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(54) **METHOD OF EXTRACTING LITHIUM FROM A RAW MATERIAL MIXTURE**

(57) A method of extracting lithium from a raw material mixture, comprising the steps of introducing a raw material mixture into a rotary kiln, subjecting the raw material mixture to a thermal treatment in the rotary kiln for melting the raw material mixture and to form alkali metal chlorides in gaseous form, maintaining the melt at a temperature of > 1150°C to allow the melt to flow to a kiln outlet of the rotary kiln, drawing off the exhaust gas together with kiln dust and the gaseous alkali metal chlorides, quenching the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides thereby condensing the alkali metal chlorides on the surface of the kiln dust, separating the condensed alkali metal chlorides from the exhaust gas, mixing the condensed alkali metal chlorides with water to obtain an aqueous solution of alkali metal chlorides, and separating the aqueous solution of alkali metal chlorides from the kiln dust.

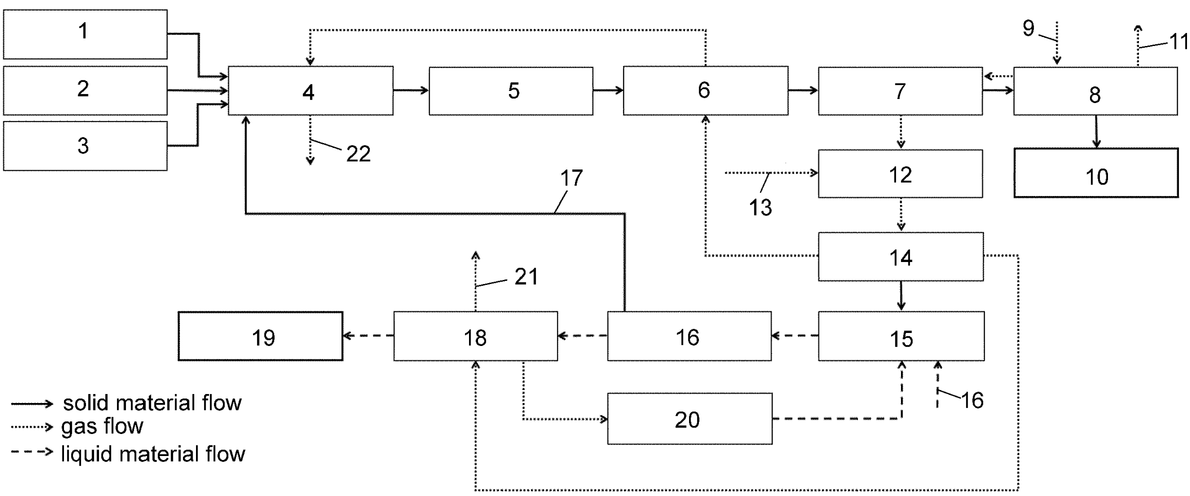

Fig. 1

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Description

[0001] The invention relates to a method of extracting lithium from a raw material mixture.

[0002] Various methods are known for recovering alkali metals, especially rare ones such as Li, Rb and Cs, and also K and Na, from silicates, aluminosilicates, phosphates and other minerals, such as lepidolite, zinnwaldite, spodumene, petalite, pollucite and amblygonite.

[0003] WO 2018/228618 A1 describes a method for recovering alkali metals including lithium from a raw material that contains a silicate mineral selected from the group of phyllosilicates containing lithium and optionally further alkali metals, such as zinnwaldite, spodumene, lepidolite, pollucite and amblygonite, an alkaline earth metal mineral, preferably a calcium mineral, such as limestone, marl and dolomite, and a reagent being capable of releasing chlorine during a thermal treatment, such as $CaCl_2$ or HCl. The raw material is subjected to heat treatment in a kiln, which results in that the structure of the silicate mineral decomposes while releasing lithium and other alkali metals which combine with chlorine to form volatile alkali metal chlorides. The alkali metal chlorides are evaporated into the exhaust gas of the kiln, and lithium and optionally additional alkali metals are subsequently recovered by condensation by drawing off 50 to 100 vol.-% of exhaust gas from the kiln at one or more different locations having different temperatures.

[0004] The remaining raw material components being present in the kiln in an at least partly melted form due to the thermal treatment are collected from the kiln and can be used as a synthetic mineral component, similar to blast furnace slag in its composition and properties, in composite cements.

[0005] The present invention aims at further improving the process described in WO 2018/228618 A1. In particular, the invention aims at adapting such a process for allowing the process to be carried out with equipment that is typically present in a cement manufacturing plant.

[0006] In order to solve this object, the invention provides a method of extracting lithium from a raw material mixture, comprising the steps of:

- providing a raw material mixture comprising:
    - a silicate mineral selected from the group of phyllosilicates containing lithium and optionally further alkali metals, such as zinnwaldite, spodumene, lepidolite, pollucite and amblygonite,
    - an alkaline earth metal mineral, preferably a calcium mineral, such as limestone, marl and dolomite,
    - a reagent containing chlorine that is not bonded to an alkali metal, said reagent being capable of releasing chlorine during a thermal treatment, such as $CaCl_2$, HCl or free Chlorine obtained from co-processing an alternative fuel,
- introducing the raw material mixture into a rotary kiln,
- subjecting the raw material mixture to a thermal treatment in the rotary kiln while burning a fuel, the fuel optionally containing said alternative fuel, wherein the thermal treatment comprises
    - melting the raw material mixture to allow the lithium and optionally the further alkali metals to combine with the chlorine of the reagent to form alkali metal chlorides in gaseous form,
    - obtaining an exhaust gas containing kiln dust and the gaseous alkali metal chlorides, the kiln dust containing chlorides,
- maintaining the melt at a temperature of > 1150°C in a kiln outlet region of the rotary kiln to allow the melt to flow to a kiln outlet of the rotary kiln,
- drawing off the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides,
- quenching the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides thereby condensing the alkali metal chlorides on the surface of the kiln dust,
- separating the condensed alkali metal chlorides adhering to the kiln dust from the exhaust gas,
- mixing the condensed alkali metal chlorides adhering to the kiln dust with water to obtain an aqueous solution of alkali metal chlorides,
- separating the aqueous solution of alkali metal chlorides from the kiln dust.

[0007] The invention is based on the finding that a process of the type described in WO 2018/228618 A1 requires special process conditions for being able to be carried out in a typical rotary kiln of a cement manufacturing plant. It was found that it requires a high temperature for melting the raw material mixture to allow the lithium and optionally the further alkali metals to combine with the chlorine of the reagent to form alkali metal chlorides in gaseous form. Further, it was found that the raw material, once melted, must not fall below the melting temperature, because this may cause material build-up that blocks the rotary kiln due to the stickiness of the material. In particular, the melt has to be maintained at a temperature of > 1150°C in a kiln outlet region of the rotary kiln to allow the melt to flow to a kiln outlet of the rotary kiln and then flow out of the kiln. Preferably, the melt is maintained at a temperature of > 1200°C in the kiln outlet region. Preferably, the temperature within the rotary kiln is controlled in order to keep the material melted along the length of the kiln and to assure the liquid phase to reach the outlet of the rotary kiln and to avoid formation of solids in the kiln.

[0008] With regard to the extraction of alkali metals, in particular lithium, it was found that their separation from the kiln exhaust gas is improved if gaseous alkali metal chlorides are drawn off from the rotary kiln together with the kiln dust. This allows quenching the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides thereby condensing the alkali metal chlorides on the surface of the kiln dust. The kiln dust typically contains chlorides, so that the kiln dust provides a highly reactive surface for condensing the alkali metal chlorides. Further, condensing the kiln dust reduces the stickiness of the material.

[0009] Considering the potentially high concentration of chlorides and sulphates in the quenching chamber and in order to provide additional reactive surface for enhancing condensation, a preferred embodiment provides that additional inert dust is added to the quenching step. For example, fien marl or limestone may be used as said inert dust. The inert dust may preferably be introduced or sprayed directly into the quenching chamber.

[0010] After the condensation, the kiln dust with the condensed alkali metal chlorides adhering thereto is separated from the exhaust gas. This separation may be performed by means of a cyclone separator or a ceramic filter. The collected dust is mixed with water, for example in a ratio between 1:2 and 1:10, and as the alkali metal chlorides are highly soluble, they are collected in an aqueous solution. The water may be filtered out via, for example using a filter press.

[0011] This aqueous solution of alkali metals chlorides can be considered the final product of the process.

[0012] Preferably, the solution of alkali metals chlorides can further be concentrated, for example using waste heat from the thermal process treatment in an industrial evaporator. In particular, the aqueous solution of alkali metal chlorides may be concentrated by evaporating water, wherein the exhaust gas separated from the condensed alkali metal chlorides adhering to the kiln dust is preferably used as a heat source for the evaporation step.

[0013] The exhaust gases from the entire process can be used in further hydrometallurgical treatment of the alkali metal solution. For example, a lithium separation may be performed by conversion to lithium carbonate, subsequent purification of lithium carbonate by recrystallization, and drying of the final lithium carbonate product.

[0014] With regard to the composition of the raw material mixture, a preferred embodiment provides that the silicate mineral is present in the raw material mixture in an amount of 20-35 wt.-%, the alkaline earth metal mineral is present in the raw material mixture in an amount of 55-75 wt.-%, and the reagent is present in the raw material mixture in an amount of 5-10 wt.-%, with the proviso that the sum of the relative amounts of the silicate mineral, the alkaline earth metal mineral and the reagent is 100 wt.-%. Preferably, the raw material mixture comprises or consists of zinnwaldite, marl and $CaCl_2$.

[0015] Exemplary compositions that have been tested are given below:

Zinnwaldite	30.67	wt. -%
Marl	61.35	wt.-% 0

(continued)

	7. 98	wt.-%
Water for granulation	13	wt. -%

Zinnwaldite	23.40	wt. -%
Marl	70.21	wt. -%
$CaCl_2$	6.39	wt.

Zinnwaldite	33.83	wt.-%
Marl	57.51	wt.-%
CaCl2	8.66	wt.-%

Zinnwaldite	33.96	wt.-%
Marl	57.72	wt.-%
CaCl2	8.32	wt.-%

Zinnwaldite	34.08	wt. -%
Marl	57.94	wt. -%
$CaCl_2$	7.98	wt.-%

Zinnwaldite	34.22	wt.-%
Marl	58.18	wt.-%
CaCl2	7.60	wt. -%

[0016] The weight ratio of the total amount of alkaline earth metal oxides to SiO_2 in the raw material mixture preferably is at least 1, i.e. $(CaO + MgO)/SiO_2 > 1$.

[0017] The weight ratio of the total amount of alkaline earth metal oxides and SiO_2 in the raw material mixture is at least 0.67, i.e. CaO + MgO + SiO2 > 0.67

[0018] According to another preferred embodiment, the reagent level is adjusted to the alkali metals concentration in the raw material mixture. Preferably, the chlorine level is 50-150 % stoichiometrically to all alkali metals in raw material mixture.

[0019] The reagent containing chlorine may be a substance that is able to release chlorine in its free form or in a bonded form, such as $CaCl_2$ or HCl. However, chlorine must not be bonded to an alkali metal. Therefore, kiln bypass dust is not considered a suitable reagent, because the chlorides are already combined with alkali metals, and not available for the extraction of lithium.

[0020] Preferably, the concentration of lithium in the silicate mineral is at least 0.2 wt.%, preferably at least 0.9 wt.%.

[0021] It is not required, that the three constituents of the raw material mixture are introduced into the rotary kiln in a premixed form. Rather, the reagent capable of releasing chlorine during thermal treatment, or a partial amount thereof, can also be introduced into the rotary kiln as a fuel for the kiln burner.

[0022] In some embodiments of the invention, the reagent capable of releasing chlorine during the thermal treatment may be chlorinated organic compounds, such as chlorinated polymers (for example polyvinylchloride, polychloroprene), polychlorinated biphenyls or halogenated oils or solvents. These compounds can be burnt in the rotary kiln as alternative fuels and their emissions contain chlorine and/or hydrogen chloride. Utilization of these flue gasses, which would otherwise need to be removed, in an industrial process and chlorine fixation are very desirable from the economic and environmental point of view.

[0023] With regard to the quenching step, a preferred embodiment provides that the quenching step comprises cooling the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides to a temperature of below 600°C. Quenching to temperatures below 600°C may be performed by using fresh air in order to avoid build-ups formation. Quenching is preferably done right at the kiln inlet border, preferably the cooling air is directed towards the exhaust gas stream and enters the first meter of the rotary kiln.

[0024] Preferably, the method comprises a pre-heating step carried out before the thermal treatment, in which the raw material mixture is preheated to a temperature slightly lower than the temperature when the first alkali metals and chlorine compounds start to melt, preferably between 600°C and 750°C. The preheating step may be performed in a rotary kiln or a grate preheater/precalciner (similar to a Lepol system). The exhaust gas from the rotary kiln may be used as a primary source of heat for preheating/precalcining, whereas secondary heat and/or start-up heat may be introduced by natural gas, pet coke or coal.

[0025] The raw material mixture may be subjected to the preheating step and the thermal treatment in the form of a dust or as granules. In the case of granules, the granules preferably have a particle size of < 3cm, preferably < 1cm. Granules may be produced by adding water to the raw material mixture, according to any known granulation process, such as by using a rotating pan. Granules avoid the formation of dust in the thermal treatment. In the case of dust, the dust has a particle size distribution corresponding to a 10-50% residue on a 90 micron sieve or having a D50 of 30-90 μm (the D50 meaning that 50% of the particles are smaller than 30-90 pm).

[0026] The rotary kiln used in the invention is understood to be a rotary kiln of the type used for producing cement clinker in a cement manufacturing plant. When producing cement clinker, the preheated and optionally pre-calcined cement raw meal is introduced into the rotary kiln through a kiln inlet, which is arranged opposite a kiln outlet. The tubular kiln has an inclination of a few degrees relative to the horizontal, so that material introduced through the kiln inlet can be slowly transported to the kiln outlet by the effect of gravity and according to the rotational speed of the kiln while being sintered. The kiln burner is arranged at the kiln outlet, so that exhaust gases are travelling through the rotary kiln in counter-current flow to the clinker and leaves the kiln via the kiln inlet.

[0027] Within the context of the present invention, the terms "kiln inlet" and "kiln outlet" are used in the same sense as described above in relation to a standard rotary kiln used for producing cement clinker.

[0028] In the method of the present invention, the raw material mixture may preferably be introduced into the rotary kiln through a kiln inlet that is arranged opposite the kiln outlet and the raw material mixture is preferably conducted in counter-current flow to the exhaust gas that is drawn off from the rotary kiln through the kiln inlet. This embodiment is suitable for raw material that is used either in the form of granules or in the form of a dust.

[0029] In an alternative embodiment of the invention, the raw material mixture being in the form of a dust may be introduced into the rotary kiln through the kiln outlet. In this way, a co-flow set up is achieved, wherein the raw material is fed to the kiln outlet next to the main burner. The dust flow is preferably sprayed into the exhaust gases from the kiln outlet side and settles down along the kiln length, then it flows as a liquid slowly back to the kiln outlet according to the rotational speed of the kiln, where it is collected and further processed.

[0030] As mentioned above, once lithium and optionally other alkali metals are extracted, the resulting material can be used as a synthetic mineral component in cement compositions. In order to produce the highest quality of synthetic mineral component, it is advantageous to avoid slow cooling of the material. At the same time, the temperature of the melt shall not fall below the melting temperature before the melt leaves the kiln through the kiln outlet. Therefore, a specific temperature control is preferred, wherein the melt is collected from the rotary kiln having a temperature still above the melting point, and then abruptly cooled. To this end, a preferred embodiment provides that the main burner of the rotary kiln is arranged outside of the kiln to assure that the flame starts at the border of the rotary kiln and that the kiln cooling zone is as short as possible.

[0031] The cooling step of the liquid material that has been collected from the rotary kiln may preferably be performed in a dry slag granulator with a spinning cup and grates. Fresh air may be used for the cooling step. A part of the preheated air may then be used in the rotary kiln as secondary air.

[0032] According to a second aspect of the invention, a device for extracting lithium from a raw material mixture is provided, comprising a rotary kiln having a kiln inlet and a kiln outlet, a kiln burner arranged at the kiln outlet, a kiln hood adjacent the kiln outlet, a quenching chamber directly connected to the kiln inlet for quenching an exhaust gas together with kiln dust and gaseous alkali metal chlorides drawn of from the kiln inlet, a separator that is connected to the quenching chamber for separating condensed alkali metal chlorides adhering to the kiln dust from the exhaust gas, a mixing tank that is connected to the separator for mixing the condensed alkali metal chlorides adhering to the kiln dust with water to obtain an aqueous solution of alkali metal chlorides, and a filter press for separating the aqueous solution of alkali metal chlorides from the kiln dust.

[0033] As mentioned above, the kiln burner may preferably be arranged outside the rotary kiln adjacent the kiln outlet for directing a flame into the rotary kiln. This results in that a high temperature is attained directly at the border of the rotary kiln so as to avoid solidification of the molten material before it is drawn off from the kiln. For using a rotary kiln of a cement manufacturing plant for carrying out the method of the invention, the kiln is preferably adapted according to the following considerations. In a normal cement manufacturing process, the kiln is lined with high temperature resistant refractory bricks. These bricks are thermally and mechanically resistant, but do not provide sufficient resistance to heat flow. This feature is advantageous especially in the sinter zone of the kiln where, due to the heat flow, the melted liquid phase solidifies and creates build-ups. This build-up then protects the refractory from mechanical and thermal stress, prolonging its lifetime. Normally, the kiln has different kinds of refractory bricks used along its length, in order to adjust the refractor lining to the thermal and mechanical stress in different kiln sections.

[0034] For carrying out the method of the present invention, the situation is different. Because of the need to keep the material melted and flowing out of the kiln, measures should be taken to stop the heat flow through the refractory lining in the kiln in order to avoid build-up formation. For this reason, the refractory lining preferably comprises two layers.

[0035] The first layer preferably is made from hard and resistant bricks. Preferably, the bricks of the first layer are rich in zirconium, which provides very high resistance to heat, mechanical stress and alkali intrusion. The second layer of the refractory lining is preferably made of thermal insulating bricks, which should avoid excessive heat flow to the kiln shell. As the second layer is protected by the first layer, there is no special requirement on the quality of the bricks, they can be usual insulating bricks, such as high alumina refractory bricks. Preferably, the first layer and the second layer of the refractory lining are each extending over the entire length of the rotary kiln. Preferably, the first layer and the second layer each consist of only one type of bricks along the kiln length.

[0036] For a co-current set-up, a preferred embodiment provides that a dust spraying device is arranged adjacent the kiln outlet for spraying the preheated raw material mixture into the rotary kiln.

[0037] In relation to the quenching chamber, a preferred embodiment provides that a cooling air duct opens into the quenching chamber, said a cooling air duct being arranged to direct a flow of cooling air towards the exhaust gas that leaves the rotary kiln through the kiln inlet.

[0038] Further, a duct for introducing inert dust may preferably open into the quenching chamber.

wherein the rotary kiln axis has an inclination of 2-7°, preferably, 5-7° relative to the horizontal.

[0039] The rotary kiln may preferably be operated at a rotary speed of between 1 and 10 rpm.

[0040] The invention will now be described in more detail with reference to the attached drawing. Fig. 1 is a block scheme of an embodiment of the process of the invention.

[0041] Fig. 1 shows that the raw material mixture consists of a phyllosilicate mineral 1 containing lithium, mineral 2 containing alkaline earth metals, and a reagent 3 capable of releasing chlorine during a thermal treatment. The three constituents are mixed and introduced into a grinder, where the raw material mixture is subjected to a grinding step 4. The grinded material is subsequently subjected to a homogenization step 5 and to a preheating/pre-calcining step 6, where the raw material mixture is preheated to a temperature of 600-750°C. The preheated material is introduced into a rotary kiln 7, where the material is subjected to a heat treatment at a temperature at which the raw material is melted while releasing lithium, the lithium combining with the chlorine of the reagent to form alkali metal chlorides in gaseous form.

[0042] The melt is collected from the outlet of the rotary kiln 7 and subjected to a quenching and cooling step 8 by using cooling air 9. The solidified melt is collected at 10 and may be used as a mineral component in composite cements. The exhaust air that has been heated as a consequence of the cooling step 8 leaves the cooler at 11 and may be used as a waste heat for further hydrometallurgical processing.

[0043] The exhaust gas of the rotary kiln 7 contains kiln dust and the gaseous alkali metal chlorides and is subjected to a quenching step 12, wherein fresh air and/or inert dust may be added to the quenching step at 13. As a consequence of the quenching step 12, the alkali metal chlorides are condensed on the surface of the kiln dust. The exhaust gas containing the kiln dust with the alkali metal chlorides adhering thereto is fed to a separator, where a dedusting step 14 is carried out in order to separate the kiln dust form the exhaust gas.

[0044] In step 15 the dust is being leached in water 16 so as to obtain an aqueous solution of alkali metal chlorides. The aqueous solution of alkali metal chlorides is subjected to a filtration step 16 for separating the aqueous solution of alkali metal chlorides from the kiln dust. The non-soluble separated dust may be recycled into the grinding step 4 via line 17. The aqueous solution may be subjected to an evaporation step 18, thereby obtaining the final product 19, which is a concentrated solution of alkali metal chlorides. The water vapor that is removed from the evaporation step 18 may be subjected to a condensation step 20 and the resulting water may be used as leaching water in step 15.

[0045] The kiln exhaust gas, from which the kiln dust was separated in step 14, may on the one hand be used to provide heat to the preheating/precalcining step 6. After being used in the preheating/precalcining step 6, the exhaust gas may further be fed to the grinding step 4, in order to dry the raw material mixture. The exhaust gas 22 leaving the grinding step 4 may be used as waste heat for further hydrometallurgical processing.

[0046] The kiln exhaust gas, from which the kiln dust was separated in step 14, may on the other hand be used as a heat source for the evaporation step 18. Again, the exhaust gas 21 leaving the evaporation step 18 may be used as waste heat for further hydrometallurgical processing.

Claims

1. A method of extracting lithium from a raw material mixture, comprising the steps of:

- providing a raw material mixture comprising:
    - a silicate mineral selected from the group of phyllosilicates containing lithium and optionally further alkali metals, such as zinnwaldite, spodumene, lepidolite, pollucite and amblygonite,
    - an alkaline earth metal mineral, preferably a calcium mineral, such as limestone, marl and dolomite,
    - a reagent containing chlorine that is not bonded to an alkali metal, said reagent being capable of releasing chlorine during a thermal treatment, such as $CaCl_2$, HCl or free Chlorine obtained from co-processing an alternative fuel,
- introducing the raw material mixture into a rotary kiln,
- subjecting the raw material mixture to a thermal treatment in the rotary kiln while burning a fuel, the fuel optionally containing said alternative fuel, wherein the thermal treatment comprises
    - melting the raw material mixture to allow the lithium and optionally the further alkali metals to combine with the chlorine of the reagent to form alkali metal chlorides in gaseous form,
    - obtaining an exhaust gas containing kiln dust and the gaseous alkali metal chlorides, the kiln dust containing chlorides,
    - maintaining the melt at a temperature of > 1150°C in a kiln outlet region of the rotary kiln to allow the melt to flow to a kiln outlet of the rotary kiln,
- drawing off the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides,
- quenching the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides thereby condensing the alkali metal chlorides on the surface of the kiln dust,
- separating the condensed alkali metal chlorides adhering to the kiln dust from the exhaust gas,
- mixing the condensed alkali metal chlorides adhering to the kiln dust with water to obtain an aqueous solution of alkali metal chlorides,
- separating the aqueous solution of alkali metal chlorides from the kiln dust.

2. Method according to claim 1, wherein an inert dust is added to the quenching step.

3. Method according to claim 1 or 2, wherein the quenching step comprises cooling the exhaust gas together with the kiln dust and the gaseous alkali metal chlorides to a temperature of below 600°C.

4. Method according to claim 1, 2 or 3, wherein the raw material mixture is preheated at a temperature of 600-750°C before the thermal treatment step, said preheating being preferably performed in a rotary kiln, a grate preheater or a cyclone preheater.

5. Method according to any one of claims 1 to 4, wherein the raw material mixture is provided in the form of granules having a particle size of < 3cm, preferably < 1cm.

6. Method according to any one of claims 1 to 4, wherein the raw material mixture is provided in the form of a dust.

7. Method according to any one of claims 1 to 6, wherein the raw material mixture is introduced into the rotary kiln through a kiln inlet that is arranged opposite the kiln outlet and the raw material mixture is conducted in counter-current flow to the exhaust gas that is drawn off from the rotary kiln through the kiln inlet.

8. Method according to claim 6, wherein the raw material mixture being in the form of a dust is introduced into the rotary kiln through the kiln outlet.

9. Method according to any one of claims 1 to 8, wherein the concentration of lithium in the silicate mineral is at least 0.2 wt.%, preferably at least 0.9 wt.%.

10. Method according to any one of claims 4 to 9, wherein the exhaust gas separated from the condensed alkali metal chlorides adhering to the kiln dust is used as a heat source for the preheating step.

11. Method according to any one of claims 1 to 10, wherein the aqueous solution of alkali metal chlorides is concentrated by evaporating water, wherein the exhaust gas separated from the condensed alkali metal chlorides adhering to the kiln dust is preferably used as a heat source for the evaporation step.

12. A device for extracting lithium from a raw material mixture, comprising a rotary kiln having a kiln inlet and a kiln outlet, a kiln burner arranged at the kiln outlet, a kiln hood adjacent the kiln outlet, a quenching chamber directly connected to the kiln inlet for quenching an exhaust gas together with kiln dust and gaseous alkali metal chlorides drawn of from the kiln inlet, a separator that is connected to the quenching chamber for separating condensed alkali metal chlorides adhering to the kiln dust from the exhaust gas, a mixing tank that is connected to the separator for mixing the condensed alkali metal chlorides adhering to the kiln dust with water to obtain an aqueous solution of alkali metal chlorides, and a filter press for separating the aqueous solution of alkali metal chlorides from the kiln dust.

13. Device according to claim 12, wherein the kiln burner is arranged outside the rotary kiln adjacent the kiln outlet for directing a flame into the rotary kiln.

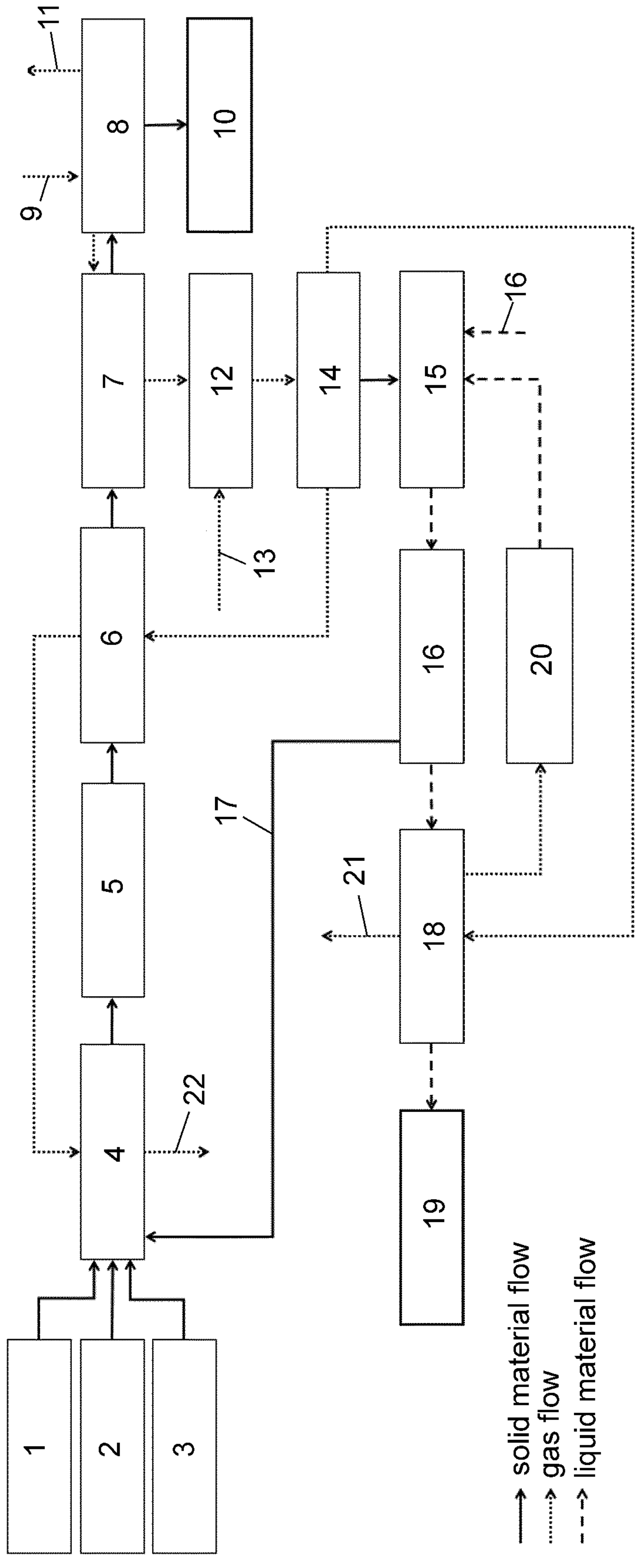
14. Device according to claim 12 or 13, wherein the inner shell of the rotary kiln, preferably including the kiln hood, comprises a refractory lining, comprising superimposed first and a second layers of refractory bricks.

15. Device according to claim 12, 13 or 14, wherein a dust spraying device is arranged adjacent the kiln outlet for spraying the raw material mixture into the rotary kiln.

16. Device according to any one of claims 12 to 15, wherein a cooling air duct opens into the quenching chamber, said a cooling air duct being arranged to direct a flow of cooling air towards the exhaust gas that leaves the rotary kiln through the kiln inlet.

17. Device according to any one of claims 12 to 16, wherein a duct for introducing inert dust opens into the quenching chamber.

18. Device according to any one of claims 12 to 17, wherein the rotary kiln axis has an inclination of 2-7°, preferably 5-7° relative to the horizontal.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solid material flow
gas flow
liquid material flow

Fig. 1

Europäisches Patentamt
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EUROPEAN SEARCH REPORT

Application Number
EP 21 02 0054

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2 627 452 A (CUNNINGHAM GEORGE L) 3 February 1953 (1953-02-03) * abstract * * column 1, line 1 - line 8 * * column 4, line 70 - column 6, line 16 * * column 3, line 1 - line 15 *	1-18	INV. C22B1/08 C22B26/12 F27B7/00
A,D	WO 2018/228618 A1 (VS CHEMICKO TECHNOLOGICKA V PRAZE [CZ]; FALTUS MILOS [CZ]) 20 December 2018 (2018-12-20) * abstract *	1-18	
A	GB 678 978 A (CIE GEOL ET MINIERE DES INGENI) 10 September 1952 (1952-09-10) * abstract *	1-18	
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TECHNICAL FIELDS SEARCHED (IPC)

C22B
F27D
F27B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	10 June 2021	Rosciano, Fabio

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 02 0054

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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