processes) only under certain conditions. Frequently, it is not technically or economically convenient to carry out further extractions, therefore these wastes, treated like refuse, must be stabilized, inertized and disposed in authorized landfill.

[0004] Such wastes are a blend or a mixture of substances chemically similar to goethite and jarosite, i.e. they are oxy-hydroxides ($\text{FeO} \bullet \text{OH}$) or mixed sulfates-hydroxides, of $\text{MeFe}_3(\text{SO}_4)_2(\text{OH})_6$ type (where Me is a metal), mainly of iron, zinc, lead and, typically, sodium or potassium. In addition there are also, to a lesser degree, mixed sulfides of these same metals.

[0005] As it is possible to deduce from the jarosite formula, i.e. $\text{MeFe}_3(\text{SO}_4)_2(\text{OH})_6$, in such residues it is present an important component of sulphur compounds (typically about 12%-15%, expressed as elemental sulphur); this fact results in difficulties in processing for ulterior recovery of metals from these residues. These difficulties generated a very interesting research topic that, recently, has been further reinforced, both because of the increased acknowledgment with respect to the dangerousness of residues containing heavy metals and consequent restriction of regulation about landfills, and, according to landfill disposal, a loss of remarkable amounts of potentially exploitable elements or substances occurs. Due to these reasons, the industry world still urges even more in order to find technically and economically viable solutions, to be used in order to carry out the additional extraction of metals (or compounds thereof) and to find landfill alternative routes.

[0006] In this field, extraction processes based on the hydrometallurgy are used, however, a route most recent studies are being oriented to is that of pyrometallurgical type processes, mainly based on the reduction and evaporation of the metals, in processes (sometimes involving melting steps) at elevated temperatures.

[0007] In WO 2008 / 052661 A1 a single-step pyrometallurgical process is disclosed for the recovery of non-ferrous metals from zinc bearing residues, in particular from by-products of the zinc and lead industry such as goethite and jarosite. A process for the recovery of metals from industrial Zn residues containing Zn, Fe and S is defined, in which Zn is fumed, Fe is slagged, and S is oxidized to SO_2 . In the process, the Zn fuming, the Fe slagging, and the S oxidation are performed in a single step process, by smelting the residues in a furnace comprising at least one submerged plasma torch generating an oxidizing gas mixture, and by feeding a solid reducing agent to the melt. The process achieves the oxidation of S and the slagging of Fe, while simultaneously achieving the reduction and the fuming of metals such as Zn.

[0008] There are various processes in such field, each with its peculiarities, advantages and disadvantages. Such processes share, however, a feature, that is, because of the involved temperatures, the generation, within the gaseous flow exiting from the reactors, also of remarkable amounts of sulphur compounds, which then are to be treated in suitable abatement systems and on turn generate remarkable amounts of refusal by-products with almost null market value. For example, the typical systems of SO_x abatement result in the production of gypsum (CaSO_4), diluted sulphuric acid, ammonium sulfate.

[0009] By resulting from production of metallurgical type, such by-products have a purity degree not suitable to reference market, or need of further expensive purification processes in order to be suitable for introduction into the reference markets. Particularly, as to the market of gypsum or ammonium sulfate based fertilizers, apart from local situations, it is impossible the introduction thereof in an already saturated market and therefore on turn these products must be treated like refusals. On the other hand, presently, elemental sulphur has yet various market outlets and a commercial value of true interest, therefore it would be preferable, in such processing, elemental sulphur as end product to be obtained.

[0010] The Waeltz process is one of the pyrometallurgical processes industrially most applied in the field of recovery, from refuse or waste, of Zinc and other non-ferrous metals. In this process dusts, mixed with coal and fluxes, are subjected to a pyrometallurgical processing in rotary drum furnace, under strongly reducing conditions; in this way, the separation of volatile components (zinc, lead, cadmium, etc.) to be recovered like zinc rich ashes is obtained (about 60% ZnO) from furnace exiting smoke. Non-volatile oxides and metals, occurring in the dust, are not recovered but remain in the slag exiting from the process.

[0011] Under Waeltz process conditions, the sulphur compounds exit from the furnace in the gaseous flow, together with volatilized metals; in order to limit the impact of such phenomenon on the process and treatment of off-gases, the feed material for Waeltz process must

have a content of sulphur compounds (expressed as elemental sulphur) not higher than 0.1% by weight.

[0012] The need to reduce or eliminate, for example, the amount of inertized jarosite and/or goethite muds to be disposed in landfill, to have a process transforming these muds into a material with characteristics suitable to be a feed for a Waeltz plant and the possibility to extract elemental sulphur from the processing of this jarosite muds, are at the same time met by the process according to the present invention offering, in addition, further advantages that will be apparent hereinafter.

[0013] A process based, as a whole, on the extraction by thermal oxidative route of sulphur compounds occurring in muds, for example in jarosite and/or goethite muds, with contemporary transformation of the occurring metals in recoverable and exploitable oxides, is therefore an object of the present invention.

[0014] According to a preferred embodiment of this process, the muds, for example jarosite and/or goethite muds, optionally preventively dried at a temperature between 90 and 200°C, are fed in a suitable closed reactor and heated at a temperature higher than 1400°C, under oxidizing and oxygen rich atmosphere.

[0015] Such temperature can be obtained preferably in a reactor with thermal plasma systems, or EAF type (Electric Arc Furnace). At the reaction temperatures and under the promoted oxidizing conditions, the sulphur compounds (in form of SO_x) are extracted by passing in vapor phase and are removed from the reactor along off-gas capture line. The exploitable occurring metals (zinc, lead, copper, silver, but also iron), thanks to the oxidizing atmosphere, remain in the melt bath, in oxide form; possible vaporized and off-gas transported metals (therefore still in oxidizing atmosphere) are transformed in metal oxide particles, which are recovered by special filters and reunited to the produced metallic oxides in the main reactor, which as a whole will be send as feed to the Waeltz process. The melted metallic oxides are discharged from the reactor and fast cooled, so as to have an easy grindable product. These materials, reunited to oxide dusts recovered from the filters placed on the off-gas line, are ground at a suitable grain size and sent as a feed to a Waeltz plant.

[0016] Sulphur, extracted from the melt bath by the off-gas line, is initially in form of SO_x ((SO₃ + SO₂)). After the elimination of the particulate matter consisting of metallic oxides, the gaseous flow containing SO_x and oxygen is sent to a multistep processing system, where it is subjected to various reduction steps, in arc plasma reactors, in the presence of carbon and hydrogen.

[0017] Such system consists of a number of steps sufficient to maximize the extraction of sulphur from the gas; the number of steps is function of the composition of the incoming gas into the multistep system. Every step carries out the work of sulphur extraction, with a certain extraction yield from the gases being processes. The single step acts on the gas in the following way: the gas is subjected to a plasma generated inside of a reactor under

reducing atmosphere, by means of the addition of a carbon and/or hydrogen source.

[0018] According to a preferred embodiment, the source of carbon and/or hydrogen consists of a gas (or a gas mixture) selected from the group consisting of H₂, CH₄, C₂H₆ and combinations thereof.

[0019] The resulting reducing reaction results in the formation of elemental sulphur, which immediately is condensed by lowering temperature below 400°C. Because of the reaction yields, in addition to elemental sulphur, the formation, in lower amounts, of minor compounds will be obtained also: the contemporary formation of CO, H₂, H₂S, COS will occur.

[0020] In the gas resulting from each reduction step it will be moreover present a fraction of SO_x: this gaseous flow that will come subjected to the successive step of the process.

[0021] The second step of the process acts in perfectly identical way to first one: the fraction of SO_x that has not reacted in the first step, is subjected to a plasma generated inside a reactor kept under reducing atmosphere by means of the addition of a source of carbon and/or hydrogen. According to a preferred embodiment, the source of carbon or hydrogen consists of a gas (or a gas mixture) selected from the group consisting of H₂, CH₄, C₂H₆ and combinations thereof.

[0022] A part of H₂S occurring in the gaseous flow is transformed in H₂ and elemental sulphur; the SO_x are transformed mainly in elemental sulphur, H₂S e COS; and the formation of CO/H₂ continues also

[0023] The third step (if it is necessary to be carried out) will perform the same work exactly as carried out by two previous steps and so on.

[0024] At the end of the reduction steps, the residual gas, mainly consisting of CO, H₂, H₂S, COS, plus a very little fraction of SO_x, immediately will be cooled to a temperature lower than 50°C; this in order to allow the condensation and recovery in liquid form of the residual fraction of SO₃, which is sent upstream to multistep process starting.

[0025] The residual fraction of SO₂, along with CO, H₂, H₂S and COS, is subjected to an arc plasma reducing treatment, without addition of exogenous reducing agents. Such treatment results mainly in syngas (CO, H₂, plus a minimal part of H₂O, CO₂, SO₂), that will be accumulated and used for the production of heat and/or electric power.

[0026] The syngas, based on the equipment it will have to power (endothermic engine, microturbine, boiler etc.) possibly will be subjected to additional purification treatments, in order to be suitable to produce energy.

[0027] Up to here a description of general type of the process of the invention has been reported. With the aid of the unique enclosed figure and of the example a more detailed description now will be carried out, aimed at a better understanding of the process as well as of the objects, features and advantages thereof.

[0028] The unique enclosed figure, figure 1, represents

a flow-chart of an embodiment of the process according to the invention.

Example 1

[0029] In the test jarosite muds are used, the average composition thereof being as listed below:

Parameter	Value	U.M.
Zn	8.63	%
Pb	5.27	%
Cd	0.07	%
Cu	0.35	%
FeO	28.02	%
CaO	1.05	%
MgO	0.71	%
Al ₂ O ₃	0.98	%
SiO ₂	6.3	%
% H ₂ O	37.32	%
S total	11.37	%

[0030] 500 grams of sample, preventively dried at temperature of 110°C, are weighed; then placed inside of a reactor coated with refractory bricks, wherein the sulphur extraction step under oxidizing atmosphere is to be carried out.

[0031] The reactor used in the test consists of an external enclosure made of AISI 316 stainless steel. Internally, the reactor is coated with refractory bricks of JM 32 type from ATT S.p.a. According to this configuration, cathode and anode consist of two horizontal, metallic bars positioned in such a way that the terminal tips, where sets off the spark, are located few millimeters to each other and the sample to be treated. Cathode and anode are moved in such a way that, after the electric arc/plasma ignition, the same remains triggered and effectively can run over the sample to be treated.

[0032] In this test an electric arc is used; about DC 100 Volts are applied with a current value of 500 Ampere.

[0033] The atmosphere inside of the reactor is oxygen enriched. The mud treatment has been carried for about 15 minutes, in order to assure the complete melting and reaction of all the sample; the melted product successively has been discharged and fast cooled, so as to result in a compact but easy grindable solid.

[0034] The application of voltage difference results in discharges thus heating the sample to very high temperatures.

[0035] In such a way the sample melts and the compounds with evaporation temperatures lower than those reached within the melt bath tend to escape from the reactor. In addition the system displays the loss of oxygen

ions and undergoes a reticular rearrangement resulting in the formation of metal oxides at higher oxidation state.

[0036] In such a way all the present metallic elements are retained within the melt deriving solid matrix (with the exception of oxide micro-particulate matter, mechanically dragged within the off-gas flow), while the sulphur containing compounds escape from the matrix and are collected along the off-gas capture line. Along this line a section consisting of a filtering system (electrostatic filters) is present acting as capture device for the particulate solid matter, mainly consisting of As, Pb, Fe, Al, Zn, Cd, Cu, Mg metal oxides, thus allowing the recovery thereof. Such particulate matter is reunited to ground material coming from the melt cooling, homogenized and sent to Waeltz process.

[0037] The residual gases, mainly SO_x, O₂, H₂S (with traces of other gases like H₂O and CO₂) are passed to the multistep treatment for the separation of sulphur. The gas is conveyed into an aspiration system where it is reunited to a stoichiometrically adjusted, methane flow and injected in the first section of the multistep treatment. It consists of a transferred arc plasma torch wherein 10 s lms (standard liter per minute) of gaseous mixture consisting of about 150 g of SO₃ mixed with about 75 g of methane are injected. SO₃ present is converted in other compounds with a yield of about 91%. Due to the strongly reducing atmosphere, the main products from the transformation are:

- Elemental S: about 51 g;
- H₂S : : about 1, 7 g;
- COS: about 2.7 g;
- H₂: about 9 g;
- CO trace.

[0038] The gas, that has been subjected to plasma processing and transformed, is conveyed in an expansion room with a cooled wall where sulphur and part of the possibly formed water are condensed.

[0039] The residual gas, mainly consisting of CO, H₂, H₂S and COS, plus residual SO₃, is conveyed in a processing system wherein is subjected to strong electrical discharged. According to carried out test, such system consists of brass tube acting as channeling device towards two steel electrodes; between the electrodes an electric discharge is triggered thus resulting in molecular bond rupture. The obtained ions pass in an expansion room, wherein there is a wall acting as heat exchanger, in order to allow the formed sulphur to be condensed thus avoiding to react again with hydrogen or carbon monoxide formed due to the passage through the electric discharge of COS e H₂S. The final result is the production of condensed sulphur, that is added to that obtained in the previous step and sent to be purified, and syngas mainly consisting of CO, H₂, H₂O, CO₂ and traces of other molecules, like evidenced by mass spectroscopy analysis.

[0040] The melt solid obtained from the reactor of sul-

phur oxidative extraction has the composition (not standardized) as reported in the following table;

Parameter	Value	U.M.
Zn	9.88	%
Pb	3.47	%
Cd	0.01	%
Cu	0.47	%
Fe₂O₃	48.75	%
CaO	3.76	%
MgO	0.82	%
Al₂O₃	3.92	%
SiO₂	14.24	%
S total	<0.1	%

and it has the characteristics suitable to be sent as a feed to a Waeltz system.

[0041] The implementation, on industrial scale, of the process according to the present invention, exposed according to a general description and a particular embodiment thereof in example 1, directly downstream of the production system of exemplified jarosite muds, allows the treatment of the latter as by-products and not as waste products and allows to extract and produce elemental sulphur to be designed for sale, being possible to reach a production of about 1 ton/hour of sulphur by processing of about 7 tons/hour of muds. At last, since the solid resulting from the first reactor is suitable to be used as a feed for a Waeltz plant, in a combined cycle exploitable elements are yet extractable, like for example zinc and lead, which otherwise would be lost by material disposal in landfill.

Claims

1. Process for extraction of sulphur and metals, in oxide form, usable in the Waeltz process, from sulphur and said metal compound containing muds, for example from jarosite and goethite chemically similar substance containing muds, said method comprising the following operations:

- optional mud drying;
- introduction into closed main reactor;
- heating under oxidizing atmosphere until melting;
- transformation of metal containing compounds in oxides that remain in melt bath and of sulphur containing compounds in SO_x gas, that is ex-

tracted with gaseous flow exiting from said melt bath through off-gas line;

- discharge of resulting metal oxides and fast cooling thereof;

- addition to discharged oxides of possible powdered metal oxides recovered by filters placed in off-gas line;

- grinding of recovered metallic oxides and use thereof as feed product for Waeltz process;

- reduction, by reducing gas, of melt bath exited SO_x in a plasma generated inside a first arc-plasma reactor thus resulting in formation of elemental S that successively is condensed and recovered;

- at least once optional repetition, in a subsequent plasma reactor, of reduction for not yet reduced SO_x fraction exiting from preceding plasma reactor, along with CO, H₂, H₂S and COS, with successive condensation of obtained sulphur added to that recovered after the first reduction;

- cooling of residual gas, mainly containing CO, H₂, H₂S and COS with a very small fraction of SO_x, at a temperature < 50°C, thus recovering, in condensed form, SO₃ residual fraction that is returned to first plasma reactor;

- arc-plasma reducing treatment of residual fraction, without exogenous reducing agent addition, resulting in formation of CO, H₂, H₂O, CO₂ and SO₂ containing syngas.

2. The process according to claim 1, wherein drying of mud is carried out at a temperature in the range from 90 to 120°C.

3. The process according to claim 1 or 2, wherein main reactor is selected from the group comprising a reactor provided with thermal plasma systems and an electric arc furnace.

4. The process according to any of the preceding claims, wherein heating under oxidizing atmosphere is carried out at a temperature higher than 1400°C.

5. The process according to any of the preceding claims, wherein oxidizing atmosphere results from oxygen or oxygen rich gaseous mixture.

6. The process according to any of the preceding claims, wherein the filtration in order powdered metal oxides, dragged in gaseous flow exiting from main reactor, to be recovered, is carried out using electrostatic filters.

7. The process according to any of the preceding claims, wherein the condensation of elemental sulphur resulting from SO_x reduction is carried out at a temperature lower than 400°C.
8. The process according to any of the preceding claims, wherein reducing gas in order SO_x (i.e. SO₃ and SO₂) molecules to be reduced is selected from the group comprising H₂, CH₄, C₂H₆ and combinations thereof.

Patentansprüche

1. Verfahren zur Extraktion von Schwefel und Metallen in Oxidform, die in dem Wälz-Verfahren einsetzbar sind, aus Schwefel und die Metallverbindung enthaltenden Schlämmen, zum Beispiel aus eine Jarosit und Goethit chemisch ähnliche Substanz enthaltenden Schlämmen, wobei das Verfahren die nachstehenden Vorgänge umfasst:

- gegebenenfalls Trocknen des Schlamms;
- Einführung in einen geschlossenen Hauptreaktor;
- Erhitzen unter oxidierender Atmosphäre bis zum Schmelzen;
- Überführung von Metall enthaltenden Verbindungen in Oxide, die im Schmelzbad verbleiben, und von Schwefel enthaltenden Verbindungen in SO_x-Gas, das mit einem gasförmigen Strom, der das Schmelzbad durch die Abgasleitung verlässt, extrahiert wird;
- Ausgabe von erhaltenen Metalloxiden und schnelles Kühlen davon;
- Zugabe zu den ausgegebenen Oxiden von möglichen gepulverten Metalloxiden, die von in der Abgasleitung angeordneten Filtern gewonnen wurden;
- Zerkleinern von gewonnenen Metalloxiden und Verwendung davon als Zuführungsprodukt für das Wälz-Verfahren;
- Reduktion durch reduzierendes Gas vom das Schmelzbad verlassendem SO_x in einem Plasma, das in einem ersten Lichtbogenplasmareaktor erzeugt wird, was somit zur Bildung von elementarem S führt, der schrittweise kondensiert und gewonnen wird;
- mindestens einmal gegebenenfalls Wiederholung in einem anschließenden Plasmareaktor zur Reduktion einer noch nicht reduzierten SO_x-Fraktion, die zusammen mit CO, H₂, H₂S und COS den vorstehenden Plasmareaktor verlässt, mit fortschreitender Kondensation von erhaltenem Schwefel, der zu jenem nach der ersten Reduktion gewonnenen hinzugefügt wird;
- Kühlen von restlichem Gas, das hauptsächlich CO, H₂, H₂S und COS mit einer sehr kleinen

Fraktion von SO_x enthält, bei einer Temperatur < 50°C, wobei somit in kondensierter Form eine SO₃-Restfraktion gewonnen wird, die zu erstem Plasmareaktor zurückgeführt wird;

- Lichtbogenplasma-Reduktionsbehandlung der Restfraktion ohne exogene Reduktionsmittel-Zugabe, die zur Bildung von CO, H₂, H₂O, CO₂ und SO₂ enthaltendem Syngas führt.
2. Verfahren nach Anspruch 1, wobei das Trocknen von Schlamm bei einer Temperatur im Bereich von 90 bis 120°C ausgeführt wird.
3. Verfahren nach Anspruch 1 oder 2, wobei der Hauptreaktor aus der Gruppe, umfassend einen Reaktor, ausgestattet mit Thermoplasmasystemen und einem Elektrobogenofen, ausgewählt wird.
4. Verfahren nach einem der vorstehenden Ansprüche, wobei Erhitzen unter oxidierender Atmosphäre bei einer Temperatur höher als 1400°C ausgeführt wird.

5. Verfahren nach einem der vorstehenden Ansprüche, wobei die oxidierende Atmosphäre von Sauerstoff oder Sauerstoff-reichem gasförmigem Gemisch stammt.
6. Verfahren nach einem der vorstehenden Ansprüche, wobei die Filtration zur Gewinnung von pulverförmigen Metalloxiden, die in einem den Hauptreaktor verlassenden Gasstrom mitgezogen werden, unter Verwendung elektrostatischer Filter ausgeführt wird.
7. Verfahren nach einem der vorstehenden Ansprüche, wobei die Kondensation von bei der SO_x-Reduktion erhaltenem elementarem Schwefel bei einer Temperatur geringer als 400°C ausgeführt wird.
8. Verfahren nach einem der vorstehenden Ansprüche, wobei ein reduzierendes Gas zur Reduktion von SO_x (d.h. SO₃ und SO₂)-Molekülen, aus der Gruppe, umfassend H₂, CH₄, C₂H₆ und Kombinationen davon, ausgewählt wird.

Revendications

1. Procédé d'extraction de soufre et de métaux, sous forme d'oxydes, utilisable dans le procédé de Waeltz, à partir de boues contenant du soufre et lesdits composés métalliques, par exemple à partir de boues contenant des substances chimiquement similaires à la jarosite et à la goethite, ledit procédé comprenant les opérations suivantes :

- un séchage éventuel des boues ;
- une introduction dans un réacteur principal fermé ;

- un chauffage sous atmosphère oxydante jusqu'à la fusion ;
 - une transformation de composés contenant des métaux en oxydes qui restent dans le bain fondu et de composés contenant du soufre en gaz de type SOx, qui est extrait avec le flux gazeux sortant dudit bain fondu via une conduite d'effluent gazeux ;
 - une décharge des oxydes métalliques obtenus et leur refroidissement rapide ;
 - une addition aux oxydes déchargés d'oxydes métalliques pulvérulents éventuels récupérés par des filtres placés dans la conduite d'effluent gazeux ;
 - le broyage d'oxydes métalliques récupérés et leur utilisation comme produit d'alimentation pour un procédé de Waeltz ;
 - la réduction par un gaz réducteur du SOx déchargé du bain fondu dans un plasma généré à l'intérieur d'un premier réacteur à plasma à arc, entraînant ainsi la formation de S élémentaire qui est successivement condensé et récupéré ;
 - une répétition éventuelle au moins une fois, dans un réacteur à plasma ultérieur, de réduction pour la fraction de SOx non encore réduite sortant du réacteur à plasma précédent conjointement avec du CO, du H₂, du H₂S et du COS, avec une condensation successive du soufre obtenu ajouté à celui récupéré après la première réduction ;
 - le refroidissement du gaz résiduel contenant principalement du CO, du H₂, du H₂S et du COS avec une très faible fraction de SOx à une température < 50 °C, en récupérant ainsi sous forme condensée une fraction résiduelle de SO₃ qui est renvoyée au premier réacteur à plasma ;
 - un traitement de réduction au plasma à arc d'une fraction résiduelle sans addition d'agent réducteur exogène, entraînant la formation de gaz de synthèse contenant du CO, du H₂, du H₂O, du CO₂ et du SO₂.
2. Procédé selon la revendication 1, dans lequel le séchage de la boue est effectué à une température dans la plage de 90 à 120 °C.
3. Procédé selon la revendication 1 ou 2, dans lequel le réacteur principal est choisi dans le groupe comprenant un réacteur pourvu de systèmes de plasma thermiques et d'un four à arc électrique.
4. Procédé selon l'une quelconque des revendications précédentes, dans lequel le chauffage sous atmosphère oxydante est effectué à une température supérieure à 1400 °C.
5. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'atmosphère oxydante
- provient d'oxygène ou d'un mélange gazeux riche en oxygène.
6. Procédé selon l'une quelconque des revendications précédentes, dans lequel la filtration afin de récupérer des oxydes métalliques pulvérulents aspirés dans le flux gazeux sortant du réacteur principal est effectuée en utilisant des filtres électrostatiques.
7. Procédé selon l'une quelconque des revendications précédentes, dans lequel la condensation de soufre élémentaire résultant de la réduction du SOx est effectuée à une température inférieure à 400 °C.
8. Procédé selon l'une quelconque des revendications précédentes, dans lequel le gaz réducteur afin de réduire les molécules de SOx (c'est-à-dire SO₃ et SO₂) est choisi dans le groupe comprenant du H₂, du CH₄, du C₂H₆ et leurs combinaisons.

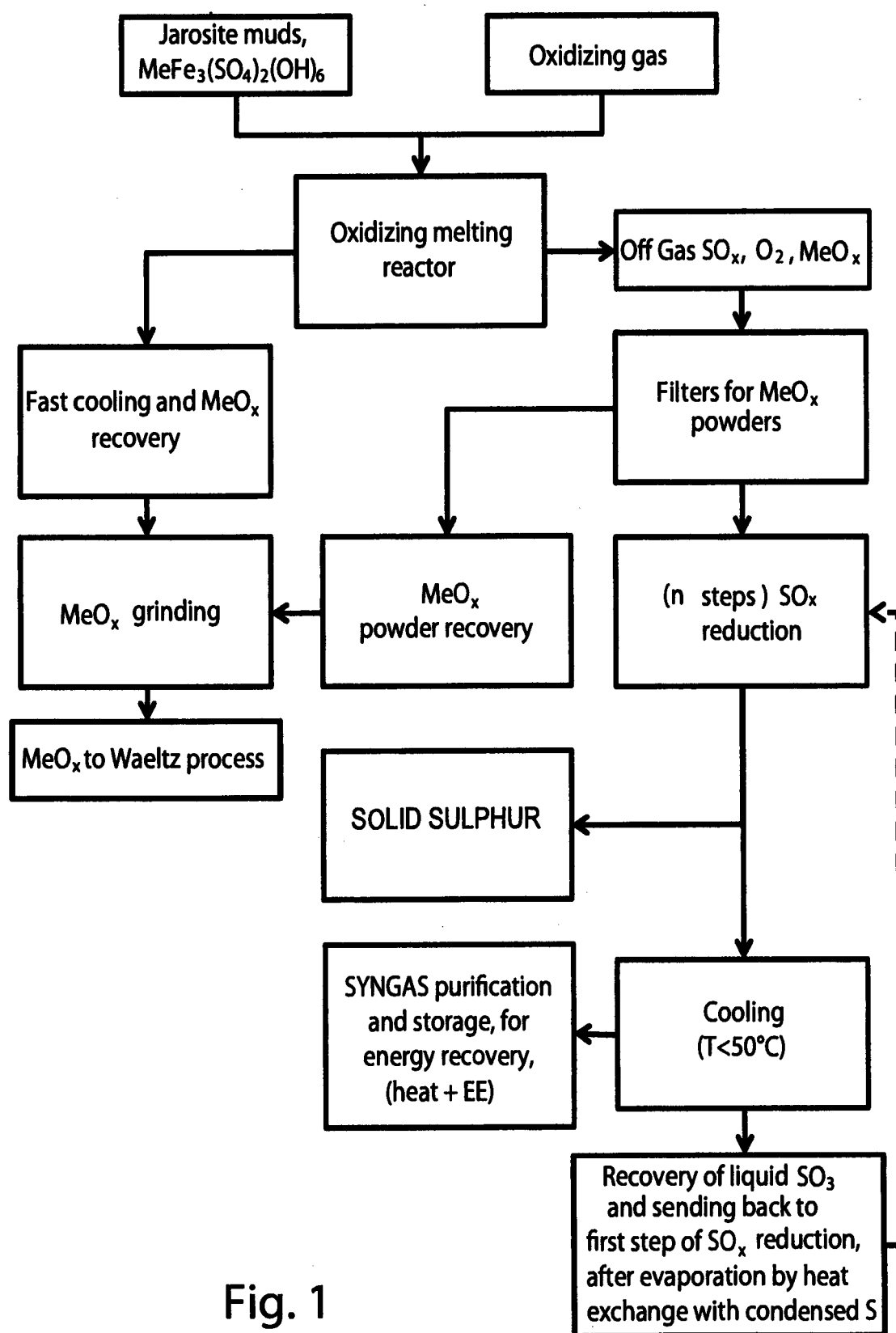


Fig. 1

REFERENCES CITED IN THE DESCRIPTION

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