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(71) Applicant: **Indaver nv**
9130 Beveren (BE)

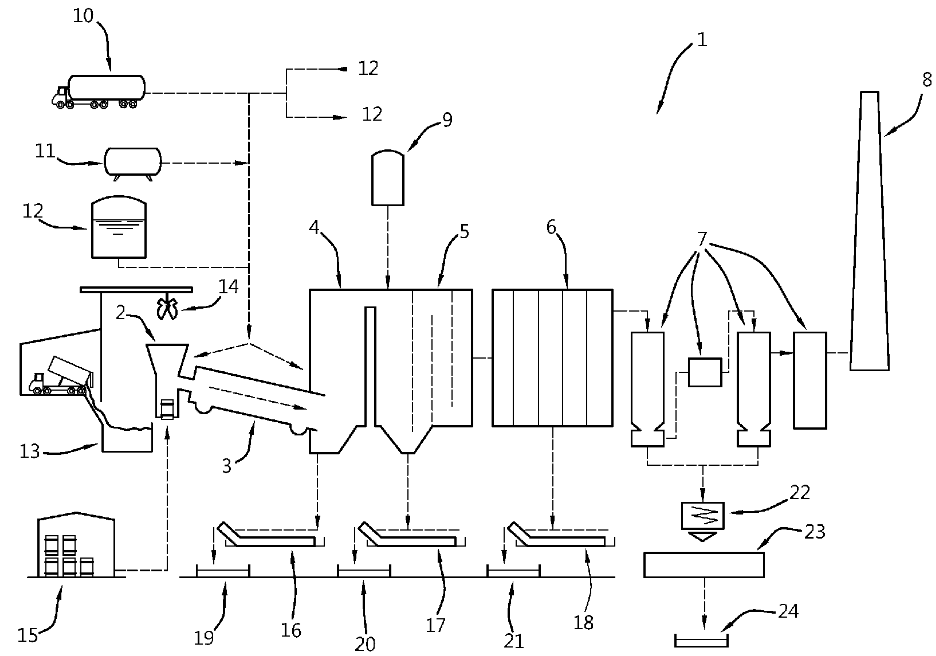
(72) Inventor: **OPDENAKKER, Stefan**
9120 Beveren (BE)

(74) Representative: **Brantsandpatents bv**
Pauline Van Pottelsberghelaan 24
9051 Ghent (BE)

(54) METHOD AND DEVICE FOR INCINERATION OF HAZARDOUS SOLID WASTE AND OBTAINED COMBUSTION PRODUCTS

(57) The present invention relates to a device for incinerating hazardous solid waste comprising a feed hopper for supplying waste to a rotary kiln, a rotary kiln, a post-combustion chamber, a steam boiler and a gas scrubbing installation, the device comprising at least one injection lance for direct injection of liquid waste into the post-combustion chamber. The invention also relates to a method for incinerating hazardous solid waste, comprising placing hazardous waste in a feed hopper, feeding the hazardous waste from the feed hopper into a rotary kiln, incinerating the hazardous waste in the rotary kiln, post-burning of incinerated hazardous waste from the rotary kiln in a post-combustion chamber, generating steam in a steam boiler using hot gases from the post-combustion chamber, scrubbing hot gases from the steam boiler in a gas scrubbing installation, wherein liquid waste is injected directly into the post-combustion chamber using at least one injection lance.

Fig. 1



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Description

TECHNICAL FIELD

[0001] The invention relates to a device for incinerating waste materials, in particular hazardous waste materials, and to a method for incinerating said hazardous waste materials.

PRIOR ART

[0002] The incineration of waste materials has long been a proven method of processing waste. This happens, for example, in rotary kilns. The rotary kilns are used in a continuous process and are therefore quite efficient. Generated heat is used for the production of steam, which in turn has further practical applications for heating homes and for the production of electricity.

[0003] Such rotary kilns are used for incinerating hazardous waste. A disadvantage of incinerating hazardous waste is that different hazardous waste materials cannot necessarily be supplied together because in certain cases they can react very violently with each other or because the hazardous waste materials are not compatible with each other. In such cases it is necessary to first burn a first hazardous waste material completely in the rotary kiln, after which a second hazardous waste material can only be supplied for incineration in the rotary kiln. Because the first hazardous waste material was completely burned up, there is no longer a continuous process, and the incineration of the hazardous waste is less efficient. Another possible disadvantage is that a hazardous waste material does not have a high calorific value, so that insufficient heat is produced to achieve complete combustion of the hazardous waste. In that case, it is necessary to introduce an auxiliary fuel into the rotary kiln in order to burn the hazardous waste completely, further reducing the efficiency of the incineration.

[0004] CN111306549 describes a green and efficient method for incinerating hazardous waste in a rotary kiln. This known method has the disadvantage that the flow rate of liquid waste materials introduced into a post-combustion chamber cannot be accurately controlled, which can lead to a loss of efficiency.

[0005] CN104501178 concerns a system for incinerating hazardous industrial waste, comprising a rotary kiln. The disadvantage of this system is that only flue gases from the rotary kiln are led to a post-combustion chamber, so that possibly hazardous waste materials are not completely incinerated and are discharged from the rotary kiln via the ashes.

[0006] The present invention aims to solve at least some of the above problems or drawbacks.

SUMMARY OF THE INVENTION

[0007] In a first aspect, the present invention relates to a device according to claim 1.

[0008] An advantage of this device is that the device comprises at least one injection lance for direct injection of liquid waste into the post-combustion chamber. As a result, two hazardous wastes that cannot be supplied together via the feed hopper, for example because the hazardous wastes are reactive with each other or are incompatible with each other, can still be incinerated simultaneously because a first hazardous waste is incinerated via the feed hopper in the rotary kiln and a second hazardous waste is atomized via the at least one injection lance in the post-combustion chamber. Because the first hazardous waste has already largely been incinerated in the rotary kiln and the second hazardous waste is immediately incinerated, the two hazardous wastes cannot react with each other. It is therefore not necessary to first burn a first hazardous waste completely in the rotary kiln in order to subsequently burn the second hazardous waste in the rotary kiln. An additional advantage is that if a first hazardous waste has insufficient calorific power, a second hazardous waste can be atomized in the post-burning chamber, in order to increase the calorific power and to achieve complete combustion of both hazardous wastes in the post-burning chamber.

[0009] Preferred embodiments of the device are set out in claims 2-9.

[0010] A specific preferred embodiment concerns a device according to claim 3.

[0011] This preferred embodiment is advantageous because a flow rate of liquid waste can be regulated by regulating the flow rate of the gas to the at least one injection lance. A control valve for gas can be controlled accurately, while a control valve in a liquid waste supply line is more subject to wear from the liquid waste and can therefore leak or get blocked and can also be controlled less accurately. Accurately controlling the flow rate of the liquid waste results in a more efficient incineration of the hazardous waste in the post-combustion chamber.

[0012] In a second aspect, the present invention relates to a method according to claim 10. This method has the advantage, among other things, that two hazardous wastes that react with each other or that are not compatible with each other can be incinerated simultaneously, because the first hazardous waste has already largely been incinerated in the rotary kiln and the second hazardous waste is incinerated immediately after atomization in the post-combustion chamber. An additional advantage of the method is that the incineration of hazardous waste can be carried out as a continuous process, because a first hazardous waste does not have to be completely incinerated before a second hazardous waste is incinerated, resulting in a more efficient incineration of the hazardous waste. The method is also advantageous in case a first hazardous waste has insufficient calorific power to burn completely. By adding a second hazardous waste in the post-combustion chamber, the calorific power in the post-combustion chamber is increased, so that both hazardous wastes burn completely, without or with only a minimal addition of auxiliary fuel. This results in a much more efficient incineration of the hazardous waste.

[0013] Preferred embodiments of the method are described in the dependent claims 11-14.

[0014] In a third aspect, the present invention relates to metals which have been recovered after incineration of hazardous waste by means of a device according to the first aspect or a method according to the second aspect.

[0015] Many hazardous wastes are supplied in metal drums and placed in the feed hopper in these metal drums. After the hazardous waste has been incinerated, these metal drums remain in ashes. By melting down these metal drums, these metals can be recovered, so that the incinerated hazardous waste has an additional economic value. An additional advantage is that these metal drums do not have to be landfilled, which can be harmful to the environment.

DESCRIPTION OF THE FIGURES

[0016] **Figure 1** shows a schematic representation of a device according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0017] Unless otherwise defined, all terms used in the description of the invention, including technical and scientific terms, have the meaning as commonly understood by a person skilled in the art to which the invention pertains. For a better understanding of the description of the invention, the following terms are explained explicitly.

[0018] In this document, "a" and "the" refer to both the singular and the plural, unless the context presupposes otherwise. For example, "a segment" means one or more segments.

[0019] The terms "comprise," "comprising," "consist of," "consisting of," "provided with," "include", "including", "contain", "containing", are synonyms and are inclusive or open terms that indicate the presence of what follows, and which do not exclude or prevent the presence of other components, characteristics, elements, members, steps, as known from or disclosed in the prior art.

[0020] Quoting numerical intervals by endpoints comprises all integers, fractions and/or real numbers between the endpoints, these endpoints included.

[0021] Atomization in the context of this document means the transformation of a bulk liquid into a mist of liquid droplets in a surrounding gas.

[0022] In the context of this document, a waste is pasty if a waste has a consistency similar to a paste, dough or gruel.

[0023] A hazardous waste is an industrial or medical waste that is harmful to the environment and/or to human health according to Regulation 1272/2008 of the European Union.

[0024] In a first aspect, the invention relates to a device for incinerating hazardous solid waste.

[0025] According to a preferred embodiment, the device comprises a rotary kiln, a feed hopper for supplying waste materials to the rotary kiln, a post-combustion chamber, a steam boiler and a gas scrubbing installation.

[0026] An outlet of the feed hopper is located on an inlet of the rotary kiln or connected to the inlet of the rotary kiln. For example, the outlet of the feed hopper is connected to the inlet of the rotary kiln by means of a ramp or a conveyor belt. A feed hopper is suitable for supplying preferably solid hazardous waste. It will be apparent to one skilled in the art that, depending on the design, a feed hopper can also be used for liquid and/or pasty hazardous wastes, if the liquid and/or pasty hazardous wastes are packaged.

[0027] The rotary kiln extends along a longitudinal axis. The rotary kiln is rotatable about the longitudinal axis. The rotary kiln is set up at an angle, with the longitudinal axis at an angle to a horizontal plane. The longitudinal axis has a first end and a second end, the first end being higher than the second end. The inlet of the rotary kiln is located at the first end of the longitudinal axis. The rotary kiln has an outlet at the second end of the longitudinal axis. A rotary kiln is advantageous for mixing and churning hazardous waste, so that complete incineration of the hazardous waste is achieved. Because the rotary kiln is set up at an angle, the contents of the kiln move under the influence of gravity towards the outlet of the rotary kiln.

[0028] The outlet of the rotary kiln preferably leads directly to the post-combustion chamber. This is advantageous for automatically introducing combustion products from the rotary kiln into the post-combustion chamber and for limiting calorific losses. The combustion products typically comprise 10% to 22% bottom ash and 78% to 90% flue gases. The flue gases typically comprise 3% to 5% boiler and fly ash. Due to heat in the post-combustion chamber, residual hazardous waste from the rotary kiln continues to burn. A complete incineration of the hazardous waste from the rotary kiln is achieved.

[0029] The device comprises at least one injection lance for direct injection of liquid waste into the post-combustion chamber. Preferably, the device comprises at least two injection lances, more preferably at least three injection lances for direct injection into the post-combustion chamber. It will be apparent to one skilled in the art that each injection lance can inject a different hazardous waste or that each injection lance can inject the same hazardous waste directly into the post-combustion chamber. It will also be apparent that an injection lance can inject a traditional auxiliary fuel into the post-combustion chamber. The at least one injection lance is advantageous for simultaneous incineration of two hazardous wastes that cannot be supplied together via the feed hopper, for example because the hazardous wastes are reactive with each other or are incompatible with each other. Because a first hazardous waste is largely incinerated in the rotary kiln via the feed hopper and a second hazardous waste is atomized via the at least one injection lance directly in the post-combustion chamber and immediately burns, the two hazardous wastes cannot react with each other. An additional advantage is that it is not necessary to burn a first hazardous waste completely in the rotary kiln in order to subsequently burn the second hazardous waste in the rotary kiln. It is also very advantageous that if a first hazardous waste has insufficient calorific power to maintain a high temperature in the post-combustion chamber, a second hazardous waste can be atomized in the post-burning chamber, in order to increase the calorific power and to achieve complete combustion of both hazardous wastes in the post-burning chamber. In this case, no or only a minimal amount of auxiliary fuel is supplied, so that a higher efficiency can be achieved in the incineration of hazardous waste.

[0030] The post-combustion chamber comprises an outlet for flue gases. The flue gas outlet of the post-combustion chamber is connected to an inlet of the steam boiler. The steam boiler comprises a heat exchanger for generating steam. To this end, heat is extracted from the flue gases.

[0031] The steam boiler comprises an outlet for flue gases. The flue gas outlet of the steam boiler is directly or indirectly connected to an input of the gas scrubbing installation. The gas scrubbing installation comprises a first section for cooling the flue gases by injection of scrubbing water. The gas scrubbing installation comprises a second section of the gas scrubbing installation for scrubbing the flue gases with scrubbing water from the first section. The second section comprises a supply of milk of lime ($Ca(OH)_2$) to regulate the acidity of the flue gases. The gas scrubbing installation comprises a third section for SO_2 removal. The third section comprises a feed for NaOH for controlling the acidity of the flue gases.

[0032] According to an embodiment, the device comprises a bunker for solid hazardous waste. The device comprises a movable crane with a gripper arm for grabbing solid hazardous waste and placing solid hazardous waste in the feed hopper of the device. The movable crane can be moved between the bunker and the feed hopper.

[0033] Preferably, the bunker and the feed hopper are placed in the same building. A bunker is advantageous for safe and temporary storage of solid hazardous waste.

[0034] According to a preferred embodiment, the device comprises at least one storage tank for the storage of liquid hazardous waste. An outlet of the at least one storage tank is connected to the at least one injection lance via a supply line. If there are multiple storage tanks, preferably all storage tanks are connected to the at least one injection lance via one or more supply lines. Preferably, each storage tank is connected to the at least one injection lance with a separate supply line, with a collector for the supply lines being placed on the at least one injection lance. If there are several injection lances, the at least one storage tank is preferably connected to all injection lances via one or more supply lines. If there are several injection lances and several storage tanks, all storage tanks are preferably connected to all injection lances via one or more supply lines. Preferably, the storage tanks and/or the supply lines and/or the injection lances comprise shut-off valves so that connections between storage tanks and injection lances can be shut off. Storage tanks are advantageous for the temporary safe storage of liquid hazardous substances.

[0035] The supply line comprises a pump. The pump is suitable for pumping the liquid hazardous liquid from the at least one storage tank to the at least one injection lance.

[0036] Preferably, the supply line comprises a filter.

[0037] The device comprises a return line from the at least one injection lance to the at least one storage tank. If there are several storage tanks, the device preferably comprises one or more return lines from the at least one injection lance to all storage tanks. The device preferably comprises a separate return line from the at least one injection lance to each storage tank, a collector for the return lines being placed on the at least one injection lance. If there are several injection lances, the device preferably comprises one or more return lines from all injection lances to the at least one storage tank. If there are several injection lances and several storage tanks, the device preferably comprises one or more return lines from all injection lances to all storage tanks. Preferably, the return lines comprise shut-off valves so that return lines between storage tanks and injection lances can be shut off. This is advantageous in order to prevent liquid hazardous waste from a first storage tank ending up via a return line in a second storage tank with another liquid hazardous waste, possibly causing an undesirable reaction. Supply lines and return lines between a first storage tank and a second storage tank are preferably separated in order to avoid possible mixing of liquid hazardous waste from the first storage tank and liquid hazardous waste from the second storage tank.

[0038] A return line comprises a control valve. A control valve comprises a controller for controlling the control valve. The device comprises a pressure sensor for measuring pressure in the supply line and/or return line. The controller of the control valve is coupled to said pressure sensor. In this context, coupled means that the controller can directly or indirectly receive measured values from said pressure sensor and/or can read them directly or indirectly.

[0039] This embodiment is advantageous for obtaining a constant pressure at an entry point of the at least one injection lance. This pressure may vary, for example, by a changing level in the at least one storage tank, by a pressure difference across the filter in the supply line, by a varying flow through the injection lance, etc. A varying pressure at the entry point of the at least one injection lance results in a varying direct injection of hazardous waste into the post-combustion chamber, resulting in an irregular supply and combustion in the post-combustion chamber. Compensating the varying pressure at the entry point of the at least one injection lance by controlling the pump in the supply line is too slow for accurate compensation because it requires changing the speed of the pump. A control valve, on the other hand, can open or close almost immediately, completely or partially, so that if the pressure at the entry point of the at least one injection lance is too high or too low, more or less liquid hazardous waste can flow back to the at least one storage tank, thereby minimizing pressure variations at the entry point of the at least one injection lance.

[0040] According to an embodiment, the device comprises a storage tank for chlorofluorocarbons (CFCs). The storage tank for CFCs is a fixed storage tank or a temporary movable storage tank. CFCs are gases that are hazardous to the environment and are responsible for the hole in the ozone layer. Freon® is the best known CFC. The storage tank is connected by a supply line to the at least one injection lance. It will be apparent to one skilled in the art that in the case of a temporary mobile storage tank, the supply line between the storage tank for CFCs and the at least one injection lance can be disconnected at least at the level of the storage tank for CFCs. CFCs are suitable to be injected directly into the post-combustion chamber as a hazardous waste.

[0041] According to a preferred embodiment, the device comprises a supply line with lifting device for feeding drums to the feed hopper. The device comprises a storage space for drums. The supply line with lifting device connects the storage space with the feed hopper. The supply line with lifting device comprises near the feed hopper a piercing means, such as for instance pins or cutters, for piercing the drums so that the drums do not explode during combustion in the rotary kiln. Hazardous waste is often transported in drums. This embodiment is advantageous because the drums do not have to be opened and emptied manually, which limits the risk of accidents.

[0042] According to an embodiment, the device comprises a connection point. The connection point is connected to the at least one injection lance by a supply line. The connection point is advantageous for connecting, for example, a tanker to the at least one injection lance. This allows hazardous waste from the tanker to be injected directly into the post-combustion chamber.

[0043] According to a preferred embodiment, the injection lance comprises a longitudinal supply channel for the supply of liquid waste. The longitudinal supply channel extends from an opening at a first end of the injection lance to an opening at an opposite second end of the injection lance. The opening at the first end is an entry point for the injection lance. The opening at the second end is an exit point of the injection lance. Concentrically around the supply channel, the injection lance comprises a gas channel for supplying a gas. The gas channel also extends from an opening at the first end to the second end. The gas channel comprises at the second end at least six outlet openings for distributing the gas, preferably at least eight outlet openings, more preferably at least ten outlet openings and even more preferably at least twelve outlet openings. The outlet openings are preferably distributed evenly over a circumference around the supply channel. The gas is preferably an inert gas. Non-limiting examples of gases are nitrogen gas, compressed air and steam. A spray head is placed on the injection lance. The spray head is placed on the injection lance at the second end. The spray head comprises an internal mixing chamber. The supply channel and the gas channel open into the internal mixing chamber.

[0044] An injection lance with a gas channel around a supply channel is advantageous for cooling the liquid waste materials during transport through the injection lance, for instance by means of nitrogen gas or compressed air. This is advantageous, for example, for cooling the injection lance itself in order to prevent the injection lance from being damaged by heat in the post-combustion chamber.

[0045] An injection lance with a gas channel around a supply channel is advantageous for heating the liquid waste during transport through the injection lance, for instance by means of steam. This is particularly advantageous in case the liquid wastes are very viscous or solidify easily in order to prevent the liquid wastes from blocking the supply channel.

[0046] The mixing chamber is advantageous for mixing the liquid waste with the gas. As a result, a mist of the liquid waste is formed. The at least six outlet openings are advantageous for an optimal distribution of the gas in the mixing chamber. By atomizing the liquid waste, the liquid waste is uniformly distributed in the post-combustion chamber, as a result of which an even combustion of the liquid waste takes place in the post-combustion chamber.

[0047] According to a further embodiment, the device comprises sensors for measuring the temperature, flow rate and density of liquid hazardous waste to the at least one injection lance in the active state of the device. The sensors may or may not be wholly or partially combined. The device further comprises a control valve for controlling a flow rate of the gas to the gas channel. The control valve comprises a controller for controlling the control valve. The controller of the control valve is coupled to the said sensors. In this context, coupled means that the controller of the control valve can directly or indirectly receive measured values from said sensors and/or can read them directly or indirectly.

[0048] This preferred embodiment is advantageous because a flow rate of liquid waste can be regulated by regulating the flow rate of the gas to the at least one injection lance. A control valve for gas can be controlled accurately, while a control valve in a liquid waste supply line is more subject to wear from the liquid waste and can therefore leak or get blocked and can also be controlled less accurately. By regulating the flow rate of the gas, the mixing chamber is filled more or less with gas and less or more with wastes. The required gas flow rate for atomizing the liquid waste depends on the flow rate, the temperature and the density of the liquid waste. Accurately controlling the flow rate of the liquid waste results in a more efficient incineration of the hazardous waste in the post-combustion chamber. This embodiment is also advantageous for avoiding flashback in the at least one injection lance. Possible flashback can be avoided by throttling the mixing chamber with gas.

[0049] This embodiment can be advantageously combined with a previously described embodiment in which the device comprises at least one storage tank, a supply line and a return line, for obtaining a regular supply and combustion of the liquid waste in the post-combustion chamber.

[0050] According to an embodiment, the device comprises a water purification installation for purifying the scrubbing water from the gas scrubbing installation. This water may still contain dust, as well as metal salts and mercury and therefore cannot be discharged. By purifying the water in the water purification installation, the scrubbing water is dischargeable.

[0051] According to a preferred embodiment, the device comprises an electrofilter for filtering flue gases from the steam boiler. The electrofilter is a dry electrofilter. This is advantageous because no water is polluted, which has to be purified. The electrofilter is advantageous for removing fly ash from flue gases leaving the steam boiler. Up to 85%, preferably 90%, more preferably 95% and even more preferably 99.5% of the fly ash is removed from the flue gases. The electrofilter is preferably placed between the steam boiler and the gas scrubbing installation.

[0052] According to a further embodiment, the device comprises an outlet for recuperating fly ash from the electrofilter. Fly ash is still a hazardous inorganic substance that requires further treatment and then safe storage.

[0053] According to a preferred embodiment, the post-combustion chamber comprises an outlet for recovery of bottom ash. Bottom ash comprises still usable metals from metal drums in which hazardous waste was introduced into the feed hopper. These metals can be recovered from the bottom ash. By recovering these metals, these metals can be reused, so that the incinerated hazardous waste has an additional economic value. An additional advantage is that these metals do not have to be landfilled, which can be harmful to the environment.

[0054] According to an embodiment, the steam boiler comprises an outlet for recovery of boiler dust.

[0055] According to a preferred embodiment, the device comprises a urea tank. The urea tank is connected to the steam boiler via a supply line. This embodiment is advantageous for feeding urea into the steam boiler, as a result of which an amount of NOx in the flue gases from the steam boiler is reduced. Nitrogen oxides are reduced to nitrogen gas. The reduction proceeds according to a selective non-catalytic reduction. Simplified, the reduction can be written as $4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6H_2O$.

[0056] According to an embodiment, the device comprises a dioxin filter. The dioxin filter is preferably placed after the gas scrubbing installation. The dioxin filter comprises a lignite filter. A lignite filter is beneficial for removing dioxins from flue gases, but also for removing furans, mercury and other heavy metals.

[0057] According to an embodiment, the steam boiler is coupled to a heat network. This is advantageous for using the steam produced for industrial applications or for heating industrial and residential buildings. The steam produced can also be used as an inert gas as in a previously described embodiment.

[0058] According to an embodiment, the steam boiler is coupled to a turbine. This is advantageous for using produced steam to produce electricity. The electricity produced can be used in the device, as well as externally for industrial and residential applications.

[0059] According to an embodiment, the device comprises an induced draught fan. The induced draught fan is preferably placed between the dioxin filter of a previously described embodiment and the gas scrubbing installation. An induced draught fan is advantageous for a good flow of flue gases from the rotary kiln to the gas scrubbing installation and from the gas scrubbing installation to the dioxin filter. Due to the induced draught fan, there is an underpressure in the device from the rotary kiln to the gas scrubbing installation and an overpressure from the gas scrubbing installation.

[0060] According to an embodiment, the device comprises at least one secondary injection lance for direct injection of hazardous liquid waste into the rotary kiln. Preferably, the device comprises at least two secondary injection lances, more preferably at least three secondary injection lances for direct injection into the rotary kiln. The secondary injection lances are preferably located at the first end of the rotary kiln. The secondary injection lances are advantageous for injecting liquid hazardous wastes directly into the rotary kiln that do not react very violently with hazardous solid wastes or with packaged liquid and/or pasty hazardous wastes supplied via the feed hopper, so that these liquid hazardous wastes can be incinerated in the rotary kiln together with the hazardous solid waste or the packaged liquid and/or pasty hazardous waste. This is also advantageous for increasing the calorific power in the rotary kiln if the hazardous solid waste or the packaged liquid and/or pasty hazardous waste has a limited calorific value, as a result of which the hazardous solid waste or the packaged liquid and/or pasty hazardous waste burn better in the rotary kiln. It will be apparent to one skilled in the art that the calorific power in the rotary kiln can also be increased by directly injecting an auxiliary fuel into the rotary kiln. It will be apparent to one skilled in the art that previously described embodiments about injection lances for direct injection of liquid waste into the post-combustion chamber also apply mutatis mutandis to secondary injection lances.

[0061] According to an embodiment, the device comprises at least one tertiary injection lance for direct injection of pasty hazardous wastes into the rotary kiln. The tertiary injection lances are preferably located at the first end of the rotary kiln. The tertiary injection lances are advantageous for injecting liquid hazardous wastes directly into the rotary kiln that do not react very violently with hazardous solid wastes or with packaged liquid and/or pasty hazardous wastes supplied via the feed hopper, so that these pasty hazardous wastes can be incinerated in the rotary kiln together with the hazardous solid waste or the packaged liquid and/or pasty hazardous waste. This is also advantageous for increasing the calorific power in the rotary kiln if the hazardous solid waste or the packaged liquid and/or pasty hazardous waste has a limited calorific value, as a result of which the hazardous solid waste or the packaged liquid and/or pasty hazardous waste burn better in the rotary kiln.

[0062] In a second aspect, the invention relates to a method for incinerating hazardous solid waste.

[0063] In a preferred embodiment the method comprises the steps of:

- placing hazardous waste in a feed hopper;
- feeding from the feed hopper of the hazardous waste into a rotary kiln;
- incineration of the hazardous waste in the rotary kiln;
- post-burning of incinerated hazardous waste from the rotary kiln in a post-combustion chamber;
- generating steam in a steam boiler using hot flue gases from the post-combustion chamber;
- scrubbing of hot flue gases from the steam boiler in a gas scrubbing installation.

[0064] An outlet of the feed hopper is located on an inlet of the rotary kiln or connected to the inlet of the rotary kiln.

[0065] The rotary kiln extends along a longitudinal axis. The rotary kiln rotates during the incineration of the hazardous waste. The rotary kiln is set up at an angle, with the longitudinal axis at an angle to a horizontal plane. The longitudinal axis has a first end and a second end, the first end being higher than the second end. The inlet of the rotary kiln is located at the first end of the longitudinal axis. The rotary kiln has an outlet at the second end of the longitudinal axis. By rotating the rotary kiln, the hazardous waste is mixed and churned up during incineration, so that the hazardous waste is burned as completely as possible. The contents of the kiln moves under the influence of gravity towards the outlet of the rotary kiln.

[0066] The outlet of the rotary kiln preferably opens directly into the post-combustion chamber, so that combustion products from the rotary kiln are automatically introduced into the post-combustion chamber. In addition, this limits calorific losses. Due to heat in the post-combustion chamber, residual hazardous waste from the rotary kiln continues to burn in the post-combustion chamber.

[0067] Liquid hazardous waste is injected directly into the post-combustion chamber using at least one injection lance, preferably using at least two injection lances, more preferably using at least three injection lances. It will be apparent to one skilled in the art that each injection lance can inject a different hazardous waste or that each injection lance can inject the same hazardous waste directly into the post-combustion chamber. It will also be apparent that an injection lance can inject a traditional auxiliary fuel into the post-combustion chamber. The liquid hazardous waste is atomized by the at least one injection lance when it is injected directly into the post-combustion chamber. The direct injection of liquid hazardous waste is particularly advantageous because two hazardous wastes that react with each other or that are not compatible with each other can be incinerated simultaneously, because a first hazardous waste has already largely been incinerated in the rotary kiln and a second hazardous waste is incinerated immediately after atomization in the post-combustion chamber, as a result of which the first hazardous waste and the second hazardous waste cannot react with each other. An additional advantage of the method is that the incineration of hazardous waste can be carried out as a continuous process, because a first hazardous waste does not have to be completely incinerated before a second hazardous waste is incinerated, resulting in a more efficient incineration of the hazardous waste. The method is also advantageous in case a first hazardous waste has insufficient calorific power to burn completely, in other words if the combustion of the first hazardous waste generates insufficient heat to maintain a high temperature in the post-combustion chamber to completely burn residues of the first hazardous waste in the post-combustion chamber. By adding a second hazardous waste in the post-combustion chamber, the calorific power in the post-combustion chamber is increased, so that both hazardous wastes burn completely, without or with only a minimal addition of auxiliary fuel. This results in a much more efficient incineration of the hazardous waste.

[0068] The post-combustion chamber comprises an outlet for flue gases. The flue gas outlet of the post-combustion chamber is connected to an inlet of the steam boiler. The hot flue gases from the post-combustion chamber flow through the steam boiler. The steam boiler comprises a heat exchanger for generating steam. To this end, heat is extracted from the flue gases.

[0069] The steam boiler comprises an outlet for flue gases. The flue gas outlet of the steam boiler is directly or indirectly connected to an input of the gas scrubbing installation. The hot flue gases from the steam boiler are cooled in a first section of the gas scrubbing installation by injection of scrubbing water. The flue gases are then scrubbed in a second section with the scrubbing water from the first section. To this end, milk of lime ($Ca(OH)_2$) is added to regulate the acidity of the flue gases. In a third section, the flue gases are scrubbed again to remove SO_2. To this end, NaOH is added to regulate the acidity of the flue gases.

[0070] According to a preferred embodiment, the method comprises the additional step of measuring temperature, flow rate and density of the liquid hazardous waste to the at least one injection lance. The at least one injection lance comprises a longitudinal supply channel for the supply of liquid or pasty hazardous waste. Concentrically around the supply channel, the at least one injection lance comprises a gas channel for supplying a gas. The gas is preferably an inert gas. Non-limiting examples of gases are nitrogen gas, compressed air and steam. A spray head is placed on the injection lance. The spray head comprises an internal mixing chamber. The supply channel and the gas channel open into the internal mixing chamber.

[0071] The flow rate of the liquid hazardous waste is controlled by regulating a pressure of the gas to said gas channel with the aid of a control valve on the basis of the measured temperature, flow rate and density.

[0072] This is advantageous because a control valve for gas can be controlled accurately, while a control valve in a liquid waste supply line is more subject to wear from the liquid waste and can therefore leak or get blocked and can also be controlled less accurately. By regulating the flow rate of the gas, the mixing chamber is filled more or less with gas and less or more with liquid waste. The required gas flow rate for atomizing the liquid waste depends on the flow rate, the temperature and the density of the liquid waste. Accurately controlling the flow rate of the liquid waste results in a more efficient incineration of the hazardous waste in the post-combustion chamber. This embodiment is also advantageous for avoiding flashback in the at least one injection lance. Possible flashback can be avoided by throttling the mixing chamber with gas.

[0073] According to a preferred embodiment, the liquid hazardous waste is supplied from a storage tank to the at least one injection lance via a supply line with the aid of a pump comprised in the supply line. Part of the liquid hazardous waste is returned to the storage tank via a return line from the at least one injection lance. A pressure in the supply line and/or return line is measured. A control valve comprised in the return line is controlled in such a way that a constant pressure is obtained at the least one injection lance.

[0074] This embodiment is advantageous for obtaining a constant pressure at an entry point of the at least one injection lance. The pressure measured in the supply line and/or return line is a measure of the pressure at the entry point of the at least one injection lance. It is assumed here that pressure losses between the point where the pressure is measured in the supply line and/or return line and the entry point of the at least one injection lance are constant. The pressure at the entry point of the at least one injection lance can vary, for example, due to a changing level in the at least one storage tank, due to a varying flow through the injection lance, etc. A varying pressure at the entry point of the at least one injection lance results in a varying direct injection of hazardous waste into the post-combustion chamber, resulting in an irregular supply and combustion in the post-combustion chamber. Compensating the varying pressure at the entry point of the at least one injection lance by controlling the pump in the supply line is too slow for accurate compensation because it requires changing the speed of the pump. A control valve, on the other hand, can open or close almost immediately, completely or partially, so that if the pressure at the entry point of the at least one injection lance is too high or too low, more or less liquid hazardous waste can flow back to the at least one storage tank, thereby minimizing pressure variations at the entry point of the at least one injection lance.

[0075] According to a preferred embodiment, the various hazardous wastes are tested for reactivity and compatibility before incineration of various hazardous wastes.

[0076] The hazardous waste is mixed with different products before incineration. These are, for example, water as a solvent, HCl as an acid, NaOH as a base, a polar solvent such as acetone, a halogenated solvent such as CH_2Cl_2, an apolar solvent such as hexane. It is tested whether there are temperature rises, whether there is gas formation, whether there is precipitation, ... both during and after mixing. This is important in order to determine whether mutual reactions can be expected if different hazardous wastes are introduced into the rotary kiln at the same time.

[0077] Different hazardous wastes are also brought into contact with each other. Incompatible hazardous waste will then react with each other, mix or just separate. Mixing or separating is important because it can affect the even and complete incineration of the hazardous waste.

[0078] If it is determined that a first and a second hazardous waste are non-reactive and compatible, they may be simultaneously introduced into the rotary kiln, allowing the first hazardous waste and the second hazardous waste to be incinerated simultaneously.

[0079] This is also advantageous when determining an optimum operating point for a device for the incineration of hazardous waste using a combustion diagram. A combustion diagram shows on the X-axis a quantity of hazardous waste that is processed per hour in the device and on the Y-axis a thermal load on the device. This is preferably expressed in tons/h. The thermal load corresponds to an amount of heat released by the incineration of the hazardous waste. This is preferably expressed in MW. A combustion diagram is basically a rectangle. A corner point at the bottom left is determined by a minimum amount of hazardous waste that must be incinerated and the minimum amount of heat that must be released in order to have a cost-effective installation, so that sufficient steam and electricity are produced, and the hazardous waste can be incinerated at an acceptable cost. A corner point at the top right is determined by a maximum amount of hazardous waste that can be incinerated in the device and a maximum amount of heat that may be released in order not to damage the device. Typically, a combustion diagram is cut off by two oblique lines. A first slanted line cuts off a corner at the top left. This is due to a first hazardous waste with a calorific value, the amount of heat released during combustion expressed in kJ/kg, which is sufficiently large, so that before the maximum amount of hazardous waste that can be incinerated in the device is reached, the maximum amount of heat that is permitted for the device is already released. A second slanted line cuts off a corner at the bottom right. This is due to a second hazardous waste with a calorific value that is so small that, only with an amount of the second hazardous waste that exceeds the minimum amount of hazardous waste that must be incinerated, an amount of heat is obtained that is equal to the minimum amount of heat which must be released during combustion. Preferably, an operating point of the device is as close as possible to the top right corner point. By determining the calorific value of various hazardous wastes and by determining whether the various hazardous wastes are reactive and compatible, a mixture of various hazardous wastes can be determined that are non-reactive and compatible and where the operating point of the device is as close as possible to the top right corner point.

[0080] According to a preferred embodiment, metals are recovered from bottom ash from the post-combustion chamber. Bottom ash still comprises usable metals. These metals come from metal drums in which hazardous waste is introduced into the feed hopper. By recovering these metals, these metals can be reused, so that the incinerated hazardous waste has an additional economic value. An additional advantage is that these metals do not have to be landfilled, which can be harmful to the environment.

[0081] According to an embodiment, the method comprises the additional step of filtering hot flue gases from the steam boiler using an electrofilter. The hot flue gases are preferably filtered in the gas scrubbing installation before scrubbing the hot flue gases. The electrofilter is advantageous for removing fly ash from flue gases leaving the steam boiler. Up to 85%, preferably 90%, more preferably 95% and even more preferably 99.5% of the fly ash is removed from the flue gases.

[0082] According to an embodiment, liquid hazardous waste is injected directly into the rotary kiln using at least one injection lance, preferably using at least two injection lances, more preferably using at least three injection lances. It will be apparent to one skilled in the art that each injection lance can inject a different hazardous waste or that each injection lance can inject the same hazardous waste directly into the rotary kiln. It will also be apparent that an injection lance can inject a traditional auxiliary fuel into the rotary kiln. The liquid hazardous waste is atomized by the at least one injection lance when it is injected directly into the rotary kiln. This embodiment is advantageous for injecting liquid hazardous wastes directly into the rotary kiln that do not react very violently with hazardous solid wastes or with packaged liquid and/or pasty hazardous wastes supplied via the feed hopper, so that these liquid hazardous wastes can be incinerated in the rotary kiln together with the hazardous solid waste or packaged liquid and/or pasty hazardous waste. This is also advantageous for increasing the calorific power in the rotary kiln if the hazardous solid waste or the packaged liquid and/or pasty hazardous waste has a limited calorific value, as a result of which the hazardous solid waste or the packaged liquid and/or pasty hazardous waste burn better in the rotary kiln.

[0083] According to an embodiment, pasty hazardous waste is injected directly into the rotary kiln using at least one injection lance. This embodiment is advantageous for injecting pasty hazardous wastes directly into the rotary kiln that do not react very violently with hazardous solid wastes or with packaged liquid and/or pasty hazardous wastes supplied via the feed hopper, so that these pasty hazardous wastes can be incinerated in the rotary kiln together with the hazardous solid waste or packaged liquid and/or pasty hazardous waste. This is also advantageous for increasing the calorific power in the rotary kiln if the hazardous solid waste or the packaged liquid and/or pasty hazardous waste has a limited calorific value, as a result of which the hazardous solid waste or the packaged liquid and/or pasty hazardous waste burn better in the rotary kiln.

[0084] One skilled in the art will appreciate that a method according to the second aspect is preferably performed using a device according to the first aspect and that a device according to the first aspect is preferably configured for performing a method according to the second aspect. Each feature described in this document, both above and below, can therefore relate to any of the three aspects of the present invention.

[0085] In a third aspect, the invention relates to metals recovered after incineration of hazardous waste by means of a device according to the first aspect or a method according to the second aspect.

[0086] Many hazardous wastes are supplied in metal drums and placed in the feed hopper in these metal drums. After the hazardous waste has been incinerated, these metal drums remain in ashes. By melting down these metal drums, these metals can be recovered, so that the incinerated hazardous waste has an additional economic value.

[0087] An additional advantage is that these metal drums do not have to be landfilled, which can be harmful to the environment.

[0088] In what follows, the invention is described by way of non-limiting figures illustrating the invention, and which are not intended to and should not be interpreted as limiting the scope of the invention.

DESCRIPTION OF THE FIGURES

[0089] **Figure 1** shows a schematic representation of a device according to an embodiment of the present invention.

[0090] The device (1) comprises a feed hopper (2) for supplying hazardous waste to a rotary kiln (3). The hazardous waste is transferred from a bunker (13) for the temporary storage of solid hazardous waste by means of a movable crane with a gripper arm (14) into the feed hopper (2). The hazardous waste can also be transferred from a drum storage (15) by a supply line with lifting device in drums into the feed hopper (2). The device (1) further comprises a connection point for a tanker (10). Liquid hazardous waste can be temporarily stored from the tanker (10) in a storage tank for liquid hazardous waste (12). Liquid hazardous waste can be injected from the tanker (10) via the connection point and supply lines directly into the rotary kiln (3) or preferably directly into a post-combustion chamber (4). The device (1) comprises a storage tank for chlorofluorocarbons (11). The chlorofluorocarbon storage tank is a fixed storage tank or a temporary movable storage tank. The chlorofluorocarbons (11) can be injected directly into the rotary kiln (3) via supply lines or preferably injected directly into the post-combustion chamber (4). As already mentioned, the device (1) comprises at least one storage tank for liquid hazardous waste (12). The liquid hazardous waste is injected from the storage tank for liquid hazardous waste (12) via supply lines directly into the rotary kiln (3) or is preferably injected directly into the post-combustion chamber (4). The hazardous wastes are incinerated in the rotary kiln (3). Under the influence of gravity, kiln content moves from the rotary kiln (3) to the outlet of the rotary kiln (3) and ends up in the post-combustion chamber (4). Due to heat in the post-combustion chamber (4), residual hazardous waste from the rotary kiln (3) continues to burn in the post-combustion chamber (4). Direct injection of liquid hazardous waste into the post-combustion chamber (4) increases the calorific power in the post-combustion chamber (4), so that the hazardous waste burns completely, without or with only a minimal addition of auxiliary fuel. Hot flue gases from the post-combustion chamber (4) heat water to steam in a steam boiler (5). The steam can be used for residential and industrial applications. The steam can also be used to drive a turbine to generate electrical power. In the steam boiler (5), urea is fed from a urea tank (9), as a result of which an amount of NOx in the flue gases from the steam boiler (5) is reduced. The hot flue gases from the steam boiler (5) are filtered in a dry electrofilter (6) and then scrubbed and filtered in a gas scrubbing installation and dioxin filter (7). Finally, the flue gases leave the installation (1) through a chimney (9). Bottom ash (19) from the rotary kiln (2) is discharged through an outlet (16). Boiler dust (20) from the steam boiler (5) is discharged through an outlet (17). Fly ash (21) from the electrofilter (6) is discharged through an outlet (18). Metals from the bottom ash (19), originating from metal drums, are recovered. Scrubbing water (22) from the gas scrubbing installation (7) is purified in a water purification installation (23). Residue (24), comprising sludge, is discharged.

[0091] The numbered elements in the figures are:

1 device
2 feed hopper
3 rotary kiln
4 post-combustion chamber
5 steam boiler
6 electrofilter
7 gas scrubbing installation and dioxin filter
8 chimney
9 urea tank
10 tanker
11 storage tank for chlorofluorocarbons
12 storage tank for liquid and/or pasty hazardous waste
13 bunker
14 movable crane with a gripper arm
15 drum storage
16 bottom ash outlet
17 boiler dust outlet
18 fly ash outlet
19 bottom ash
20 boiler dust
21 fly ash
22 scrubbing water
23 water purification installation
24 residues

Claims

1. Device for incinerating hazardous solid waste comprising a rotary kiln, a feed hopper for supplying hazardous waste to the rotary kiln, a post-combustion chamber, a steam boiler and a gas scrubbing installation, **characterized in, that** the device comprises at least one injection lance for direct injection of liquid waste into the post-combustion chamber.

2. Device according to claim 1, **characterized in, that** the injection lance comprises a longitudinal supply channel for supplying liquid waste materials, wherein the injection lance comprises a gas channel concentrically around the supply channel for supplying a gas, wherein a spray head is arranged on the injection lance, wherein the spray head comprises an internal mixing chamber, and wherein the supply channel and the gas channel open into the internal mixing chamber.

3. Device according to claim 2, **characterized in, that** the device comprises sensors for measuring, in the active state of the device, the temperature, flow rate and density of liquid hazardous waste to the at least one injection lance, the device further comprising a control valve for regulating the flow rate of the gas to the gas channel of the at least one injection lance, wherein the control valve comprises a controller and wherein the controller of the control valve is coupled to said sensors.

4. Device according to any of the preceding claims 1-3, **characterized in, that** the device comprises at least one storage tank, wherein an outlet of the at least one storage tank is connected to the at least one injection lance via a supply line, wherein the supply line comprises a pump, wherein the device comprises a return line from the at least one injection lance to the at least one storage tank, wherein the return line comprises a control valve, wherein the control valve comprises a controller, and wherein the controller of the control valve is coupled to a pressure sensor for measuring pressure in the supply line and/or return line.

5. Device according to any of the preceding claims 1-4, **characterized in, that** the device comprises an electrofilter for filtering flue gases from the steam boiler.

6. Device according to any of the preceding claims 1-5, **characterized in, that** the device comprises at least one secondary injection lance for direct injection of liquid waste materials into the rotary kiln.

7. Device according to any of the preceding claims 1-6, **characterized in that** the post-combustion chamber comprises an outlet for recovery of bottom ash.

8. Device according to any of the preceding claims 1-7, **characterized in, that** the device comprises a supply line with lifting device for supplying drums to the feed hopper.

9. Device according to any of the preceding claims 1-8, **characterized in, that** the device comprises a urea tank, the urea tank being connected to the steam boiler via a supply line.

10. Method for incinerating hazardous solid waste comprising:

- placing hazardous waste in a feed hopper;
- feeding from the feed hopper of the hazardous waste into a rotary kiln;
- incineration of the hazardous waste in the rotary kiln;
- post-burning of incinerated hazardous waste from the rotary kiln in a post-combustion chamber;
- generating steam in a steam boiler using hot flue gases from the post-combustion chamber;
- scrubbing of hot flue gases from the steam boiler in a gas scrubbing installation;

characterized in, that liquid hazardous waste is injected directly into the post-combustion chamber using at least one injection lance.

11. Method according to claim 10, **characterized in, that** the method comprises the additional step of measuring the temperature, flow rate and density of the liquid hazardous waste to the at least one injection lance, wherein the at least one injection lance comprises a longitudinal supply channel for the supply of liquid hazardous waste, wherein the at least one injection lance concentrically around the supply channel comprises a gas channel for supplying a gas, wherein the flow rate of the liquid hazardous waste is controlled by regulating a pressure of the gas to said gas channel using a control valve based on the measured temperature, flow rate and density.

12. Method according to claim 10 or 11, **characterized in, that** the liquid hazardous waste is supplied from a storage tank to the at least one injection lance via a supply line with the aid of a pump comprised in the supply line, wherein part of the liquid hazardous waste is returned from the at least one injection lance to the storage tank via a return line, wherein a pressure in the supply line and/or return line is measured, and wherein a control valve comprised in the return line is controlled in such a way that a constant pressure is obtained at the at least one injection lance.

13. Method according to claim 10, 11 or 12, **characterized in, that** the different hazardous wastes are tested for reactivity and compatibility before incineration of different hazardous wastes.

14. Method according to any of claims 10-13, **characterized in, that** metals are recovered from bottom ash from the post-combustion chamber.

15. Metals recovered after incineration of hazardous waste using a device according to any of claims 1-9 or a method according to any of claims 10-14.

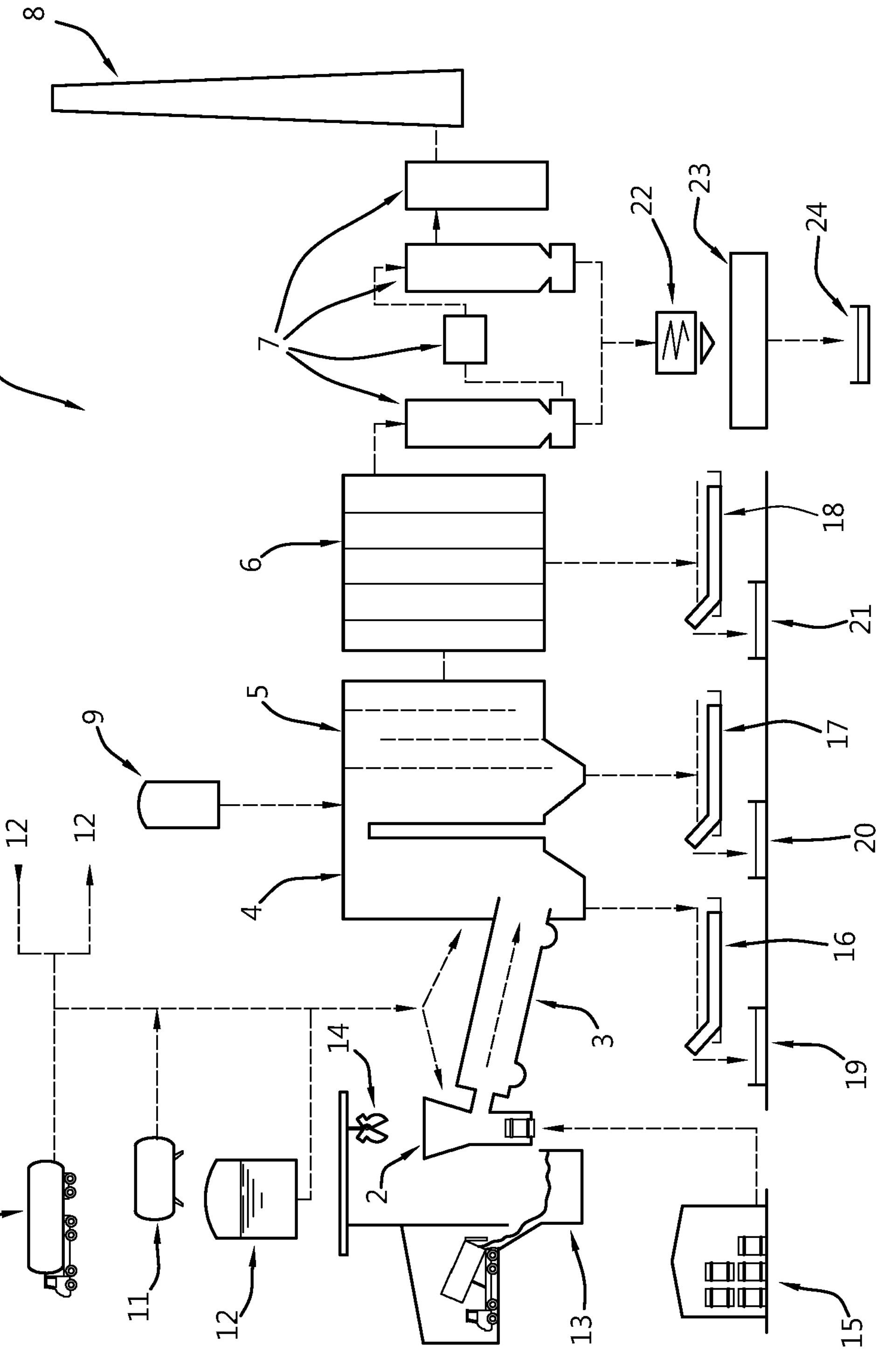

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 22 21 4864

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 Y A	CN 111 306 549 A (UNIV NANJING AERONAUTICS & ASTRONAUTICS; LIU SIYU) 19 June 2020 (2020-06-19) * paragraph [0028] - paragraph [0044]; figures 1-3 *	1,4-10, 12-15 2 3,11	INV. F23G5/00 F23G5/20 F23G5/16 F23G7/00
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TECHNICAL FIELDS SEARCHED (IPC)

F23G

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	17 April 2023	Theis, Gilbert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 21 4864

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17-04-2023

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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