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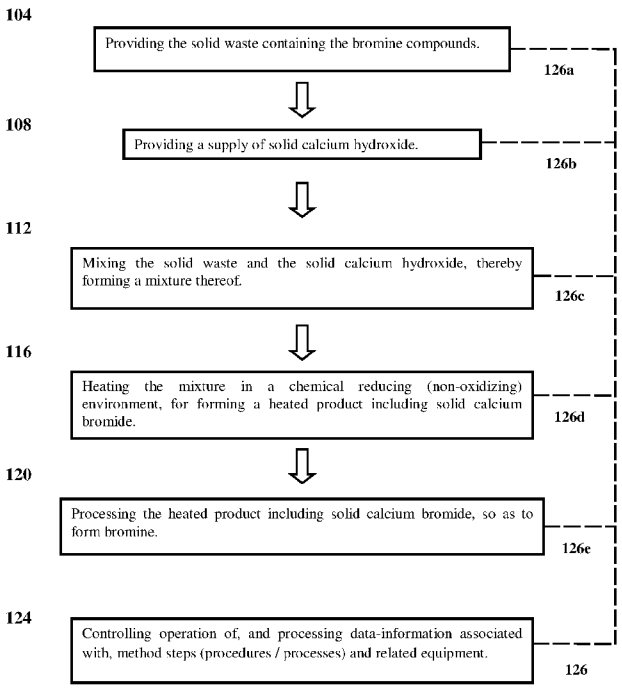
[Continued on next page]

(54) Title: RECOVERING BROMINE FROM SOLID WASTE CONTAINING BROMINE COMPOUNDS, AND APPLICATIONS THEREOF

100 FIG. 1A

{*Recovering bromine from solid waste containing bromine compounds.*}



(57) Abstract: Recovering bromine from solid waste containing bromine compounds, and applications thereof, such as for recovering bromine in a form suitable for reuse, or for manufacturing bromine salt (for example, calcium bromide). Bromine recovery method and system include: providing and mixing (i) solid waste containing bromine compounds and (ii) solid calcium hydroxide; heating the mixture in a chemical reducing (non-oxidizing) environment, thereby forming heated product consisting essentially of only solid calcium bromide (salt); and processing the heated product, to form bromine. Calcium bromide manufacturing method and system include: providing and mixing (i) solid waste containing bromine compounds and (ii) solid calcium hydroxide; heating the mixture in a chemical reducing (non-oxidizing) environment, thereby forming solid calcium bromide (salt). Applicable to processes of, or involving, manufacturing bromine-based flame (fire) retardant materials.

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RECOVERING BROMINE FROM SOLID WASTE CONTAINING BROMINE COMPOUNDS, AND APPLICATIONS THEREOF

RELATED APPLICATION

This application claims the benefit of priority under 35 USC 119(e) of U.S. Provisional Patent Application No. 62/117,492, filed February 18, 2015, entitled "Recovering Bromine From Solid Waste Containing Bromine Compounds, And Applications Thereof", the contents of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

The present invention, in some embodiments thereof, relates to recovering bromine from solid waste containing bromine compounds, and applications thereof, such as for recovering bromine in a form suitable for reuse, or for manufacturing bromine salt (for example, calcium bromide).

BACKGROUND OF THE INVENTION

Flame (or fire) retardant materials (additives, ingredients, substances), also referred to as flame (or fire) retardants, are used in manufacturing countless different types and kinds of products encompassed by, or relating to, numerous fields. Such products are commercially used and applied in a wide variety of industries, such as construction (building materials), floors and floor coverings, roofs and roof coverings, furniture, upholstery, carpeting (rugs), clothing (textiles), electrical and electronics equipment, packaging, agriculture, transportation, aerospace, and military. Flame (fire) retardant materials are used for the objective of providing flame (fire) retardant properties to, or improving flame (fire) retardant properties of, such commercially used products.

The most widely used category of flame (fire) retardant materials consists of bromine-based flame (fire) retardant materials, which are made of or from, and include, (organic or/and inorganic) types of bromine compounds or brominated types of (organic or/and inorganic) compounds that have an inhibitory effect on combustion (ignition, burning) of combustible (ignitable, flammable) materials. Such organic types of bromine compounds

or brominated types of organic compounds (i.e., organobromide compounds) are commonly known and referred to as brominated flame retardant (BFR) compounds, or as brominated flame retardants (BFRs).

In processes of, or involving, manufacturing bromine-based flame retardant materials, a large amount of waste in solid form is generated, which, after special handling/processing (to neutralize or/and stabilize potentially hazardous bromine compounds), needs to be disposed of, typically, in a landfill. Such processes are accompanied by costs relating to special handling/processing of the solid waste, costs relating to landfill disposal of the solid waste, and costs relating to unused (non-consumed) bromine leftover in the solid waste. For example, in such processes, each ton (2000 pounds) of (input) raw material (organic or/and inorganic) bromine compounds generates about one-half ton (1000 pounds) of solid waste, of which about 30 % is of unused (non-consumed) bromine that is disposed of.

In such processes, the solid waste may contain substantial amounts of unused (non-consumed) bromine. If such unused bromine can be recovered, recycled (reused), or/and used for other applications (e.g., other manufacturing processes requiring bromine), then overall costs associated with manufacturing bromine-based flame retardant materials can be significantly reduced and profit increased.

SUMMARY OF THE INVENTION

The present invention, in some embodiments thereof, relates to recovering bromine from solid waste containing bromine compounds, and applications thereof, such as for recovering bromine in a form suitable for reuse, or for manufacturing bromine salt (for example, calcium bromide).

According to an aspect of some embodiments of the present invention, there is provided a method for recovering bromine from solid waste containing bromine compounds, the method comprising: providing the solid waste containing the bromine compounds; providing a supply of solid calcium hydroxide; mixing the solid waste and the solid calcium hydroxide, thereby forming a mixture thereof; heating the mixture in a chemical reducing (non-oxidizing) environment, for forming a heated product including solid calcium bromide; and processing the heated product including solid calcium bromide, so as to form bromine.

According to an aspect of some embodiments of the present invention, there is provided a method for manufacturing solid calcium bromide from solid waste containing bromine compounds, the method comprising: providing the solid waste containing the bromine compounds; providing a supply of solid calcium hydroxide; mixing the solid waste

and the solid calcium hydroxide, thereby forming a mixture thereof; and heating the mixture in a chemical reducing (non-oxidizing) environment, so as to form solid calcium bromide.

According to some embodiments of the invention, there is supplying an amount of the solid calcium hydroxide corresponding to stoichiometric equivalent of amount of bromine contained in bromine compounds of the provided solid waste.

According to some embodiments of the invention, the mixing is performed in a manner so that the mixture formed therefrom is in a powdered form.

According to some embodiments of the invention, the heating is performed with an operating temperature in a range of between about 400 °C and about 800 °C.

According to some embodiments of the invention, the heating is performed with an operating pressure in a range of between about 0.1 atmosphere (atm) [76.0 mm Hg], and about 2 atmospheres (atm) [1520 mm Hg].

According to some embodiments of the invention, the heating includes removing gases formed therefrom.

According to some embodiments of the invention, the heating includes forcibly transferring and moving the heated mixture, and the heated product of calcium bromide formed therefrom, from start to finish of the heating.

According to some embodiments of the invention, the forcibly transferring and moving is performed using a forced mass transfer device.

According to some embodiments of the invention, the forced mass transfer device includes one or more controllably rotatable components configured and operative to controllably rotate with an operating speed or rate of rotation in a range of between about 1 round per minute (rpm) and about 30 rounds per minute (rpm).

According to some embodiments of the invention, the heating is performed with a chemical reaction residence time in a range of between about 20 minutes (min) and about 60 minutes (min).

According to some embodiments of the invention, processing of the heated product including calcium bromide includes dissolving the heated product of solid calcium bromide in water, thereby forming an aqueous solution of calcium bromide.

According to some embodiments of the invention, there is subjecting the calcium bromide aqueous solution to a separation procedure, thereby separating bromine from the aqueous solution.

According to some embodiments of the invention, processing the heated product including calcium bromide includes heating the heated product of solid calcium bromide in presence of oxygen, thereby forming solid calcium oxide and gaseous bromine.

According to some embodiments of the invention, there is condensing the gaseous bromine, thereby forming liquid bromine.

According to some embodiments of the invention, the method further comprises controlling operation of, and processing data-information associated with, providing the solid waste, providing the supply of solid calcium hydroxide, the mixing, and the heating, via a process control / data-information processing unit.

According to some embodiments of the invention, the method further comprises controlling operation of, and processing data-information associated with, processing the solid calcium bromide.

According to an aspect of some embodiments of the present invention, there is provided a system for recovering bromine from solid waste containing bromine compounds, the system comprising: a solid waste input unit, for receiving and containing the solid waste; a solid calcium hydroxide supply unit, for supplying solid calcium hydroxide to the solid waste; a mixing unit, operatively connected to the solid waste input unit and the solid calcium hydroxide supply unit, for mixing the solid waste and the solid calcium hydroxide, and wherein is formed a mixture thereof; a heating unit, operatively connected to the mixing unit, for heating the mixture in a chemical reducing (non-oxidizing) environment, and wherein is formed a heated product comprising solid calcium bromide; and a chemical processing unit, operatively connected to the heating unit, for processing the solid calcium bromide, and wherein is formed bromine.

According to an aspect of some embodiments of the present invention, there is provided a system for manufacturing solid calcium bromine from solid waste containing bromine compounds, the system comprising: a solid waste input unit, for receiving and containing the solid waste; a solid calcium hydroxide supply unit, for supplying solid calcium hydroxide to the solid waste; a mixing unit, operatively connected to the solid waste input unit and the solid calcium hydroxide supply unit, for mixing the solid waste and the solid calcium hydroxide, and wherein is formed a mixture thereof; and a heating unit, for heating the mixture in a chemical reducing (non-oxidizing) environment, and wherein is formed solid calcium bromide.

According to some embodiments of the invention, the solid calcium hydroxide supply unit is configured to supply an amount of the solid calcium hydroxide corresponding to

stoichiometric equivalent of amount of bromine contained in bromine compounds of the provided solid waste.

According to some embodiments of the invention, the mixing unit includes a mixing device configured to mix the solid waste and the solid calcium hydroxide, whereby the mixture formed therefrom is in a powdered form.

According to some embodiments of the invention, the heating unit is configured to heat the mixture at an operating temperature in a range of between about 400 °C and about 800 °C.

According to some embodiments of the invention, the heating unit is configured to heat the mixture at an operating pressure in a range of between about 0.1 atmosphere (atm) [76.0 mm Hg], and about 2 atmospheres (atm) [1520 mm Hg].

According to some embodiments of the invention, the heating unit is configured to remove gases formed during the heating of the mixture.

According to some embodiments of the invention, the heating unit includes a heating device configured to forcibly transfer and move the mixture, and the heated product of calcium bromide formed therefrom, through the heating device during the heating.

According to some embodiments of the invention, the heating device includes a forced mass transfer device configured to effect the forcible transfer and movement through the heating device.

According to some embodiments of the invention, the heating device includes a heating chamber, wherein is located the forced mass transfer device.

According to some embodiments of the invention, the forced mass transfer device includes a controllably rotatable component configured and operative to controllably rotate as a controllably rotatable screw or similarly geometrically configured and operative type of rotatable component.

According to some embodiments of the invention, the controllably rotatable component is configured and operative to controllably rotate with an operating speed or rate of rotation in a range of between about 1 round per minute (rpm) and about 30 rounds per minute (rpm).

According to some embodiments of the invention, the heating unit is configured to heat the mixture for a chemical reaction residence time in a range of between about 20 minutes (min) and about 60 minutes (min).

According to some embodiments of the invention, the system further comprises a process control / data-information processing unit, operatively connected to, and, controlling

operation of and processing data-information associated with, the solid waste input unit, the solid calcium hydroxide supply unit, the mixing unit, and the heating unit.

According to some embodiments of the invention, the process control / data-information processing unit is further operatively connected to, and, controlling operation of and processing data-information associated with, the chemical processing unit.

All technical or/and scientific words, terms, or/and phrases, used herein have the same or similar meaning as commonly understood by one of ordinary skill in the art to which the invention pertains, *unless otherwise specifically defined or stated herein*. Methods, materials, and examples described herein are illustrative only and are not intended to be necessarily limiting. Although methods or/and materials equivalent or similar to those described herein can be used in practicing or/and testing embodiments of the invention, exemplary methods or/and materials are described below. In case of conflict, the patent specification, including definitions, will control.

Implementation of some embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of some embodiments of the invention, several selected tasks could be implemented by hardware, by software, by firmware, or a combination thereof, using an operating system.

For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip, as a circuit, or a combination thereof. As software, selected tasks of some embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks of exemplary embodiments of the method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions or/and data. Alternatively or additionally, optionally, the data processor includes a non-volatile storage, for example, a magnetic hard-disk or/and removable media, for storing instructions or/and data. Optionally, a network connection is provided as well. Optionally, a display or/and a user input device such as a keyboard or mouse is provided as well.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the present invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the

drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative description of some embodiments of the present invention. In this regard, the description taken together with the accompanying drawings make apparent to those skilled in the art how some embodiments of the present invention may be practiced.

In the drawings:

FIG. 1A is a flow diagram of an exemplary embodiment of a method for recovering bromine from solid waste containing bromine compounds, in accordance with some embodiments of the invention;

FIG. 1B is a flow diagram of exemplary steps (procedures / processes) of processing the solid calcium bromide [salt] formed via the exemplary embodiment of the method for recovering bromine from solid waste containing bromine compounds presented in FIG. 1A, in accordance with some embodiments of the invention;

FIG. 2 is a schematic (process flow type) diagram of an exemplary embodiment of a system for recovering bromine (also applicable to manufacturing solid calcium bromide [salt]) from solid waste containing bromine compounds, in accordance with some embodiments of the invention; and

FIG. 3 is a flow diagram of an exemplary embodiment of a method for manufacturing solid calcium bromide [salt] from solid waste containing bromine compounds, in accordance with some embodiments of the invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to recovering bromine from solid waste containing bromine compounds, and applications thereof, such as for recovering bromine in a form suitable for reuse, or for manufacturing bromine salt (for example, calcium bromide).

In processes of, or involving, manufacturing bromine-based flame retardant materials, a large amount of waste in solid form is generated, which, after special handling/processing (to neutralize or/and stabilize potentially hazardous bromine compounds), needs to be disposed of, typically, in a landfill. Such processes are accompanied by costs relating to special handling/processing of the solid waste, costs relating to landfill disposal of the solid waste, and costs relating to, typically, substantial amounts of, unused (non-consumed) bromine leftover in the solid waste.

Some embodiments of the invention provide unique ways (for example, involving mixing, heating, chemical processing, and, controlling processes and equipment) for such

unused (non-consumed) bromine leftover in the solid waste to be recovered, recycled (reused), or/and used for other applications (e.g., other manufacturing processes requiring bromine). Some embodiments of the invention are applicable for significantly reducing overall costs, and increasing profits, associated with manufacturing bromine-based flame retardant materials. Some embodiments of the invention are suitable in applications involving manufacturing bromine-based flame retardant materials without requiring special handling/processing involved in neutralizing, stabilizing, or/and disposing of potentially hazardous bromine compounds. Some embodiments of the bromine recovery process, and of the solid calcium bromide manufacturing process, are highly efficient in terms of producing relatively small amounts of waste or/and side products. Some embodiments of the invention provide highly efficient and cost effective ways of recovering bromine, as well as of manufacturing high quality solid calcium bromide salt.

Steps or procedures, sub-steps or sub-procedures, and, equipment and materials, system units, system sub-units, devices, assemblies, sub-assemblies, mechanisms, structures, components, elements, and configurations, and, peripheral equipment, utilities, accessories, and materials, as well as operation and implementation, of exemplary embodiments, alternative embodiments, specific configurations, and, additional and optional aspects, characteristics, or features, thereof, of some embodiments of the present invention, are better understood with reference to the following illustrative description and accompanying drawings. Throughout the following illustrative description and accompanying drawings, same reference notation and terminology (i.e., numbers, letters, symbols) are consistently used and refer to same steps or procedures, structures, components, elements, or/and features. It is to be understood that the invention is not necessarily limited in its application to any particular sequential ordering of method steps or procedures, or to particular details of construction or/and arrangement of device, apparatus, or/and system components, set forth in the following illustrative description. The invention is capable of other embodiments or of being practiced or carried out in various ways.

An aspect of some embodiments of the present invention is a method for recovering bromine from solid waste containing bromine compounds.

Referring now to the drawings, FIG. 1A is a flow diagram of an exemplary embodiment (indicated as, and referred to by, reference number **100**), including the indicated exemplary steps (procedures / processes) thereof, of a method for recovering bromine from solid waste containing bromine compounds. In FIG. 1A, the exemplary embodiment **100** of the method includes exemplary steps (procedures / processes) represented by separate blocks

(frames) which are assigned reference numbers, for example, **104**, **108**, **112**, etc.. Herein, the exemplary embodiment **100** of a method for recovering bromine from solid waste containing bromine compounds is also referred to as the bromine recovery method.

As shown in FIG. 1, in a non-limiting manner, and in some embodiments, such as exemplary embodiment **100**, the bromine recovery method includes the following exemplary steps (procedures / processes).

In **104**, there is providing the solid waste containing the bromine compounds.

In **108**, there is providing a supply of solid calcium hydroxide [$Ca(OH)_2$ (solid)], commonly known and referred to as lime.

In **112**, there is mixing the solid waste and the solid calcium hydroxide, thereby forming a mixture thereof.

In **116**, there is heating the mixture in a chemical reducing (non-oxidizing) environment (i.e., an environment absent of chemical *oxidation* conditions, and with presence of chemical *reduction* conditions), thereby forming a heated product including solid calcium bromide [$CaBr_2$ (salt)].

In **120**, there is processing the heated product including solid calcium bromide [$CaBr_2$ (salt)], so as to form bromine [Br_2].

In exemplary embodiments of the invention, performance of exemplary steps (procedures / processes) **104**, **108**, **112**, **116**, and **120**, results in recovering bromine from the solid waste containing the bromine compounds.

In exemplary embodiments, the bromine recovery method additionally includes exemplary step (procedure / process) **124**, wherein there is controlling operation of, and processing data-information associated with, method steps (procedures / processes) **104**, **108**, **112**, **116**, and **120**, and related equipment used for performing thereof. More specifically, in **124**, there is controlling operation of, and processing data-information associated with, method steps (procedures / processes), and related equipment used for performing: **104** - providing the solid waste containing the bromine compounds; **108** - providing a supply of solid calcium hydroxide; **112** - mixing the solid waste and the solid calcium hydroxide, thereby forming a mixture thereof; **116** - heating the mixture in a chemical reducing (non-oxidizing) environment, thereby forming a heated product including solid calcium bromide; and **120** - processing the heated product including solid calcium bromide, so as to form bromine. In FIG. 1A, such controlling and processing of the bromine recovery method steps (procedures / processes), and related equipment used for performing thereof, are schematically represented by dashed line **126** extending from **124** and connecting to dashed

lines **126a**, **126b**, **126c**, **126d**, and **126e**, extending from the respective method steps (procedures / processes) **104**, **108**, **112**, **116**, and **120**.

FIG. 1B is a flow diagram of exemplary steps (procedures / processes) of bromine recovery method step (procedure / process) **120** of processing the heated product including the solid calcium bromide (salt), for example, as formed via the exemplary embodiment **100** of the method for recovering bromine from solid waste containing bromine compounds presented in FIG. 1A.

In exemplary embodiments of the bromine recovery method, the step (procedure / process) **120** of processing the (cooled or hot) heated product including solid calcium bromide may include exemplary steps (procedures / processes) **130** and **134**, for example, as presented in FIG. 1B. In **130**, there is dissolving the heated product (of solid calcium bromide [$CaBr_2$ (salt)]) in water, thereby forming an aqueous solution of calcium bromide. In **134**, there is subjecting the calcium bromide aqueous solution to a separation procedure, thereby separating bromine from the aqueous solution.

In exemplary embodiments, the step (procedure / process) **120** of processing the (cooled or hot) heated product (of solid calcium bromide [$CaBr_2$ (salt)]), instead of (i.e., alternatively to), or, in addition to (i.e., separately, in parallel or concurrently), including steps (procedures / processes) **130** and **134**, may include exemplary steps (procedures / processes) **138** and **142**, for example, as presented in FIG. 1B. In **138**, there is heating the (cooled or hot) heated product (of solid calcium bromide [$CaBr_2$ (salt)]) in presence of oxygen, thereby forming solid calcium oxide [CaO] and gaseous bromine [Br_2]. In **142**, there is condensing the gaseous bromine, thereby forming liquid bromine.

In exemplary embodiments, as part of controlling operation of, and processing data-information associated with, the step (procedure / process) **120** of processing the heated product including solid calcium bromide, there is controlling operation of, and processing data-information associated with, exemplary steps (procedures / processes) **130** and **134** or/and exemplary steps (procedures / processes) **138** and **142**.

Another aspect of some embodiments of the present invention is a system for recovering bromine from solid waste containing bromine compounds.

The system for recovering bromine from solid waste containing bromine compounds, in a non-limiting manner, and in some embodiments, includes: a solid waste input unit, a solid calcium hydroxide supply unit, a mixing unit, a heating unit, and a chemical processing unit. In some embodiments, the bromine recovery system additionally includes a process control / data-information processing unit.

FIG. 2 is a schematic (process flow type) diagram of an exemplary embodiment (indicated as, and referred to by, reference number **200**), including the indicated exemplary units, devices, assemblies, components, functionalities, and features thereof, of a system for recovering bromine from solid waste containing bromine compounds.

The exemplary embodiment **200** of the system shown in FIG. 2, in a non-limiting manner, is suitable for implementing some embodiments of the method for recovering bromine from solid waste containing bromine compounds, such as exemplary embodiment **100** of the bromine recovery method presented in FIGs. 1A and 1B. Similarly, the exemplary embodiment **100** of the method presented in FIGs. 1A and 1B, in a non-limiting manner, is suitable for implementing some embodiments of the system for recovering bromine from solid waste containing bromine compounds, such as exemplary embodiment **200** of a bromine recovery system presented in FIG. 2. Herein, the exemplary embodiment **200** of a system for recovering bromine from solid waste containing bromine compounds is also referred to as the bromine recovery system.

As shown in FIG. 2, in a non-limiting manner, and in some embodiments, such as exemplary embodiment **200**, the bromine recovery system includes the following exemplary (chemical process / chemical processing) units: a solid waste input unit, a solid calcium hydroxide supply unit, a mixing unit, a heating unit, and a chemical processing unit. In some embodiments, the bromine recovery system additionally includes a process control / data-information processing unit.

Solid waste input unit **206** is for receiving and containing the solid waste **204**. Solid waste **204** is fed or input to the bromine recovery system via solid waste input unit **206**, and held or contained in a holding or containing vessel (container), for example, holding or containing vessel (container) **208**.

Solid calcium hydroxide supply unit **210** is for supplying solid calcium hydroxide [$Ca(OH)_2$], for example, solid calcium hydroxide **212**, to the solid waste **204**. Solid calcium hydroxide supply unit **210** includes a holding or containing vessel (container), for example, holding or containing vessel (container) **214**, for holding or containing the solid calcium hydroxide **212**, and from which the solid calcium hydroxide **212** is supplied to the solid waste **204**.

Mixing unit **216**, operatively connected to the solid waste input unit **206** and the solid calcium hydroxide supply unit **210**, is for mixing the solid waste **204** and the solid calcium hydroxide **212**, and wherein is formed a mixture **218** of the solid waste **204** and the solid calcium hydroxide **212**.

Heating unit **220**, operatively connected to the mixing unit **216**, is for heating the mixture of the solid waste **204** and the solid calcium hydroxide **212**, in a chemical reducing (non-oxidizing) environment (i.e., absence of chemical *oxidation* conditions, and presence of chemical *reduction* conditions), and wherein is formed a heated product **222** including solid calcium bromide [$CaBr_2$ (salt)].

Chemical processing unit **224**, operatively connected to the heating unit **220**, is for processing the heated product **222** including solid calcium bromide [$CaBr_2$ (salt)], and wherein is formed bromine [Br_2] **226**.

In exemplary embodiments of the invention, processing the solid waste **204** via the solid waste input unit **206**, the solid calcium hydroxide supply unit **210**, the mixing unit **216**, the heating unit **220**, and the chemical processing unit **224**, results in recovering bromine **226** from the solid waste **204** containing the bromine compounds.

As illustratively described hereinabove, and shown in FIG. 1A, in exemplary embodiments of the invention, such as exemplary embodiment **100**, the bromine recovery method additionally includes exemplary step (procedure / process) **124**, wherein there is controlling operation of, and processing data-information associated with, method steps (procedures / processes), and related equipment used for performing: **104** - providing the solid waste containing the bromine compounds; **108** - supplying solid calcium hydroxide; **112** - mixing the solid waste and the solid calcium hydroxide, thereby forming a mixture thereof, **116** - heating the mixture in a chemical reducing (non-oxidizing) environment (i.e., an environment absent of chemical *oxidation* conditions, and with presence of chemical *reduction* conditions), thereby forming a heated product including solid calcium bromide; and **120** - processing the heated product including solid calcium bromide, so as to form and obtain the bromine.

Accordingly, as shown in FIG. 2, in exemplary embodiments of the invention, such as exemplary embodiment **200**, the bromine recovery system additionally includes a process control / data-information processing unit **228**, operatively connected to, and, controlling operation of and processing data-information associated with, the other bromine recovery system process units (and components therein), namely, the solid waste input unit **206**, the solid calcium hydroxide supply unit **210**, the mixing unit **216**, the heating unit **220**, and the chemical processing unit **224**. In a complimentary manner, in exemplary embodiments, each of the bromine recovery system process units (and components therein), namely, solid waste input unit **206**, solid calcium hydroxide supply unit **210**, mixing unit **216**, heating unit **220**, and chemical processing unit **224**, is operatively connected to, and controlled by, process

control / data-information processing unit **228**. Operative connections and configurations between the process control / data-information processing unit **226** and each of the other bromine recovery system process units (and components therein) are schematically represented by the double headed dotted line arrows **230** surrounding process control / data-information processing unit **228**.

Following are additional illustrative description and details of some embodiments of the method, and some embodiments of the system, for recovering bromine from solid waste containing bromine compounds. As appropriate, reference is made to the exemplary drawings (figures) of some embodiments of the invention. For example, in a non-limiting manner, and in some embodiments, such as exemplary embodiment **100** (FIGs. 1A, 1B) of the bromine recovery method and the following illustratively described exemplary steps (procedures / processes), sub-steps (sub-procedures / sub-processes) thereof, and features thereof. Additionally, for example, in a non-limiting manner, and in some embodiments, such as exemplary embodiment **200** (FIG. 2) of the bromine recovery system and the following illustratively described exemplary components (units, devices, assemblies, mechanisms, equipment, structures), functionalities thereof, and features thereof.

> providing the solid waste containing the bromine compounds // solid waste input unit

The solid waste containing bromine compounds, for example, solid waste **204**, is provided by / supplied from, for example, a commercial producer or manufacturer of flame (fire) retardant materials consisting of bromine-based flame (fire) retardant materials. The bromine-based flame (fire) retardant materials are made of or from, and include, (organic or/and inorganic) types of bromine compounds or brominated types of (organic or/and inorganic) compounds. Such organic types of bromine compounds or brominated types of organic compounds (i.e., organobromide compounds) are commonly known and referred to as brominated flame retardant (BFR) compounds, or as brominated flame retardants (BFRs).

In general, the solid waste **204** may include any number and type or kind of organic or/and inorganic bromine compounds.

Solid waste input unit **206** includes holding or containing vessel (container) **208**, for receiving and holding or containing the solid waste **204**, and from which the solid waste **204** is fed or input (for example, via chemical [solids] transport line **232**) to the mixing unit **216**.

> providing a supply of solid calcium hydroxide // solid calcium hydroxide supply unit

Solid calcium hydroxide supply unit **210** includes holding or containing vessel (container) **214**, for holding or containing the solid calcium hydroxide [$Ca(OH)_2$ (solid)] **212**, and from which the solid calcium hydroxide **212** is supplied (for example, via chemical [solids] transport line **234**) to the mixing unit **216**.

In exemplary embodiments, there is supplying an amount or quantity of the solid calcium hydroxide **212** that corresponds to the stoichiometric equivalent of the amount or quantity of bromine contained in the bromine compounds of the solid waste **204**. In exemplary embodiments, the stoichiometric equivalent is in terms of stoichiometric *molar* equivalent of the (molar) amount or quantity of bromine contained in the bromine compounds of the solid waste **204**. Thus, in exemplary embodiments, there is supplying the stoichiometric (molar) amount or quantity of the solid calcium hydroxide **212** that corresponds to the stoichiometric equivalent of the (molar) amount or quantity of bromine contained in the bromine compounds of the solid waste **204**.

In exemplary embodiments, an amount or quantity of the solid calcium hydroxide **212** is supplied to the solid waste **204** such that chemical reaction (occurring inside the heating unit **220**) between the two reactants, solid calcium hydroxide **212** and solid waste **204**, goes to full, or nearly full, completion, for forming the solid calcium bromide [$CaBr_2$ (salt)] **222**, whereby, the entire initial amount or quantity of each reactant is fully, or near fully, consumed, while leaving no, or minimal, excess of either reactant, as well as forming minimal amounts or quantities of side products.

> mixing the solid waste and the solid calcium hydroxide // mixing unit

In exemplary embodiments, initially, the solid waste **204** is fed or input (for example, via chemical [solids] transport line **232**) to the mixing unit **216**, and then, the solid calcium hydroxide **212** is supplied (for example, via chemical [solids] transport line **234**) to the mixing unit **216** (already containing the solid waste **204**). Alternatively, in exemplary embodiments, initially, the solid calcium hydroxide **212** is supplied (for example, via chemical [solids] transport line **234**) to the mixing unit **216**, and then, the solid waste **204** is fed or input (for example, via chemical [solids] transport line **232**) to the mixing unit **216** (already containing the solid calcium hydroxide **212**).

Mixing unit **216** includes a mixing device, for example, mixing device **236**, for receiving, and then mixing, the solid waste **204** and the solid calcium hydroxide **212**, and

wherein is formed the mixture **218** of the solid waste **204** and the solid calcium hydroxide **212**.

In exemplary embodiments, mixing device **236** is configured and operative to mix solids, such as solid waste **204** and solid calcium hydroxide **212**. In exemplary embodiments, mixing device **236** is configured and operative to mix powders, for example, wherein solid waste **204** or/and solid calcium hydroxide **212** are solids in powder form (i.e., powdered solids), whereby the mixture **218** formed therefrom is in a powdered form. In exemplary embodiments, mixing device **236** is configured and operative to mix non-powdered forms of the solid waste **204** or/and the solid calcium hydroxide **212**, whereby the mixture **218** formed therefrom is in a powdered form.

In exemplary embodiments, mixing device **236** includes one or more mixing assemblies, mixing mechanisms, or/and mixing elements, such as mixing agitators or/and mixing impellers, configured and operative to insure uniform, thorough, and complete mixing of solid waste **204** and solid calcium hydroxide **212** inside mixing device **236**, for forming a uniform mixture **218** of the solid waste **204** and the solid calcium hydroxide **212**, prior to the mixture **218** being fed (for example, via chemical [solids] transport line **238**) to the heating unit **220**.

> heating the mixture of solid waste and solid calcium hydroxide // heating unit

The mixture **218** of the solid waste **204** and the solid calcium hydroxide **212** is heated, in a chemical reducing (non-oxidizing) environment (i.e., absence of chemical *oxidation* conditions, and presence of chemical *reduction* conditions), thereby forming a heated product including solid calcium bromide [$CaBr_2$ (salt)].

Heating unit **220**, operatively connected to the mixing unit **216**, is configured and operative to heat the mixture of the solid waste **204** and the solid calcium hydroxide **212**, in absence of oxygen (i.e., absence of chemical *oxidation* conditions, and presence of chemical *reduction* conditions). In the heating unit **220**, chemical reactions take place in the mixture **218** between the solid waste **204** and the solid calcium hydroxide **212**, to thereby form the solid calcium bromide [$CaBr_2$ (salt)] **222**.

Heating unit **220** includes a heating device, for example, heating device **240**, which includes, for example, an input assembly, a heating chamber, and an output assembly. In exemplary embodiments, the heating device **240** includes, or/and is operatively connected to, and is supplied heat by, one or more heating assemblies, heating mechanisms, or/and heating

elements, herein, generally referred to as one or more heaters. In exemplary embodiments, the heating device **240** is configured and operative as a type of oven or as a type of furnace.

In exemplary embodiments, heating device **240** includes heating device input assembly **242**, heating chamber **244**, and heating device output assembly **246**.

Heating device input assembly **242** is configured and operative to receive (from mixing unit **216** [for example, via chemical [solids] transport line **238**]), and provide passage of, the mixture **218** of the solid waste **204** and the solid calcium hydroxide **212** into the heating chamber **244**.

Heating chamber **244** is configured and operative to receive (from mixing unit **216**), to hold or contain, and to heat, the mixture **218** of the solid waste **204** and the solid calcium hydroxide **212**, which chemically reacts and forms the heated product **222** (including the solid calcium bromide [$CaBr_2$ (salt)], as well as other possible solid reaction products).

In exemplary embodiments, the heating device **240** is configured and operative such that the heating chamber **244** includes, or/and is operatively connected to, and is supplied heat by, one or more heaters (heating assemblies, heating mechanisms, or/and heating elements). For example, in FIG. 2, the one or more heaters are schematically represented by the pair of heaters referenced by **248**. As shown therein, in a non-limiting manner, heaters **248** are configured on the outside of the heating chamber **244**. In exemplary embodiments, heaters **248** may, additionally, or, alternatively, be configured on the inside of the heating chamber **244**. In exemplary embodiments, the one or more heaters (heating assemblies, heating mechanisms, or/and heating elements) are powered by electricity, for example, as resistive type electrical heaters.

Heating device output assembly **246** is configured and operative to provide passage of the formed heated product **222** (including the solid calcium bromide [$CaBr_2$ (salt)], as well as other possible solid reaction products) out of the heating chamber **244**. For effecting such passage and exiting of the heated product **222** out from the heating chamber **244** of the heating device **240**, in exemplary embodiments, the heating device output assembly **246** includes, or is operatively connected to, an exit flange. Alternatively, or additionally, in exemplary embodiments, the heating device output assembly **246** includes, or is operatively connected to, an exit valve assembly or mechanism, for example, exit valve assembly or mechanism **262**.

Chemical reaction heating, temperature, pressure conditions / parameters, characteristics

In exemplary embodiments, the heating unit **220**, in general, and the heating device **240** (including the heating chamber **244**) in particular, are configured and operative to heat the mixture **218** of the solid calcium hydroxide **212** and the solid waste **204**, in a chemical reducing (non-oxidizing) environment (absence of chemical *oxidation* conditions, and presence of chemical *reduction* conditions), for effecting formation of the heated product including the solid calcium bromide [$CaBr_2$ (salt)] **222**.

In exemplary embodiments, the heating unit **220**, in general, and the heating device **240** (including the heating chamber **244**), in particular, are configured and operative to heat the mixture **218** of the solid calcium hydroxide **212** and the solid waste **204** at a relatively high temperature, for example, wherein the operating temperature (during the heating process) is in a range of between about 400 °C and about 800 °C. In exemplary embodiments, the heating unit **220**, in general, and the heating device **240**, in particular, are configured and operative to heat the mixture **218** of the solid calcium hydroxide **212** and the solid waste **204** at a temperature of about 500 °C. For effecting such heating environment at relatively high temperature, in exemplary embodiments, the heaters **248** (heating assemblies, heating mechanisms, or/and heating elements) are configured and operative to supply / provide heat to the heating chamber **244**, during the heating process, so as to obtain therein an operating temperature in a range of between about 400 °C and about 800 °C, for example, at a temperature of about 500 °C.

In exemplary embodiments, the heating unit **220**, in general, and the heating device **240** (including the heating chamber **244**), in particular, are configured and operative to provide and maintain a chemical *reducing* environment (i.e., absent of chemical *oxidation* conditions, and presence of chemical *reduction* conditions), during the heating process, for effecting formation of the heated product including the solid calcium bromide [$CaBr_2$ (salt)] **222**. During the heating process, oxygen gas, or/and other possible oxidizing type gases, may be formed, which, undesirably, could provide chemical oxidation conditions inside the heating chamber **244**. Additionally, during the heating process, hazardous gaseous hydrogen bromide [HBr (gas)] may also be formed. In FIG. 2, gases formed during the heating process are generally referenced by the small circles **250**.

For providing and maintaining a chemical *reducing* environment (i.e., absent of chemical *oxidation* conditions, and presence of chemical *reduction* conditions), as well as for removing (venting) gaseous hydrogen bromide [HBr (gas)], which may be formed during the heating process, in exemplary embodiments, the heating unit **220**, in general, and the heating

device **240** (including the heating chamber **244**), in particular, are configured and operative to remove (vent) gases formed during the heating process. For effecting such removing (venting) of oxidizing gas or gases **250**, in exemplary embodiments, the heating unit **220**, in general, and the heating device **240** (including the heating chamber **244**), in particular, include, or/and are operatively connected to, one or more gas removing (venting) assemblies, or/and gas removing (venting) mechanisms, herein, generally referred to as one or more gas removing (venting) devices.

For example, as shown in FIG. 2, the heating unit **220** includes a gas removing (venting) device, for example, gas removing (venting) device **252**, such as a vacuum pump, operatively connected (for example, via chemical [gas] transport line **254**) to the heating chamber **244** of the heating device **240**, and configured to remove (vent, pump out) gases **250** formed inside the heating chamber **244** of the heating device **240** during the heating process.

In some embodiments of the invention, gases **250** (including, for example, hazardous hydrogen bromide [HBr (gas)]) formed inside the heating chamber **244** of the heating device **240** during the heating process, and removed (vented, pumped out), for example, by gas removing (venting) device **252**, are then subjected to a gas cleaning (scrubbing) process, for example, including operation of one or more gas cleaning (scrubbing) assemblies, or/and gas cleaning (scrubbing) mechanisms, herein, generally referred to as one or more gas cleaning (scrubbing) devices. In such exemplary embodiments, such as exemplary embodiment **200**, the bromine recovery system is configured and operative to clean (scrub) gases **250** formed inside the heating chamber **244** of the heating device **240** during the heating process. In such exemplary embodiments, for example, the heating unit **220** includes, or/and is operatively connected to, a gas cleaning (scrubbing) device, for example, gas scrubber **256**. In exemplary embodiments, gases **250** formed inside the heating chamber **244** of the heating device **240** during the heating process, and removed (vented, pumped out), for example, by gas removing (venting) device **252**, are then directed, for example, via chemical [gas] transport line **258**, into the gas scrubber **256**.

In exemplary embodiments, the heating unit **220**, in general, and the heating device **240** (including the heating chamber **244**), in particular, are configured and operative to heat the mixture **218** of the solid calcium hydroxide **212** and the solid waste **204** under an operating pressure being in a relatively wide range, for example, spanning from below atmospheric pressure, for example, about 0.1 atmosphere (atm) [76.0 mm Hg], to above atmospheric pressure, for example, about 2 atmospheres (atm) [1520 mm Hg]. For effecting such heating environment within the indicated pressure range, in exemplary embodiments, the

gas removing (venting) device **252** (such as a vacuum pump) is configured and operative to remove (vent, pump out) gases **250** from inside the heating chamber **244**, during the heating process, for obtaining therein an operating pressure in a range of between about 0.1 atmosphere (atm) [76.0 mm Hg], and about 2 atmospheres (atm) [1520 mm Hg].

Chemical reaction mass transfer conditions / parameters, characteristics

In exemplary embodiments, the heating unit **220**, in general, and the heating device **240** (including the heating chamber **244**), in particular, are configured and operative to (forcibly) transfer (transport, move) the heated mixture **218** of the solid calcium hydroxide **212** and the solid waste **204**, and the solid reaction products **222** (consisting essentially of the solid calcium bromide [CaF_2 (salt)], as well as relatively small amounts of other possible solid reaction products formed therefrom), during the heating process (for example, from start to finish of the heating process), through the heating device **240** (the heating chamber **244**), from the heating device input assembly **242**, through and out of the heating chamber **244**, and towards and into the heating device output assembly **246**. For effecting such (forced) mass transfer (transport, moving) of the heated mixture **218** (and solid reaction products **222** formed therefrom) through the heating device **240** (heating chamber **244**) during the heating process, in exemplary embodiments, the heating unit **220**, in general, and the heating device **240** (including the heating chamber **244**), in particular, include one or more forced mass transfer assemblies, or/and forced mass transfer mechanisms, herein, generally referred to as one or more forced mass transfer devices.

For example, as shown in FIG. 2, heating unit **220** includes a forced mass transfer device, for example, forced mass transfer device **260**, included as part of, and located inside, the heating device **240** (via inside the heating chamber **244**), and configured to (forcibly) transfer (transport, move) the heated mixture **218** of the solid calcium hydroxide **212** and the solid waste **204**, and solid reaction products **222** formed therefrom, during the heating process (for example, from start to finish of the heating process), through the heating device **240** (the heating chamber **244**), from the heating device input assembly **242**, through and out of the heating chamber **244**, and towards and into the heating device output assembly **246**. For example, in FIG. 2, such forced mass transfer (transport, movement) of the heated mixture **218**, and of the heated solid reaction products **222** formed therefrom, during the heating process, through the heating device **240** (the heating chamber **244**), is represented by the three dashed line arrows surrounding the forced mass transfer device **260**.

In exemplary embodiments, the forced mass transfer device **260** includes one or more controllably rotatable components (structures, elements) that are configured and operative to controllably rotate, for example, in the form of a controllably rotatable screw or similarly geometrically configured and operative type of rotatable component (structure, element). In exemplary embodiments of the forced mass transfer device **260**, each of the one or more controllably rotatable components (structures, elements) is configured and operative to rotate wherein the operating speed or rate of rotation, during the heating process (for example, from start to finish of the heating process), is in a range of between about 1 round per minute (rpm) and about 30 rounds per minute (rpm).

In exemplary embodiments of the forced mass transfer device **260**, the controllably rotatable screw or similarly configured and operative type of rotatable component (structure, element) is made of one or more types or kinds of (inert, non-reactive) material(s), for example, high grade stainless steel, which is substantially inert or non-reactive, and does not *chemically* affect (i.e., chemically react with, or cause chemical reaction of) the heated mixture **218** of the solid calcium hydroxide **212** and the solid waste **204**, or the heated solid reaction products **222** formed therefrom, during the heating process. Such exemplary material(s) of construction of the rotatable screw prevents, or at least minimizes, possible undesirable and unwanted side reactions which may take place during forced mass transfer of the various heated contents inside the heating chamber **244**.

Chemical reaction (heating chamber) residence time conditions / parameters, characteristics

For heating the mixture of the solid waste **204** and the solid calcium hydroxide **212**, to thereby form the heated product including solid calcium bromide [$CaBr_2$ (salt)] **222**, total residence time (time period) of the reactants and products, and therefore, of the chemical reaction, inside the heating chamber **244** of the heating device **240** is a function of several process operating conditions and parameters. Exemplary process operating conditions and parameters are as follows.

(i) Temperature and pressure conditions inside of the heating device **240** (heating chamber **244**) during the heating process. Chemical reaction (heating chamber) residence time is a function of the chemical kinetics of the chemical reactions taking place during heating of the mixture **218** of the solid waste **204** and the solid calcium hydroxide **212** inside the heating chamber **244**. In turn, chemical kinetics of the chemical reactions taking place inside the heating chamber **244** is a function of the operating temperature and operating pressure during the heating process.

(ii) Initial chemical composition or make-up of the solid waste **204**, in terms of the initial relative amount or proportion of the bromine compounds in the solid waste **204**.

(iii) Total amount or quantity (mass, weight, volume) of the mixture **218** of the solid waste **204** and the solid calcium hydroxide **212** fed into the heating device **240** (heating chamber **244**) of the heating unit **220**, which, in turn, is based on the initial amounts or quantities (masses, weights, volumes) of the solid waste **204** and of the solid calcium hydroxide **212** fed into and supplied to the mixing unit **216**. For example, in exemplary embodiments, the initial amount or quantity (mass, weight) of the solid calcium hydroxide **212** fed into and supplied to the mixing unit **216** is based on supplying an amount or quantity of the solid calcium hydroxide **212** that corresponds to the stoichiometric equivalent of the amount or quantity of bromine contained in the bromine compounds of the solid waste **204**.

(iv) Rate of forced mass transfer of the heated mixture **218** of the solid calcium hydroxide **212** and the solid waste **204**, and solid reaction products (consisting essentially of solid calcium bromide) **222** formed therefrom, during the heating process, through the heating device **240** (the heating chamber **244**), from the heating device input assembly **242**, through and out of the heating chamber **244**, and towards and into the heating device output assembly **246**. In exemplary embodiments which include operation of a forced mass transfer device, such as forced mass transfer device **260**, the rate of forced mass transfer of the heated mixture **218** and the solid reaction products **222** during the heating process, through the heating chamber **244**, is a direct function of the operating speed or rate of rotation of the one or more controllably rotatable components (structures, elements) of the forced mass transfer device **260**. In exemplary embodiments, during the heating process, the rate of forced mass transfer of the heated mixture **218** affects the rate(s) of heat transfer taking place inside the heated mixture **218**, as well as throughout the heating chamber **244**. This, in turn, may affect the chemical kinetics taking place during the heating process, which, in turn, may affect the overall chemical reaction (heating chamber) residence time.

Actual observed chemical reaction (heating chamber) total residence time will be some function of the above described exemplary process operating conditions and parameters. In exemplary embodiments, for heating the mixture of the solid waste **204** and the solid calcium hydroxide **212**, to thereby form the heated product including solid calcium bromide [$CaBr_2$ (salt)] **222**, chemical reaction (heating chamber) residence time (time period) inside the heating chamber **244** of the heating device **240** is in a range of between about 20 minutes (min) and about 60 minutes (min), for example, about 40 minutes (min).

Chemical reaction exit conditions / parameters, characteristics

In exemplary embodiments, the heated product **222** (consisting essentially of solid calcium bromide [$CaBr_2$ (salt)]) formed in the heating unit **220** during the heating process, exits the heating chamber **244** of the heating device **240**, by passing through heating device output assembly **246**. In exemplary embodiments, the heated product **222** passes through an exit flange and then through an exit valve assembly or mechanism, whereupon the heated product **222** is collected for further processing, or/and use.

For effecting such passage and exiting of the solid calcium bromide **222** out from the heating chamber **244** of the heating device **240**, in exemplary embodiments, the heating device output assembly **246** includes, or is operatively connected to, an exit flange. Alternatively, or additionally, in exemplary embodiments, the heating device output assembly **246** includes, or is operatively connected to, an exit valve assembly or mechanism, for example, exit valve assembly or mechanism **262**.

In exemplary embodiments, the exit valve assembly or mechanism, for example, exit valve assembly or mechanism **262**, is configured and operative to be controllably opened and closed in a controllable timed manner, for example, according to a pre-determined open/close timing schedule, to thereby enable quick passage therethrough of the heated product **222** with minimal entry of air back into the heating chamber **244**. In exemplary embodiments, the exit valve assembly or mechanism **262** includes a knife valve, or/and a double gate valve, that is/are configured and operative to be controllably opened and closed in a controllable timed manner, for example, according to a pre-determined open/close timing schedule, to thereby enable quick passage therethrough of the heated product **222** with minimal entry of air back into the heating chamber **244**.

Following the heating process, for example, after exiting the heating unit **220**, for example, via the heating device output assembly **246**, and passing through the exit valve assembly or mechanism **262**, the (hot) heated product **222** including solid calcium bromide [$CaBr_2$ (salt)] is transferred (for example, via chemical [solids] transport line **264**) to, and collected, for example, in a product collection vessel or container **266**. In exemplary embodiments, the collected (hot) heated product **222** including solid calcium bromide [$CaBr_2$ (salt)] is allowed to cool down to room temperature under ambient air. After cooling, the collected (cooled) heated product **222** including solid calcium bromide [$CaBr_2$ (salt)] can be stored for future use, or/and subjected to further processing and use thereof. Alternatively, in exemplary embodiments, the collected (hot) heated product **222** including solid calcium bromide [$CaBr_2$ (salt)], while still hot, is directly subjected to further processing, for

example, as illustratively described hereinabove, via exemplary steps (procedures / processes) **130** and **134**, or/and via exemplary steps (procedures / processes) **138** and **142**, for example, as presented in FIG. 1B.

Chemical reaction product characteristics

As previously stated hereinabove, in exemplary embodiments, an amount or quantity of the solid calcium hydroxide **212** is supplied (in a stoichiometric equivalent) to the solid waste **204** such that chemical reaction (occurring inside the heating unit **220**) between the two reactants, solid calcium hydroxide **212** and solid waste **204**, goes to full, or nearly full, completion, for forming the heated product **222** consisting essentially of solid calcium bromide [$CaBr_2$ (salt)], whereby, essentially the entire initial amount or quantity of each reactant is essentially fully consumed, while leaving essentially no excess of either reactant, as well as forming essentially no side products. Accordingly, in exemplary embodiments, upon completion of the heating process, the chemical reaction product profile / distribution of the heated product **222** consists essentially of pure (nearly 100 %) (white) solid calcium bromide [$CaBr_2$ (salt)]. Essentially all the bromine compounds present in the initially provided solid waste **204** reacted with the initially supplied solid calcium hydroxide [$Ca(OH)_2$] **212**, for forming the product of (white) solid calcium bromide [$CaBr_2$ (salt)].

In exemplary embodiments, the bromine recovery process results in producing a relatively small amount of waste. For example, upon completion of the heating process, the only waste produced is a relatively small amount of water condensate formed inside the gas removing (venting) device, for example, gas removing (venting) device **252** (vacuum pump), which removed (vented, pumped out) gases **250** formed inside the heating chamber **244** of the heating device **240** during the heating process. Such water condensate may contain a relatively small amount of salt(s) in addition to calcium bromide [$CaBr_2$ (salt)], and may also contain a relatively small amount of liquid phase hydrogen bromide (hydrobromic acid) [HBr (liquid)]. In exemplary embodiments, such water condensate accounts for less than about 5 % (weight/weight) of the total amount of the mixture **218** (solid waste **204** + solid calcium hydroxide **212**) which enters into the heating chamber **244** of the heating unit **220**. Accordingly, the bromine recovery process is relatively highly efficient in terms of producing relatively small amounts of waste or/and side products.

> processing the solid calcium bromide // chemical processing unit

As shown in FIG. 2, in exemplary embodiments, part, or the entirety, of the collected (and cooled or still hot) heated product including solid calcium bromide [$CaBr_2$ (salt)] **222** is subjected to further processing, for example, by a chemical processing unit, for example, chemical processing unit **224**. In exemplary embodiments, chemical processing unit **224** is operatively connected (for example, via product collection vessel or container **266** and chemical [solids] transport line **268**) to the heating unit **220**, and utilized to process the collected heated product **222**, to thereby form bromine [Br_2] **226**.

Reference is again made to FIG. 1B, a flow diagram of exemplary steps (procedures / processes) of the bromine recovery method step (procedure / process) **120** of processing the heated product including solid calcium bromide [$CaBr_2$ (salt)] **222**, for example, as formed via the exemplary embodiment **100** of the method for recovering bromine from solid waste containing bromine compounds presented in FIG. 1A.

In exemplary embodiments of the bromine recovery method, the step (procedure / process) **120** of processing the (cooled or hot) heated product including solid calcium bromide may include exemplary steps (procedures / processes) **130** and **134**, for example, as presented in FIG. 1B. In **130**, there is dissolving the heated product (of solid calcium bromide [$CaBr_2$ (salt)]) **222** in water, thereby forming an aqueous solution of calcium bromide [$CaBr_2$ (aqueous salt)]. In **134**, there is subjecting the calcium bromide aqueous solution to a separation procedure, thereby separating out and obtaining the bromine [Br_2] **226**.

In exemplary embodiments, the step (procedure / process) **120** of processing the (cooled or hot) heated product (of solid calcium bromide [$CaBr_2$ (salt)]) **222**, instead of (i.e., alternatively to), or, in addition to (i.e., separately, in parallel or concurrently), including steps (procedures / processes) **130** and **134**, may include exemplary steps (procedures / processes) **138** and **142**, for example, as presented in FIG. 1B. In **138**, there is heating the (cooled or hot) heated product (of solid calcium bromide [$CaBr_2$ (salt)] **222** in presence of oxygen, thereby forming solid calcium oxide [CaO (solid)] and gaseous bromine [Br_2 (gas)] **226**. In **142**, there is condensing the gaseous bromine, thereby forming liquid bromine [Br_2 (liquid)] **226**.

In exemplary embodiments of the bromine recovery system, such as exemplary embodiment **200** shown in FIG. 2, chemical processing unit **224** is configured and operative to perform the exemplary steps (procedures / processes) of the bromine recovery method step (procedure / process) **120** of processing the heated product (of solid calcium bromide [$CaBr_2$ (salt)] **222**, so as to form and obtain the bromine [Br_2] **226**.

For example, chemical processing unit **224** includes the necessary equipment and apparatuses for dissolving the (cooled or hot) heated product (of solid calcium bromide [$CaBr_2$ (salt)]) **222** in water, thereby forming an aqueous solution of calcium bromide [$CaBr_2$ (aqueous salt)], as well as for subjecting the calcium bromide aqueous solution to a separation procedure, for example, involving, precipitation, distillation or/and extraction, among other possible separation procedures, thereby separating out and obtaining the bromine [Br_2] **226**. Alternatively, or additionally, for example, chemical processing unit **224** includes the necessary equipment and apparatuses for heating the (cooled or hot) heated product (of solid calcium bromide [$CaBr_2$ (salt)]) **222** in presence of oxygen, thereby forming solid calcium oxide [CaO (solid)] and gaseous bromine [Br_2 (gas)] **226**, as well as condensing the gaseous bromine, thereby forming liquid bromine [Br_2 (liquid)] **226**.

> controlling operation of, and processing data-information associated with the method and system // process control / data-information processing unit

In exemplary embodiments of the invention, such as exemplary embodiment **100** of the bromine recovery method presented in FIGs. 1A and 1B, and such as exemplary embodiment **200** of the bromine recovery system presented in FIG. 2, via process control / data-information processing unit **228**, there is controlling operation of, and processing data-information associated with, method steps (procedures / processes), and related equipment used for performing: providing the solid waste **204** containing the bromine compounds, providing a supply of solid calcium hydroxide **212**, mixing the solid waste **204** and the solid calcium hydroxide **212**, thereby forming a mixture **218** thereof, heating the mixture **218** in a chemical reducing (non-oxidizing) environment (i.e., an environment absent of chemical *oxidation* conditions, and with presence of chemical *reduction* conditions), thereby forming a heated product **222** including solid calcium bromide, processing the heated product **222** including solid calcium bromide, so as to form bromine **226**.

In FIG. 1A, such controlling and processing of the bromine recovery method steps (procedures / processes), and related equipment used for performing thereof, are schematically represented by dashed line **126** extending from **124** and connecting to dashed lines **126a**, **126b**, **126c**, **126d**, and **126e**, extending from the respective method steps (procedures / processes) **104**, **108**, **112**, **116**, and **120**. In FIG. 2, such controlling and processing of bromine recovery method steps (procedures / processes), and related equipment used for performing thereof, as well as operative connections and configurations between the process control / data-information processing unit **226** and each of the other bromine recovery

system process units (and components therein), namely, the solid waste input unit **206**, the solid calcium hydroxide supply unit **210**, the mixing unit **216**, the heating unit **220**, and the chemical processing unit **224**, are schematically represented by the double headed dotted line arrows **230** surrounding process control / data-information processing unit **228**.

In exemplary embodiments, such as exemplary embodiment **200**, the bromine recovery system, in general, and process control / data-information processing unit **228**, in particular, includes automatic electrical or/and electronic operating, controlling, and monitoring (measuring) of the numerous operating parameters and conditions of system process units, components, assemblies, mechanisms, and operative connections.

In exemplary embodiments, electrical or/and electronic input/output, feedforward and feedback transmission and reception of electrical or/and electronic control data, information, and command, communication signals between system process units, components, and assemblies, mechanisms, and, power supply and process control equipment, are provided by (wired or/and wireless) electrical or/and electronic input/output control data, information, and command, communications lines, which may include, for example, cables, bundles, or/and buses of wires.

In exemplary embodiments, operative connections and configurations between the process control / data-information processing unit **228**, and each of the other system process units (and components therein), namely, the solid waste input unit **206**, the solid calcium hydroxide supply unit **210**, the mixing unit **216**, the heating unit **220**, and the chemical processing unit **224**, are in the form of a (wired or/and wireless) electrical or/and electronic network of input/output data-information control signal communications lines, for example, in FIG. 2, also represented by double headed dotted line arrows **230**.

Additional exemplary structural, functional, and operational features of system process units, and components thereof

Following are described additional exemplary structural, functional, and operational features of some embodiments of the bromine recovery system, such as exemplary embodiment **200** shown in FIG. 2. These relate to the various system process units (and components therein), namely, solid waste input unit **206**, solid calcium hydroxide supply unit **210**, mixing unit **216**, heating unit **220**, and chemical processing unit **224**, and to the numerous operative connections therebetween.

In exemplary embodiments, any one or more of the process units, components, assemblies, or/and mechanisms, may include its own separate (local) power supply and (local)

process control equipment, whereby, for example, such localized power supply and process control equipment is operatively connected to, and configured to operate in conjunction with, process control / data-information processing unit **228**. Alternatively, any one or more of the process units, components, assemblies, or/and mechanisms, may be directly operatively connected to a centralized (global) power supply, for example, which is operatively connected to, or associated with, centralized (global) process control / data-information processing unit **228**.

In exemplary embodiments, such power supply is a multi-functional, multi-operational type of power supply, configured to supply power according to any of various different types of spatial or/and temporal power configurations, modes, formats, schemes, and schedules, involving synchronous, serial (sequential), periodic, non-periodic, or asynchronous, supply of power in the form of dc or/and ac voltage or/and current, to the system process units, components, assemblies, mechanisms, of the bromine recovery system. Such power supply is configured to operate in conjunction with process control / data-information processing unit **228**.

In exemplary embodiments, the bromine recovery system includes appropriate solids or/and fluid (mass) transfer equipment, such as pipes, tubes, connecting elements, adaptors, fittings, pumps, valves, vents, fans, switches, and, fluid (mass) flow controlling, metering, sensing, and measuring devices, such as solids or/and fluid (mass) flow controllers, meters, and sensors, as well as associated mechanisms, assemblies, components, and elements thereof, which are made of suitable materials, for fully enabling system process units, components, and assemblies, to perform the herein illustratively described functions and operations.

In exemplary embodiments, the bromine recovery system includes appropriate heating and heat transfer equipment, such as heaters, heating jackets, heating elements, insulation, pipes, tubes, connecting elements, adaptors, fittings, valves, vents, fans, switches, and, heat (temperature) controlling, sensing, and measuring devices, such as temperature controllers, sensors, and thermocouples, as well as associated mechanisms, assemblies, components, and elements thereof, which are made of suitable materials, for fully enabling system process units, components, and assemblies, to perform the herein illustratively described functions and operations.

Another aspect of some embodiments of the present invention is a method for manufacturing solid calcium bromide from solid waste containing bromine compounds.

FIG. 3 is a flow diagram of an exemplary embodiment (indicated as, and referred to by, reference number **300**), including the indicated exemplary steps (procedures / processes) thereof, of a method for manufacturing solid calcium bromide [$CaBr_2$ (salt)] from solid waste containing bromine compounds. Herein, the exemplary embodiment **300** of the method for manufacturing solid calcium bromide [$CaBr_2$ (salt)] from solid waste containing bromine compounds is also referred to as solid calcium bromide manufacturing method **300**.

As shown in FIG. 3, in a non-limiting manner, and in some embodiments, such as exemplary embodiment **300**, the solid calcium bromide manufacturing method includes the following exemplary steps (procedures / processes).

In **304**, there is providing the solid waste containing the bromine compounds.

In **308**, there is providing a supply of solid calcium hydroxide [$Ca(OH)_2$ (solid)].

In **312**, there is mixing the solid waste and the solid calcium hydroxide, thereby forming a mixture thereof.

In **316**, there is heating the mixture in a chemical reducing (non-oxidizing) environment (i.e., an environment absent of chemical *oxidation* conditions, and with presence of chemical *reduction* conditions), so as to form solid calcium bromide [$CaBr_2$ (salt)].

In exemplary embodiments of the invention, performance of exemplary steps (procedures / processes) **304**, **308**, **312**, and **316**, results in manufacturing solid calcium bromide from the solid waste containing the bromine compounds.

In exemplary embodiments, solid calcium bromide manufacturing method **300** additionally includes exemplary step (procedure / process) **320**, wherein there is controlling operation of, and processing data-information associated with, method steps (procedures / processes) **304**, **308**, **312**, and **316**, and related equipment used for performing thereof. More specifically, in **320**, there is controlling operation of, and processing data-information associated with, method steps (procedures / processes), and related equipment used for performing: **304** - providing the solid waste containing the bromine compounds; **308** - providing a supply of solid calcium hydroxide; **312** - mixing the solid waste and the solid calcium hydroxide, thereby forming a mixture thereof; and **316** - heating the mixture in a chemical reducing (non-oxidizing) environment, so as to form solid calcium bromide. In FIG. 3, such controlling and processing of solid calcium bromide manufacturing method **300** steps (procedures / processes), and related equipment used for performing thereof, are schematically represented by dashed line **322** extending from **320** and connecting to dashed lines **322a**, **322b**, **322c**, and **322d**, extending from the respective method steps (procedures / processes) **304**, **308**, **312**, and **316**.

Another aspect of some embodiments of the present invention is a system for manufacturing solid calcium bromide from solid waste containing bromine compounds.

The system for manufacturing solid calcium bromide from solid waste containing bromine compounds, in a non-limiting manner, and in some embodiments, includes: a solid waste input unit, a solid calcium hydroxide supply unit, a mixing unit, and a heating unit. In some embodiments, the calcium bromide manufacturing system additionally includes a process control / data-information processing unit.

The exemplary embodiment **200** of the system shown in FIG. 2, is, in a non-limiting manner, suitable for implementing some embodiments of the method for manufacturing solid calcium bromide from solid waste containing bromine compounds, such as exemplary embodiment **300** of the solid calcium bromide manufacturing method presented in FIG. 3. Similarly, the exemplary embodiment **300** of the method presented in FIG. 3, is, in a non-limiting manner, suitable for implementing some embodiments of the system for manufacturing solid calcium bromide from solid waste containing bromine compounds, such as exemplary embodiment **200** of a solid calcium bromide manufacturing system presented in FIG. 2. Herein, the exemplary embodiment **200** of a system for manufacturing solid calcium bromide from solid waste containing bromine compounds is also referred to as the solid calcium bromide manufacturing system.

Hereinabove additional illustrative description and details of some embodiments of the method, and some embodiments of the system, for recovering bromine from solid waste containing bromine compounds, for example, as presented in FIGs. 1A and 2, are similarly applicable for implementing and practicing some exemplary embodiments of a method and system for manufacturing solid calcium bromide from solid waste containing bromine compounds, for example, as presented in FIGs. 3 and 2, respectively.

A particular difference regards the bromine recovery method and system which include the exemplary step (procedure / process) **120** of processing the heated product including solid calcium bromide [$CaBr_2$ (salt)], for example, via the chemical processing unit **224**, so as to form bromine [Br_2]. Such exemplary step (procedure / process) of forming bromine is unnecessary in exemplary embodiments of the solid calcium bromide manufacturing method and system, since the exemplary step (procedure / process) **316** of heating the mixture (of solid waste and solid calcium hydroxide), for example, via the heating unit **220**, in a chemical reducing (non-oxidizing) environment, results in forming the desired reaction (manufactured) product, namely, solid calcium bromide [$CaBr_2$ (salt)].

Similar to some embodiments of the bromine recovery process, some embodiments of the solid calcium bromide manufacturing process are highly efficient in terms of producing relatively small amounts of waste or/and side products.

In exemplary embodiments of the calcium bromide manufacturing method and system, for example, as shown in FIGs. 2 and 3, following the heating process, for example, via the heating device output assembly **246**, and passing through the exit valve assembly or mechanism **262**, the (hot) solid calcium bromide [$CaBr_2$ (salt)] product **222** is transferred (for example, via chemical [solids] transport line **264**) to, and collected, for example, in a product collection vessel or container **266**. In exemplary embodiments, the (hot) solid calcium bromide [$CaBr_2$ (salt)] product **222** is allowed to cool down to room temperature under ambient air. After cooling, the collected (cooled) solid calcium bromide [$CaBr_2$ (salt)] product **222** can be stored for future use.

For example, the collected solid calcium bromide [$CaBr_2$ (salt)] product **222** can be used as a chemical reagent in numerous different types and kinds of chemical reactions and commercial manufacturing processes. Another exemplary use involves dissolving the collected solid calcium bromide [$CaBr_2$ (salt)] product **222** in water, to thereby form an aqueous solution of calcium bromide [$CaBr_2$ (aqueous salt)], which can be used in commercial drilling fluids. The manufactured solid calcium bromide [$CaBr_2$ (salt)] product **222**, either in an 'as is' solid salt form, or in an aqueous solution form, can be also used in a wide variety of applications, for example, in the medical field (as an ingredient in medicines / medications), in the food industry (as an ingredient in foods, for example, as a food preservative), photographic applications, and in the field of fire prevention (for example, as a flame (fire) retardant, or as an ingredient in flame (fire) retardant materials.

Additional embodiments, implementations, practices, and applications thereof

Additional embodiments, implementations, practices, and applications, of the invention are as follows.

In a non-limiting manner, some embodiments of the invention may be suitable for recovering other types of halogens from solid waste containing compounds of such halogens (i.e., halogenated organic or/and inorganic compounds).

For example, since bromine [Br_2] is a member in the halogen group of elements, some embodiments of the invention may be suitable for recovering other halogens, such as fluorine [F_2], chlorine [Cl_2], or/and iodine [I_2], from solid waste containing compounds of such halogens, singly, or in combination.

Additionally, in a non-limiting manner, since calcium [Ca] is a member in the alkaline earth group of elements, some embodiments of the invention may be suitable for manufacturing other types of alkaline earth type bromine salts (alkaline earth bromides), singly, or in combination.

For example, hereinabove illustratively described exemplary embodiments of the invention involve use of the solid hydroxide form of the alkaline earth element calcium, namely, solid calcium hydroxide [$Ca(OH)_2$ (solid)] (lime), for being mixed with the solid waste containing bromine compounds, for forming the alkaline earth (calcium) bromide salt, namely, solid calcium bromide [$CaBr_2$ (salt)]. Exemplary embodiments of the invention may be implemented or practiced by using the solid hydroxide form of other alkaline earth elements, such as solid beryllium hydroxide [$Be(OH)_2$ (solid)], solid magnesium hydroxide [$Mg(OH)_2$ (solid)], solid strontium hydroxide [$Sr(OH)_2$ (solid)], or/and solid barium hydroxide [$Ba(OH)_2$ (solid)], for being mixed with the solid waste, for forming the respective alkaline earth bromide salt, namely, beryllium bromide [$BeBr_2$ (salt)], magnesium bromide [$MgBr_2$ (solid)], strontium bromide [$SrBr_2$ (solid)], or/and barium bromide [$BaBr_2$ (solid)].

Each of the following terms written in singular grammatical form: 'a', 'an', and 'the', as used herein, means 'at least one', or 'one or more'. Use of the phrase 'one or more' herein does not alter this intended meaning of 'a', 'an', or 'the'. Accordingly, the terms 'a', 'an', and 'the', as used herein, may also refer to, and encompass, a plurality of the stated entity or object, *unless otherwise specifically defined or stated herein*, or, *unless the context clearly dictates otherwise*. For example, the phrases: 'a unit', 'a device', 'an assembly', 'a mechanism', 'a component', 'an element', and 'a step or procedure', as used herein, may also refer to, and encompass, a plurality of units, a plurality of devices, a plurality of assemblies, a plurality of mechanisms, a plurality of components, a plurality of elements, and, a plurality of steps or procedures, respectively.

Each of the following terms: 'includes', 'including', 'has', 'having', 'comprises', and 'comprising', and, their linguistic / grammatical variants, derivatives, or/and conjugates, as used herein, means 'including, but not limited to', and is to be taken as specifying the stated component(s), feature(s), characteristic(s), parameter(s), integer(s), or step(s), and does not preclude addition of one or more additional component(s), feature(s), characteristic(s), parameter(s), integer(s), step(s), or groups thereof. Each of these terms is considered equivalent in meaning to the phrase 'consisting essentially of'.

Each of the phrases 'consisting of' and 'consists of', as used herein, means 'including and limited to'.

The phrase 'consisting essentially of', as used herein, means that the stated entity or item (system, system unit, system sub-unit, device, assembly, sub-assembly, mechanism, structure, component, element, or, peripheral equipment, utility, accessory, or material, method or process, step or procedure, sub-step or sub-procedure), which is an entirety or part of an exemplary embodiment of the disclosed invention, or/and which is used for implementing an exemplary embodiment of the disclosed invention, may include at least one additional 'feature or characteristic' being a system unit, system sub-unit, device, assembly, sub-assembly, mechanism, structure, component, or element, or, peripheral equipment, utility, accessory, or material, step or procedure, sub-step or sub-procedure), but only if each such additional 'feature or characteristic' does not materially alter the basic novel and inventive characteristics or special technical features, of the claimed entity or item.

The term 'method', as used herein, refers to steps, procedures, manners, means, or/and techniques, for accomplishing a given task including, but not limited to, those steps, procedures, manners, means, or/and techniques, either known to, or readily developed from known steps, procedures, manners, means, or/and techniques, by practitioners in the relevant field(s) of the disclosed invention.

Throughout this disclosure, a numerical value of a parameter, feature, characteristic, object, or dimension, may be stated or described in terms of a numerical range format. Such a numerical range format, as used herein, illustrates implementation of some exemplary embodiments of the invention, and does not inflexibly limit the scope of the exemplary embodiments of the invention. Accordingly, a stated or described numerical range also refers to, and encompasses, all possible sub-ranges and individual numerical values (where a numerical value may be expressed as a whole, integral, or fractional number) within that stated or described numerical range. For example, a stated or described numerical range 'from 1 to 6' also refers to, and encompasses, all possible sub-ranges, such as 'from 1 to 3', 'from 1 to 4', 'from 1 to 5', 'from 2 to 4', 'from 2 to 6', 'from 3 to 6', etc., and individual numerical values, such as '1', '1.3', '2', '2.8', '3', '3.5', '4', '4.6', '5', '5.2', and '6', within the stated or described numerical range of 'from 1 to 6'. This applies regardless of the numerical breadth, extent, or size, of the stated or described numerical range.

Moreover, for stating or describing a numerical range, the phrase 'in a range of *between* about a first numerical value *and* about a second numerical value', is considered equivalent to, and meaning the same as, the phrase 'in a range of *from* about a first numerical

value *to* about a second numerical value', and, thus, the two equivalently meaning phrases may be used interchangeably. For example, for stating or describing the numerical range of room temperature, the phrase 'room temperature refers to a temperature in a range of between about 20 °C and about 25 °C', and is considered equivalent to, and meaning the same as, the phrase 'room temperature refers to a temperature in a range of from about 20 °C to about 25 °C'.

The term 'about', as used herein, refers to ± 10 % of the stated numerical value.

It is to be fully understood that certain aspects, characteristics, and features, of the invention, which are, for clarity, illustratively described and presented in the context or format of a plurality of separate embodiments, may also be illustratively described and presented in any suitable combination or sub-combination in the context or format of a single embodiment. Conversely, various aspects, characteristics, and features, of the invention which are illustratively described and presented in combination or sub-combination in the context or format of a single embodiment, may also be illustratively described and presented in the context or format of a plurality of separate embodiments.

Although the invention has been illustratively described and presented by way of specific exemplary embodiments, and examples thereof, it is evident that many alternatives, modifications, or/and variations, thereof, will be apparent to those skilled in the art. Accordingly, it is intended that all such alternatives, modifications, or/and variations, fall within the spirit of, and are encompassed by, the broad scope of the appended claims.

All publications, patents, and or/and patent applications, cited or referred to in this disclosure are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent, or/and patent application, was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this specification shall not be construed or understood as an admission that such reference represents or corresponds to prior art of the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

WHAT IS CLAIMED IS:

1. A method for recovering bromine from solid waste containing bromine compounds, the method comprising:

providing the solid waste containing the bromine compounds;

providing a supply of solid calcium hydroxide;

mixing the solid waste and said solid calcium hydroxide, thereby forming a mixture thereof;

heating said mixture in a chemical reducing (non-oxidizing) environment, for forming a heated product comprising solid calcium bromide; and

processing said heated product, so as to form bromine.

2. The method of claim 1, comprising supplying an amount of said solid calcium hydroxide corresponding to stoichiometric equivalent of amount of bromine contained in bromine compounds of the provided solid waste.

3. The method of claim 1, wherein said mixing is performed in a manner so that said mixture formed therefrom is in a powdered form.

4. The method of claim 1, wherein said heating is performed with an operating temperature in a range of between about 400 °C and about 800 °C.

5. The method of claim 1, wherein said heating is performed with an operating pressure in a range of between about 0.1 atmosphere (atm) [76.0 mm Hg], and about 2 atmospheres (atm) [1520 mm Hg].

6. The method of claim 1, wherein said heating includes removing gases formed therefrom.

7. The method of claim 1, wherein said heating includes forcibly transferring and moving said heated mixture, and said heated product formed therefrom, from start to finish of said heating.

8. The method of claim 7, wherein said forcibly transferring and moving is performed using a forced mass transfer device.

9. The method of claim 8, wherein said forced mass transfer device includes one or more controllably rotatable components configured and operative to controllably rotate with an operating speed or rate of rotation in a range of between about 1 round per minute (rpm) and about 30 rounds per minute (rpm).

10. The method of claim 1, wherein said heating is performed with a chemical reaction residence time in a range of between about 20 minutes (min) and about 60 minutes (min).

11. The method of claim 1, wherein said processing includes dissolving said heated product of solid calcium bromide in water, thereby forming an aqueous solution of calcium bromide.

12. The method of claim 11, further comprising subjecting said calcium bromide aqueous solution to a separation procedure, thereby separating bromine from said aqueous solution.

13. The method of claim 1, wherein said processing includes heating said heated product of solid calcium bromide in presence of oxygen, thereby forming solid calcium oxide and gaseous bromine.

14. The method of claim 13, further comprising condensing said gaseous bromine, thereby forming liquid bromine.

15. The method of claim 1, further comprising controlling operation of, and processing data-information associated with, said providing the solid waste, said providing said supply of solid calcium hydroxide, said mixing, and said heating, via a process control / data-information processing unit.

16. The method of claim 15, further comprising controlling operation of, and processing data-information associated with, said processing said solid calcium bromide.

17. A method for manufacturing solid calcium bromide from solid waste containing bromine compounds, the method comprising:

providing the solid waste containing the bromine compounds;

providing a supply of solid calcium hydroxide;

mixing the solid waste and said solid calcium hydroxide, thereby forming a mixture thereof; and

heating said mixture in a chemical reducing (non-oxidizing) environment, so as to form solid calcium bromide.

18. The method of claim 17, comprising supplying an amount of said solid calcium hydroxide corresponding to stoichiometric equivalent of amount of bromine contained in bromine compounds of the provided solid waste.

19. The method of claim 17, wherein said mixing is performed in a manner so that said mixture formed therefrom is in a powdered form.

20. The method of claim 17, wherein said heating is performed with an operating temperature in a range of between about 400 °C and about 800 °C.

21. The method of claim 17, wherein said heating is performed with an operating pressure in a range of between about 0.1 atmosphere (atm) [76.0 mm Hg], and about 2 atmospheres (atm) [1520 mm Hg].

22. The method of claim 17, wherein said heating includes removing gases formed therefrom.

23. The method of claim 17, wherein said heating includes forcibly transferring and moving said heated mixture from start to finish of said heating.

24. The method of claim 23, wherein said forcibly transferring and moving said heated mixture is performed using a forced mass transfer device.

25. The method of claim 24, wherein said forced mass transfer device includes one or more controllably rotatable components configured and operative to controllably rotate with an operating speed or rate of rotation in a range of between about 1 round per minute (rpm) and about 30 rounds per minute (rpm).

26. The method of claim 17, wherein said heating is performed with a chemical reaction residence time in a range of between about 20 minutes (min) and about 60 minutes (min).

27. The method of claim 17, further comprising controlling operation of, and processing data-information associated with, said providing the solid waste, said providing said supply of solid calcium hydroxide, said mixing, and said heating, via a process control / data-information processing unit.

28. A system for recovering bromine from solid waste containing bromine compounds, the system comprising:

a solid waste input unit, for receiving and containing the solid waste;

a solid calcium hydroxide supply unit, for supplying solid calcium hydroxide to the solid waste;

a mixing unit, operatively connected to said solid waste input unit and said solid calcium hydroxide supply unit, for mixing the solid waste and said solid calcium hydroxide, and wherein is formed a mixture thereof;

a heating unit, operatively connected to said mixing unit, for heating said mixture in a chemical reducing (non-oxidizing) environment, and wherein is formed a heated product comprising solid calcium bromide; and

a chemical processing unit, operatively connected to said heating unit, for processing said heated product, and wherein is formed bromine.

29. The system of claim 28, wherein said solid calcium hydroxide supply unit is configured to supply an amount of said solid calcium hydroxide corresponding to stoichiometric equivalent of amount of bromine contained in bromine compounds of the provided solid waste.

30. The system of claim 28, wherein said mixing unit includes a mixing device configured to mix the solid waste and said solid calcium hydroxide, whereby said mixture formed therefrom is in a powdered form.

31. The system of claim 28, wherein said heating unit is configured to heat said mixture at an operating temperature in a range of between about 400 °C and about 800 °C.

32. The system of claim 28, wherein said heating unit is configured to heat said mixture at an operating pressure in a range of between about 0.1 atmosphere (atm) [76.0 mm Hg], and about 2 atmospheres (atm) [1520 mm Hg].

33. The system of claim 28, wherein said heating unit is configured to remove gases formed during said heating of said mixture.

34. The system of claim 28, wherein said heating unit includes a heating device configured to forcibly transfer and move said mixture, and said heated product formed therefrom, through said heating device during said heating.

35. The system of claim 34, wherein said heating device includes a forced mass transfer device configured to effect said forcible transfer and movement through said heating device.

36. The system of claim 35, wherein said heating device includes a heating chamber, wherein is located said forced mass transfer device.

37. The system of claim 35, wherein said forced mass transfer device includes a controllably rotatable component configured and operative to controllably rotate as a controllably rotatable screw or similarly geometrically configured and operative type of rotatable component.

38. The system of claim 37, wherein said controllably rotatable component is configured and operative to controllably rotate with an operating speed or rate of rotation in a range of between about 1 round per minute (rpm) and about 30 rounds per minute (rpm).

39. The system of claim 28, wherein said heating unit is configured to heat said mixture for a chemical reaction residence time in a range of between about 20 minutes (min) and about 60 minutes (min).

40. The system of claim 28, further comprising a process control / data-information processing unit, operatively connected to, and, controlling operation of and processing data-information associated with, said solid waste input unit, said solid calcium hydroxide supply unit, said mixing unit, and said heating unit.

41. The system of claim 40, wherein said process control / data-information processing unit is further operatively connected to, and, controlling operation of and processing data-information associated with, said chemical processing unit.

42. A system for manufacturing solid calcium bromine from solid waste containing bromine compounds, the system comprising:

a solid waste input unit, for receiving and containing the solid waste;

a solid calcium hydroxide supply unit, for supplying solid calcium hydroxide to the solid waste;

a mixing unit, operatively connected to said solid waste input unit and said solid calcium hydroxide supply unit, for mixing the solid waste and said solid calcium hydroxide, and wherein is formed a mixture thereof; and

a heating unit, for heating said mixture in a chemical reducing (non-oxidizing) environment, and wherein is formed solid calcium bromide.

43. The system of claim 42, wherein said solid calcium hydroxide supply unit is configured to supply an amount of said solid calcium hydroxide corresponding to stoichiometric equivalent of amount of bromine contained in bromine compounds of the provided solid waste.

44. The system of claim 42, wherein said mixing unit includes a mixing device configured to mix the solid waste and said solid calcium hydroxide, whereby said mixture formed therefrom is in a powdered form.

45. The system of claim 42, wherein said heating unit is configured to heat said mixture at an operating temperature in a range of between about 400 °C and about 800 °C.

46. The system of claim 42, wherein said heating unit is configured to heat said mixture at an operating pressure in a range of between about 0.1 atmosphere (atm) [76.0 mm Hg], and about 2 atmospheres (atm) [1520 mm Hg].

47. The system of claim 42, wherein said heating unit is configured to remove gases formed during said heating of said mixture.

48. The system of claim 42, wherein said heating unit includes a heating device configured to forcibly transfer and move said mixture, and said solid calcium bromide formed therefrom, through said heating device during said heating.

49. The system of claim 48, wherein said heating device includes a forced mass transfer device configured to effect said forcible transfer and movement through said heating device.

50. The system of claim 49, wherein said heating device includes a heating chamber, wherein is located said forced mass transfer device.

51. The system of claim 49, wherein said forced mass transfer device includes a controllably rotatable component configured and operative to controllably rotate as a controllably rotatable screw or similarly geometrically configured and operative type of rotatable component.

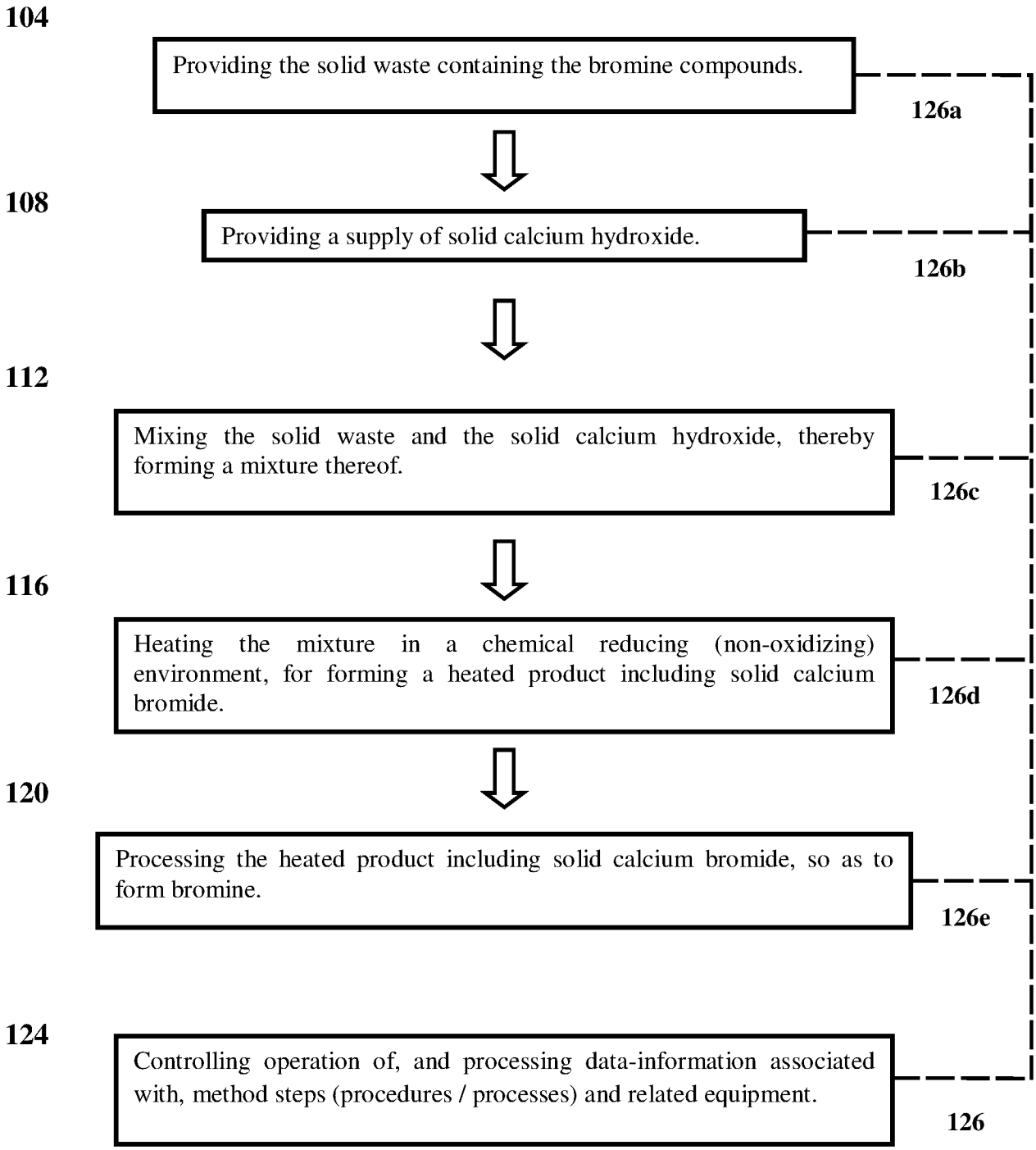
52. The system of claim 51, wherein said controllably rotatable component is configured and operative to controllably rotate with an operating speed or rate of rotation in a range of between about 1 round per minute (rpm) and about 30 rounds per minute (rpm).

53. The system of claim 42, wherein said heating unit is configured to heat said mixture for a chemical reaction residence time in a range of between about 20 minutes (min) and about 60 minutes (min).

54. The system of claim 42, further comprising a process control / data-information processing unit, operatively connected to, and, controlling operation of and processing data-information associated with, said solid waste input unit, said solid calcium hydroxide supply unit, said mixing unit, and said heating unit.

100 FIG. 1A

{*Recovering bromine from solid waste containing bromine compounds.*}



100 **FIG. 1B**

{*Recovering bromine from solid waste containing bromine compounds.*}

130 Dissolving the heated product (of solid calcium bromide) in water, thereby forming an aqueous solution of calcium bromide.

⇩

134 Subjecting the calcium bromide aqueous solution to a separation procedure, thereby separating bromine from the aqueous solution.

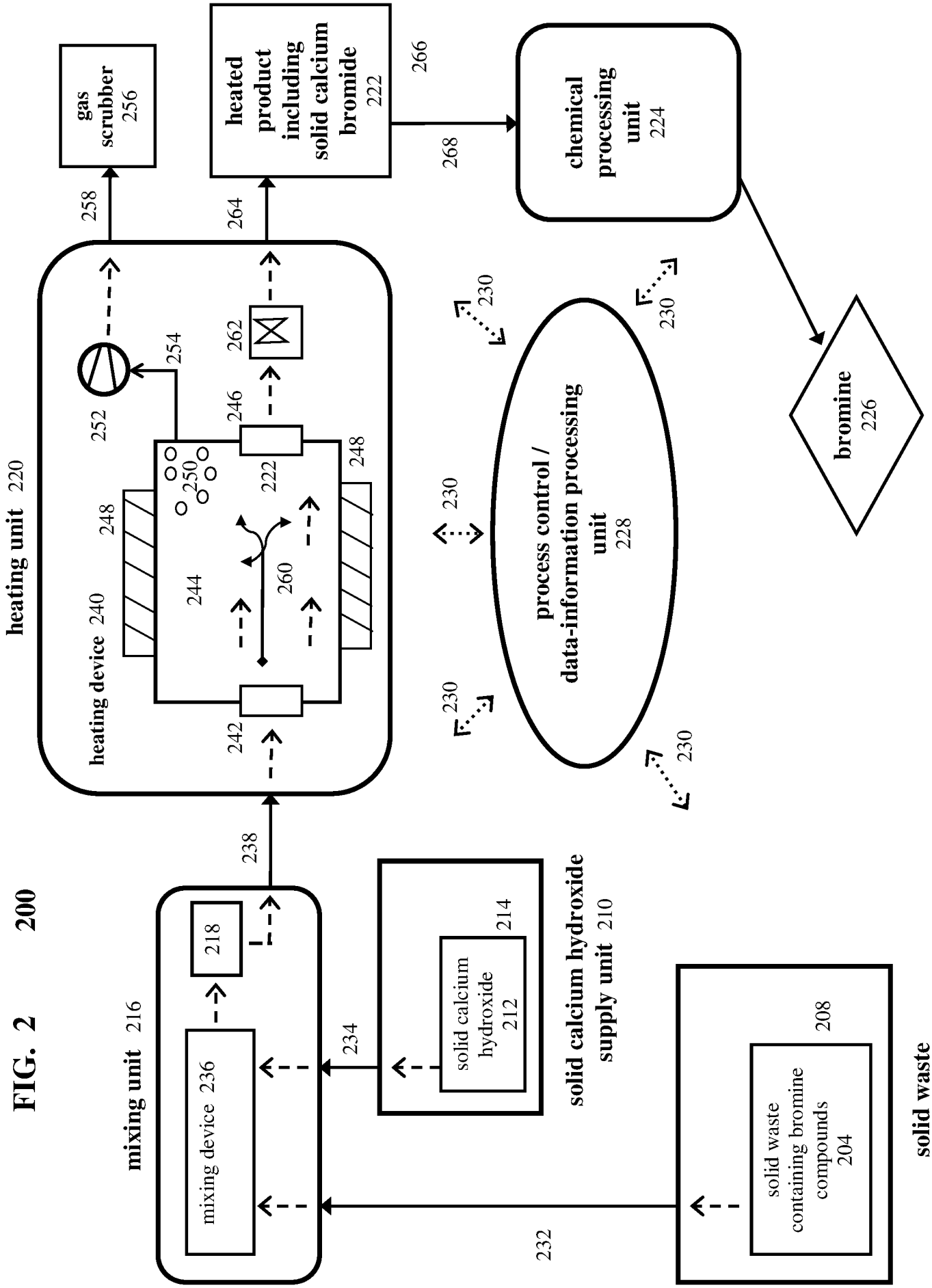
---

138 Heating the heated product (of solid calcium bromide) in presence of oxygen, thereby forming solid calcium oxide and gaseous bromine.

⇩

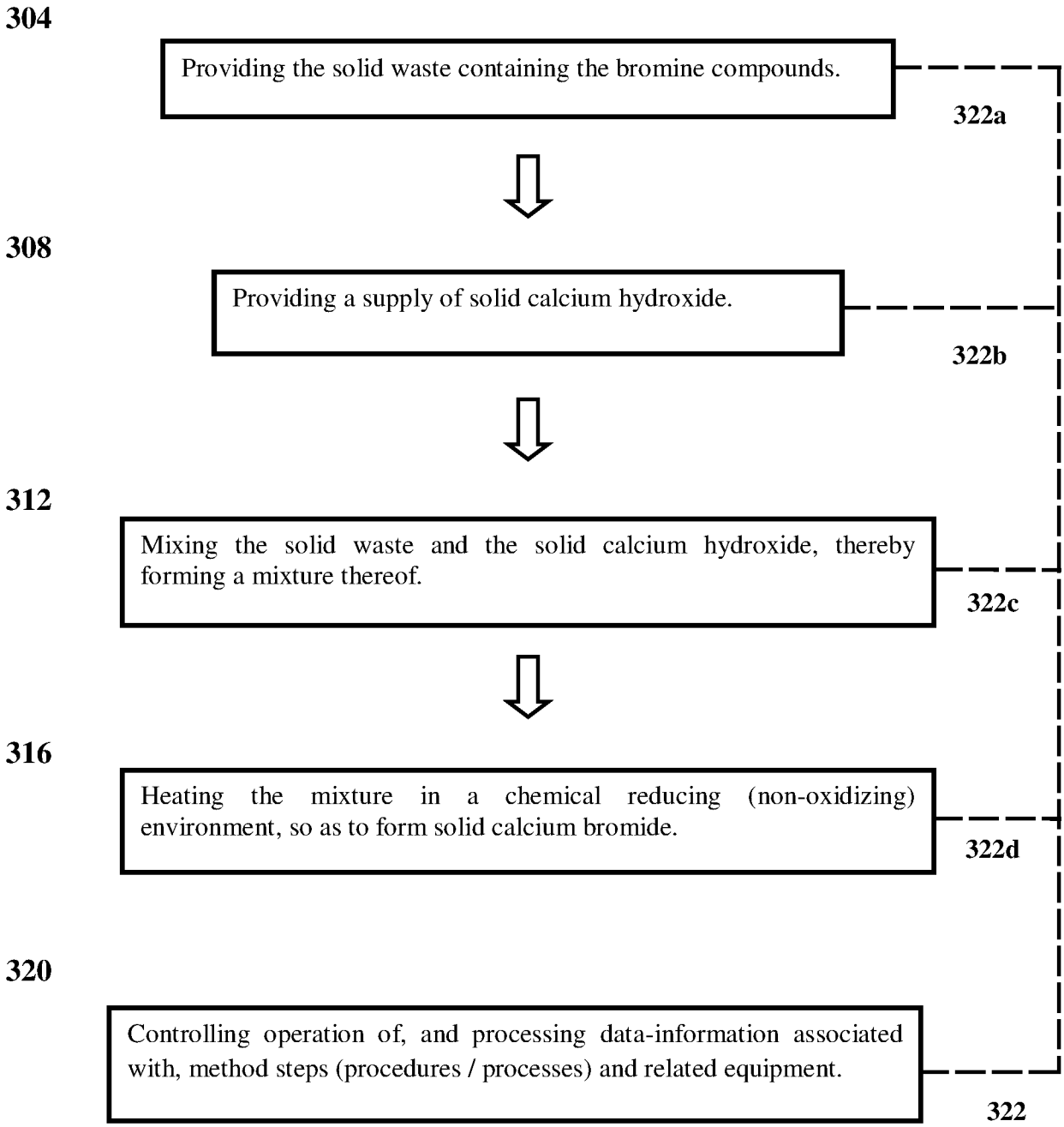
142 Condensing the gaseous bromine, thereby forming liquid bromine.

FIG. 2


200
mixing unit 216
mixing device 236
218
238
234
solid calcium hydroxide 212
214
solid calcium hydroxide supply unit 210
232
solid waste containing bromine compounds 204
208
solid waste input unit 206
heating unit 220
heating device 240
242
244
246
248
250
252
254
258
260
262
264
gas scrubber 256
heated product including solid calcium bromide 222
266
268
chemical processing unit 224
bromine 226
process control / data-information processing unit 228
230

300 FIG. 3

{*Manufacturing calcium bromide from solid waste containing bromine compounds.*}



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/050883

A. CLASSIFICATION OF SUBJECT MATTER
INV. C01B7/09 C01F11/34
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C01B C01F

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2008/106346 A2 (ALBEMARLE CORP [US]; SAUER JOE D [US]; COOK GEORGE W [US]; HALL TYSON) 4 September 2008 (2008-09-04) abstract claims 1,2,6,8 -----	1-54
A	VEHLOW J ET AL: "Recycling of bromine from plastics containing brominated flame retardants in state-of-the-art combustion facilities", INTERNET CITATION, June 2002 (2002-06), pages 1-18, XP002495114, Retrieved from the Internet: URL:http://www.ebfrip.org/publications.htm] [retrieved on 2008-09-05] 4. Bromine recycling potential ----- -/--	1-54

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

"E" earlier application or patent but published on or after the international filing date

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2016	30/05/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Alvarez Rodriguez, C

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/050883

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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