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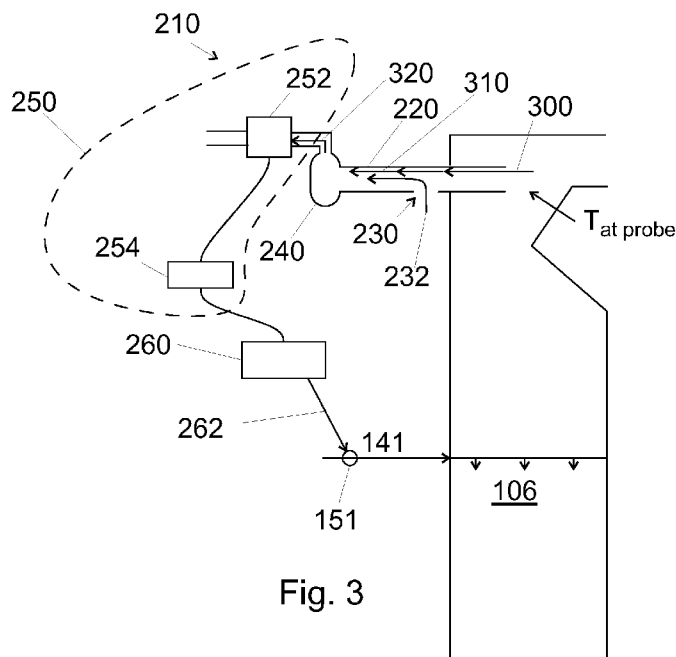
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- (54) Title:** A THERMAL SYSTEM AND A METHOD FOR CONTROLLING A THERMAL PROCESS



- (57) Abstract:** A method for controlling a thermal process, which produces energy and/or fuel in a thermal device. The method comprises producing some gaseous compound comprising measurable particles and conveying at least part of the gaseous compound comprising measurable particles to an analyzer. The method further comprises detecting, using the analyzer, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles; providing information indicative of the electric charge of at least some of the particles; and controlling, by a flow controller and by using the information indicative of the electric charge of at least some of the particles, a flow into or out of the thermal device. In addition, a corresponding thermal system.



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A THERMAL SYSTEM AND A METHOD FOR CONTROLLING A THERMAL PROCESS

Field of the Invention

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This invention relates to a thermal system. The invention relates to methods for controlling a thermal process, such as the operation of the thermal system, for example a thermal device of the thermal system. The thermal device may refer e.g. to a boiler, a pyrolysis reactor, a torrefaction reactor, or
10 a gasifier. The thermal process or the operation of the thermal system may be controlled by controlling a flow into or out of the thermal device.

Background of the Invention

15 Thermal processes are often controlled by measuring some process parameters of the process. The parameters are measured e.g. to decrease the amount of alkali chlorides and/or alkali sulfates of flue gases of a boiler. Alkali chlorides tend to corrode and/or adhere onto surfaces of the thermal device, thereby increasing the maintenance needs. The amount of alkali chlorides
20 and/or alkali sulfates can be controlled e.g. by adding some additives to the boiler and/or to the feedstock of the material to be burned, such as biomass and/or waste.

Currently, devices that can be used to monitor the alkali chloride or alkali
25 sulfate content of flue gases are relatively expensive. Therefore, it is not always economically feasible to include such monitoring devices to power plants, at least to small power plants. Therefore, the maintenance needs for small power plants are typically not reduced by the control of the process, as the thermal system lacks the equipment for the control.

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Summary of the Invention

It has been observed that the electric charge of some of the particles of a flue
gas can be used for controlling a boiler. More generally, it has been observed
35 that the electric charge of some of the particles of a gaseous compound emitted by a thermal system can be used for controlling the thermal system

or a thermal process that is carried out in the thermal device of the thermal system. The thermal system can be suitable for the production of energy and/or fuel; e.g. a power plant is suitable for producing energy, while a pyrolysis reactor is suitable for producing fuel.

5

An embodiment of a method for controlling a thermal process, wherein the thermal process produces energy and/or fuel in a thermal device, comprises:

- producing some gaseous compound comprising measurable particles,
- conveying at least part of the gaseous compound comprising measurable
- 10 particles to an analyzer,
- detecting, using the analyzer, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles,
- providing information indicative of the electric charge of at least some of the particles, and
- 15 - controlling, by a flow controller and by using the information indicative of the electric charge of at least some of the particles, a flow into or out of the thermal device.

An embodiment of the method comprises

- 20 - producing, as a product or a side product, a gaseous compound and/or a gaseous compound comprising particles,
- optionally, condensing at least part of the gaseous compound to particles, thereby producing gaseous compound comprising particles,
- conveying at least part of the gaseous compound comprising particles to a
- 25 particle separator,
- separating some particles from the gaseous compound comprising particles such that particles having a size of at most a first size are passed and some particles are arrested, to produce gaseous compound comprising measurable particles.

30

An embodiment of thermal system suitable for the production of energy and/or fuel comprises

- a thermal device, suitable for the production of energy and/or fuel, wherein the thermal system is arranged to produce gaseous compound comprising
- 35 measurable particles,

- at least one flow controller for controlling a flow into or out of the thermal device,
- a controller for controlling the flow controller,
- an analyzer, and
- 5 - means for conveying at least part of the gaseous compound comprising measurable particles to the analyzer, wherein
 - the analyzer is arranged to detect the electric charge of at least some of the particles of the gaseous compound comprising measurable particles,
 - the analyzer is arranged to provide information indicative of the electric
 - 10 charge of at least some of the particles, and
 - the controller is arranged to control the flow controller using the information indicative of the electric charge of at least some of the particles.

15 In this way, the flow controller is or the flow controllers are arranged to control at least a flow into or out of the thermal device.

Description of the Drawings

- 20 Figure 1 shows, in a side view, a thermal device, suitable for use in a thermal system,
- Figure 2 shows, in a side view, a thermal system comprising means for controlling the thermal device,
- Figure 3 shows in more detail an embodiment of a thermal system, in particular the analyzer and the controller,
- 25 Figure 4 shows an example of measurement results from the system of Fig. 3,
- Figure 5a shows an example of a thermal system, further comprising an electric charger,
- Figure 5b shows an example of a thermal system, comprising means for
- 30 producing two streams of gaseous compound comprising measurable particles,
- Figure 6a shows an example of measurement results from the system of Fig. 5a, wherein the electric charge of particles is measured as function of particle size, and the particles are further charged,
- 35 and

Figure 6b shows an example of measurement results from the system of Fig. 5a, wherein the electric charge of particles is measured as function of particle size, without further charging the particles; and the ratio of the current without further charging to the current with further charging.

Detailed Description of the Invention

Figure 1 shows a boiler 100. The boiler 100 comprises a furnace 106. On top of the furnace 106, a superheater area 114 and an economizer area 116 are located. Material to be burnt, which is referred to as fuel mix, such as biomass and/or waste, is fed to the furnace by the feeding means 143. A first part of the fuel mix, such as waste material and/or biomass, is fed to the feeding means 143 by the feeding means 143a. A second part of the fuel mix, such as biomass, coal and/or peat, is fed to the means 143 by the feeding means 143b. Alternatively, the means 143a and 143b could feed the corresponding material directly to the furnace 106. As for the terms biomass and peat, some authors define peat as a specific biomass. However, in this context the terms biomass and peat are kept separate. Thus biomass may refer to material of biological origin except for peat. Specifically biomass may refer to material comprising or derived from wood. Specifically biomass may refer to material comprising or derived from an agricultural product. It is evident, that even if two types of material may be fed to the furnace with the equipment of Fig. 1, a system wherein the embodiments of the present invention are applicable, may comprise means for feeding only one type of material to be burnt. It is also evident, that the fuel mix may comprise more than two types of material to be burnt. Typically the composition of the fuel mix is adjusted to adjust the sulfur content of the fuel mix, and thereby affecting the properties of the flue gas. Compositions of the fuel mix may include waste material; biomass; coal; peat; waste material and biomass; waste material and coal; and waste material and peat. Preferably the fuel mix comprises at least waste material and even more preferably waste material some other material to be burnt. Any or all of the aforementioned feeding means 143, 143a, and 143b, may comprise a conveyor, such as a screw conveyor or a belt conveyor.

In addition, air is supplied to the furnace by the feeding means 142. The feeding means 142 may comprise a channel, such as a pipe, and/or a nozzle. Moreover, additive material is supplied using the feeding means 141. The additive material may be solid material or comprised by a liquid solution.

5 The feeding means 141 may comprise at least one of a conveyor (e.g. screw or belt conveyor), a pipe and/or a nozzle. As the boiler 100 produces energy in the form of heat, heat is recovered. Heat is recovered e.g. in a superheater, located in the superheater area 114. The superheater recovers heat to a heat transfer medium, such as water. The feeding means 144, such as a
10 pipe, is used to feed the heat transfer medium to a superheater. Heat can also be recovered in an economizer, located in the economizer area 116. The economizer recovers heat to the (or another) heat transfer medium, such as water. The feeding means 145, such as a pipe, is used to feed the (or the other) heat transfer medium to the economizer. In between the superheater
15 114 area and the economizer area 116 the flue gases flow in a channel. The flue gas flow is depicted with the arrow 120. Still further, the flue gases are let out from the process. The arrow 146 depicts means for letting the flue gas out of the thermal device 100, such as a flue gas duct.

20 It is noted that in some other thermal devices, such as a torrefaction reactor, air is not supplied to the thermal device. Moreover, additive material is not necessarily fed to the thermal device.

It has been observed that the electric charge of at least some particles
25 comprised by the flue gas of a boiler bear evidence on the composition and/or the amount of the additive feed 141. Thus, it has been observed that the electric charge of some of the particles emitted by a thermal device 100 and comprised by a gaseous compound can be used to control a flow into or out of the thermal device 100. In addition to control, optimization of the said
30 flow and/or the composition of the flow becomes possible.

Some terms are herein below defined with reference to Fig. 3.

- Gaseous compound 300. A thermal device 100 produces gas as a product or a side product. This gas is called "gaseous compound" 300.
35 This gaseous compound may comprise particles, whereby the gaseous compound 300 may be an aerosol. In addition or alternatively,

the gaseous compound 300 may comprise gaseous compound that is condensable to particles.

- Gaseous compound comprising particles 310. This gas comprises particles, and is, by definition, an aerosol. It may comprise (un-processed) gaseous compound 300. It may comprise gaseous compound 300, of which a part has been condensed to particles. Moreover, as depicted in Fig. 3, the gaseous compound comprising particles 310 may further comprise dilute gas 232.
- Gaseous compound comprising measurable particles 320. This is a gas comprising the particles that are to be measured in an analyzer 250 (e.g. the Faraday cup 252). Thereby also this gas is an aerosol. The gaseous compound comprising measurable particles 320 may be processed from a gas flow, e.g. by arresting at least some, e.g. at least most, of the large particles from the gas flow. The gaseous compound comprising measurable particles 320 may comprise at least a part of the gaseous compound 300, consist of at least a part of the gaseous compound 300, consist of at least a part of the gaseous compound 300 and a dilute gas 232, comprise at least a part of the gaseous compound comprising particles 310, consist of at least a part of the gaseous compound comprising particles 310, consist of at least a part of the gaseous compound comprising particles 310 and a dilute gas 232. Furthermore, the gaseous compound comprising measurable particles may be processed using any one of the aforementioned gases.

In the embodiment of Fig. 3, the gaseous compound comprising measurable particles 320 is obtained by removing some particles from the composition of a dilute gas 232 and the gaseous compound comprising particles 310. The gaseous compound comprising particles 310 is obtained, by cooling and thereby by condensing, from the gaseous compound 300.

Figure 2 shows an embodiment of a thermal system 200 suitable for the production of energy and/or fuel, in particular energy such as heat. Accordingly, Fig. 2 depicts a thermal process wherein the thermal process produces energy and/or fuel in a thermal device. Moreover, Fig. 2 depicts the control of the process. With reference to Figs. 2 and 3, in addition to an

embodiment of a thermal system, an embodiment of a method for controlling the thermal process and/or the thermal device is described.

In an embodiment, a thermal system 200 comprises

- 5 - a thermal device 100, suitable for the production of energy and/or fuel, and arranged to produce a gaseous compound comprising measurable particles 320 (cf. Fig. 3). Preferably the thermal device 100 is arranged to produce at least heat; optionally also at least one of electricity and fuel. Preferably heat is recovered.

10

A corresponding method comprises

- feeding feedstock material into the thermal device 100 of the thermal system 200,
- producing some gaseous compound comprising measurable particles 320
15 (Fig. 3), and
- conveying at least part of the gaseous compound comprising measurable 320 particles to an analyzer 250.

20 The gaseous compound comprising measurable particles 320 is produced in a thermal system 200, wherein the thermal system comprises the thermal device 100.

The term "thermal device" refers to a device wherein thermal reactions occur for the production of energy, such as heat and/or electricity, and/or fuel.
25 Preferably, the thermal device is arranged to produce at least heat. Preferably heat is recovered from the thermal device. Preferably the thermal device comprises a heat exchanger for recovering heat. Specific examples include a boiler, a pyrolysis reactor, a torrefaction reactor, and a gasifier. In an advantageous example, the thermal device is a fluidized bed boiler for
30 reasons to be discussed.

The thermal system 200 of Fig. 2 comprises

- a thermal device 100, suitable for the production of energy and/or fuel, and arranged to produce, as a product or a side product, a gaseous compound
35 300 and/or a gaseous compound comprising particles 310.

Flue gas is produced by the thermal process as a side product of energy production. The flue gas is a gaseous compound 300. The flue gas may comprise solid particles. Thereby the flue gas may be referred to as a "gaseous compound comprising particles" 310. In case the flue gas is extremely hot, the flue gas does not necessarily comprise solid particles. However, some compounds of the flue gas, such as alkali chlorides, are condensable to particles. Moreover, hot the flue gas may comprise large particles that are too large to be measured, and comprise compounds that are condensable to smaller measurable particles.

10

In general, some of the gaseous compounds of the flue gas condense when the temperature decreases such that the partial pressure of the gaseous compound exceeds the saturated vapor pressure in that temperature. For example, the vapor pressure of sodium chloride is 1.5 Pa at 670 °C and 820 Pa at 980 °C. Thus, if the partial pressure of NaCl at 980 °C is e.g. 100 Pa, condensing some of the NaCl gas to NaCl particles occurs when the temperature decreases down to 670 °C, since the saturated partial pressure at 670 °C is only 1.5 Pa. In lower temperatures the partial pressure of the NaCl gas is the flue gas is even lower, whereby further cooling down further condenses some of the NaCl gas to particles. The flue gas may comprise some particles at the higher temperature, and the smaller particles of interest may be produced by this condensing.

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A corresponding method comprises producing, in the thermal device 100, as a product or a side product, a gaseous compound 300 and/or a gaseous compound comprising particles 310.

25

The thermal system 200 optionally comprises a condenser. The system of Fig. 2 comprises a condenser in the form of a pipe 220 that is arranged to convey some of the flue gas 300 to an analysis system 210. Such a condenser is arranged to condense at least part of the gaseous compound 300 to particles, thereby producing a gaseous compound comprising particles 310 (cf. Fig. 3).

30

Correspondingly, a method optionally comprises condensing at least part of the gaseous compound 300 to particles, thereby producing the gaseous compound comprising particles 310.

- 5 Thus, the thermal system 200 of Fig. 2 or the corresponding method produces, either directly or after said condensing, a gaseous compound comprising particles 310.

10 The system 200 comprises means for feeding at least one type of feedstock material into the thermal device. In Fig. 2 the system comprises the means 141 for feeding the additive material, means 142 for feeding air, and the means 143 for feeding the fuel mix, wherein the fuel mix is provided by feeding first material with the means 143a and/or second material with the means 143b. Furthermore the system of Fig. 2 comprises the means 143 and
15 144 for feeding heat transfer material to a heat exchanger, and the means 146, such as a channel, for letting out at least some gaseous compound 300 and/or at least some gaseous compound comprising particles 310 from the thermal device 100.

- 20 A corresponding method comprises feeding feedstock material into the thermal device, such as air, the material to be burnt, or the additive material.

The system 200 further comprises at least one means for controlling a flow into or out of the thermal device 100. The means for controlling a flow may be
25 referred to as a flow controller. Referring to Fig. 2, these means for controlling a flow include

- the means 151 for controlling the flow of the additive material. The means 151 may comprise a valve for controlling liquid additive material or a motor of a conveyor for controlling the speed of the
30 conveyor for the (solid) additive material.
- the means 152 for controlling the flow of air, such as a valve.
- the first means 153a such as a motor of a conveyor 143a for controlling the flow of the first material to be burnt.
- the second means 153b such as a motor of a conveyor 143b for
35 controlling the flow of the second material to be burnt.

- 5 - the means 154 for controlling the flow and/or temperature of the heat transfer medium into a superheater. The means 154 may comprise at least one of a valve, a heater, a cooler, and a heat exchanger. By controlling the feed of the heat transfer medium to a superheater, the flow of energy out of the thermal device 100 is controlled. In addition to the flow, the temperature of the heat transfer medium can be controlled.
- 10 - the means 155 for controlling the flow and or temperature of the heat transfer medium into an economizer. The means 155 may comprise at least one of a valve, a heater, a cooler, and a heat exchanger. By controlling the feed of the heat transfer medium to an economizer, the flow of energy out of the thermal device 100 is controlled. In addition to the flow, the temperature of the heat transfer medium can be controlled.
- 15 - the means 156 for controlling the flow of flue gas out of the thermal device 100. The means 156 may comprise at least one of a valve, and a damper. By controlling the flow of the gaseous compound 300 and/or at least some of the gaseous compound comprising particles 310 out of the thermal device 100, the temperature and/or pressure in
20 the furnace can be controlled.

By using at least one of these means 151 – 156, also the temperature and/or the pressure inside the thermal device 100 can be controlled. Any or all of the flow controllers 151 to 156 may be arranged to receive a signal from a
25 controller 260 (Fig. 3), and arranged, using this signal, to control the corresponding flow.

The system 200 further comprises a controller 260 for controlling the means (e.g. 151) for controlling a flow. In Fig. 2, the controller is part of the analysis
30 system 210. The controller 260 is shown in more detail in Fig. 3. The controller 260 is arranged to send a signal 262 to at least one flow controller (e.g. signal 262 in Fig. 3 to the flow controller 151, and/or the other signals 262 in Fig. 2). As depicted in Fig. 2, the controller may be arranged to control at least one of the means (151, 152, 153a, 153b, 154, 155, 156) for
35 controlling a flow in to our out of the thermal device 100.

The system further comprises an analyzer 250. The analyzer 250 may comprise multiple components, as will be discussed in more detail later.

5 In an embodiment of the method or the system, the means for controlling a flow (151, 152, 153a, 153b, 154, 155, 156) is arranged to control at least one of

- the feed of an additive material into the thermal device 100, wherein examples of the additive material include ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$), ferrous sulphate (FeSO_4), aluminum sulphate ($\text{Al}_2(\text{SO}_4)_3$), ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$), ammonium bisulphate ($(\text{NH}_4)\text{HSO}_4$), sulphuric acid (H_2SO_4), and elemental sulfur,
- air feed into the thermal device,
- the flow of the fuel mix into the thermal device, such as the biomass or waste material feed into the thermal device,
- 15 - the composition of the fuel mix flow, such as at least one, preferably both of the waste material feed into the thermal device and the biomass and/or coal and/or peat feed into the thermal device,
- flow of the gaseous compound out of the thermal device, and
- flow of energy out of the thermal device, such as by controlling the circulation of water in the system or by controlling the temperature of the water circulating in the system.

As discussed above, the system may comprise means for producing gaseous compound comprising measurable particles 320, as will be detailed later. The gaseous compound 300 or the gaseous compound comprising particles 310 may, in some embodiment, be used as the gaseous compound comprising measurable particles 320. The means for producing gaseous compound comprising measurable particles 320 comprises

- 30 - means for producing gaseous compound 300, such as the thermal device 100,
- means for producing gaseous compound comprising particles 310, which comprises the means for producing gaseous compound 300 and optionally further comprises a condenser and/or a pipe 220 to condense some of the compounds of the gaseous compound 300, and
- 35 - optionally, a particle separator 240; arranged to pass particles comprised by the gaseous compound comprising particles 310 and

having a first size; and to arrest some other particles of the gaseous compound comprising particles 310.

5 The system comprises means, such as a pipe, for conveying at least part of the gaseous compound comprising measurable particles 320 to the analyzer 250. The analyzer 250 is arranged to detect the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320. The analyzer 250 is further arranged to provide information indicative of the electric charge of at least some of these particles.

10

A corresponding method comprises conveying at least part of the gaseous compound comprising measurable particles 320 to an analyzer 250.

15 Still further, the controller 260 is arranged to control the means for controlling a flow (151, 152, 153a, 153b, 154, 155, 156) using the information indicative of the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320.

An embodiment of the method comprises

- 20 - detecting, using the analyzer 250, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320,
- providing information indicative of the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320, and
25 - controlling, (i) by a flow controller (151, 152, 153a, 153b, 154, 155, 156) and (ii) by using the information indicative of the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320, a flow into or out of the thermal device 100.

- 30 An embodiment of the method comprises
- optimizing, (i) by a flow controller (151, 152, 153a, 153b, 154, 155, 156) and (ii) by using the information indicative of the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320, a flow into or out of the thermal device 100.

35

In a preferred embodiment, the feed of an additive material into a boiler is controlled and/or optimized. In the preferred embodiment, the additive material is selected such that the additive material affects, when reacting in the thermal device, the content of the alkali halides, such as alkali chlorides, in the flue gas. In particular, some additive materials, when reacting in the thermal device with the alkali chlorides of the flue gas, form some alkali sulfate(s) and some hydrogen chloride. Alkali sulfates and hydrogen chloride corrode and/or adhere onto surfaces of the thermal device much less than the corresponding alkali chloride. More generally, some additive materials, when reacting in the thermal device with the alkali halides of the flue gas, form some alkali sulfates and some hydrogen halide.

As the electric charge of the particles is of interest, it is evident that an embodiment comprises detecting, using the analyzer 250, and without further electrically charging at least some of the particles to be detected, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320. A corresponding system may comprise means, such as a pipe, for conveying at least some of the particles to an analyzer 250 without further electrically charging them.

As discussed above, a flow may be controlled directly, such as the flows corresponding to the means 141, 142, 143, and 146. Alternatively, a flow may be controlled indirectly, such as the flow of energy (out of the thermal device 100) may be controlled by controlling the flow of a heat transfer medium (cf. the means 144, 145).

It is noted that an analyzer 250 that is arranged to detect the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320 is relatively cheap. Moreover, a particle separator 240 is relatively cheap. Therefore, investment costs of the analysis system 210 are relatively low.

The thermal system of Fig. 2 further comprises a particle separator 240, as detailed in Fig. 3. The particle separator 240 may comprise at least one of a cyclone, an impactor disc, a part of an electric low pressure impactor (ELPI), and a filter. The particle separator 240 arranged to pass particles having a

first size and to arrest some other particles. In general, the particle separator 240 is arranged to pass small particles and to arrest at least some of, preferably most of (such as at least 75 % of), substantially all (such as at least 95 % of), or all, large particles. Thereby a gaseous compound comprising mainly or only small particles is passed through the particle separator 240. The limit between “small” and “large” will be discussed below. It is clear that the gaseous compound comprising particles 310, as discussed above, comprises the particles that are passed through the particle separator 240 and further comprises the particles that are arrested in the particle separator 240. In the particle separator 240, a gaseous compound comprising measurable particles 320 is produced.

An impactor disc and the ELPI require some maintenance and/or cleaning work, when a stage, such as disc, becomes dirty. A cyclone is preferred as the particle separator, since the cyclone arrests large particles, and these particles can be conveyed to a container. The size of the container can be made so large that the emptying of it can be made simultaneously with other maintenance tasks. Thus, in a preferred embodiment, the particle separator 240 comprises a cyclone.

A corresponding method comprises

- conveying at least part of the gaseous compound comprising particles 310 to a particle separator 240,
- separating some particles from the gaseous compound comprising particles 310 such that particles having a first size are passed, to produce gaseous compound comprising measurable particles 320. Specifically, particles having a size smaller than or equal to a limit are passed. Thus, the first size may refer to sizes of at most the limit.

The method may further comprise arresting some particles from the gaseous compound comprising particles 310, to produce gaseous compound comprising measurable particles 320. The method may comprise arresting at least some of the particles having a size greater than the first size from the gaseous compound comprising particles 310. For explicit amounts of “at least some”, cf. above.

Moreover, the system of Fig. 2 comprises an outlet, such as the pipe 220, for conveying at least a part of the gaseous compound 300 and/or at least part of the gaseous compound comprising particles 310 to the particle separator 240 (or in some embodiments directly to the analyzer 250). Moreover, Fig. 2
5 shows means, such as a pipe, for conveying at least part of the gaseous compound comprising measurable particles 320 to the analyzer 250.

The operation principle of the analysis system 210 will be explained in some detail below.

10

In a thermal device 100, oxidation and other chemical reactions occur at relatively high temperature. The temperature may be e.g. at least 600 °C, but more typically, at least in some points of the thermal device 100, temperatures above 700 °C, 800 °C, or 900 °C occur. At these temperatures, some of
15 the solid or liquid materials that are fed to the thermal device 100 dissociate to at least two ions. Since the material that is fed to the thermal device 100 is in general electrically neutral, at least one of the ions is positively charged and at least one of the ions is negatively charged. At the high temperature these ions may be in gaseous form.

20

When the temperature decreases, these ions form solid or liquid particles or adhere on some other solid or liquid particles. It has surprisingly been found a correlation between the electric charge and the size of the particles. For example in general, large particles may be charged in one way (e.g.
25 positively, and in total), while small particles are charged in another way (e.g. negatively, and in total). However, this correlation depends on the feedstock materials that are fed to the thermal process or thermal device 100. In another example, small particles are positively charged (in total), while large particles are negatively charged (in total). In the embodiment of Fig. 2, the
30 particle separator 240 is used to remove some of the particles. Typically the particle separator 240 is used to remove large particles from the gaseous compound comprising particles 310, to produce the gaseous compound comprising measurable particles 320. Since the (removed) large particles have a different electric charge than the (passed) small particles, the electric
35 charge of the particles in the analyzer 250 will, in some cases, be non-zero in

total. The term “in total” here meaning total electric charge of all detected particles; as detected in the analyzer 250.

5 However, as is implicitly clear, the particle separator 240 is not needed, it suffices to measure the electric charge of particles as function of size. However, a separator may be beneficial, since it may reduce the maintenance work, as discussed above.

10 In a first specific example, additive material was fed to a thermal process (i.e. into a boiler 100, the boiler being a thermal device 100) to reduce the alkali halide content and/or the alkali sulfate content of the flue gas.

The term alkali halide refers to a compound comprising

- 15 - an alkali atom from the group IA of the periodic table of elements, excluding hydrogen, i.e. one of Li, Na, K, Rb, Cs, and Fr; and
- a halogen atom from the group VIIA of the periodic table of elements, i.e. one of F, Cl, Br, I, and At.

20 Typically, the additive material is arranged to reduce the alkali chloride content of the flue gas. The term alkali chloride refers to one of the chlorides LiCl, NaCl, KCl, RbCl, CsCl, and FrCl. Especially NaCl and KCl enhance corrosion in boilers. Moreover, the additive material can be arranged to reduce the alkali bromide content of the flue gas.

25 In the specific example (Fig. 4, sulphate), the additive material comprised ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$). In the process, Ferric sulphate dissociates to at least one positive iron ion (Fe^+) and to at least one negative sulphate ion (SO_4^-). After cooling down the flue gas, the positive iron ion(s) form(s) or adhere(s) onto at least one large particle. The negative sulphate ion(s) form(s) or adhere(s) onto small particle(s). In the particle separator 240, the positively charged particles are removed from the gaseous compound comprising particles 310. Thereby the gaseous compound comprising measurable particles 320 comprise particles, of which electric charge is negative on the average.

35

Thereby, a flow of negatively charged particles is conveyed to the analyzer 250, and a negative total electric charge is observed. The amount of negatively charged particles bears evidence on the sufficiency of the feed of the additive material, such as ferric sulphate. This information can therefore
5 be used to control the process and/or the thermal system 200.

From the discussion it is evident that the performance of the particle separator 240 is important in embodiments, wherein the electric charge is not measured as function of particle size. However, the actual size of passed
10 particles and arrested particles may depend on the materials used in the thermal process. As discussed above, an embodiment of the method comprises arresting some particles such that particles having the first size are passed (through the particle separator 240). In an embodiment, the first size is at most 10 μm , preferably at most 5 μm , and more preferably at most
15 1 μm .

Moreover, not necessarily all the small particles are analyzed. It may be that the electric charge of the smallest particles is not measured. Alternatively, the electric charge of these very small particles may become detected together
20 with the electric charge of larger particles. For example, when an ELPI is used as the detector, and the electric charger of the ELPI is not used, particles having the size of less than 7 nm are either not measured, or they may impact an impactor plate of the EPLI corresponding to larger particles. Thus, these particles become measured, but at an impactor plate that
25 corresponds to larger particles.

In an embodiment of the system 200 or the method, the analyzer 250 is arranged to detect the electric charge of at least such particles that have the size of at least 10 nm. In some of these embodiments, analyzer 250 is
30 arranged to detect the electric charge of at least such particles that have the size of at least 25 nm, or at least 75 nm.

In some embodiments, the particle separator 240 may be integrated with the analyzer 250. Thereby, an analyzer 250 may comprise a particle separator.
35 As is implicitly clear, an analyzer is arranged to detect the electric charge of at least the particles having the size of at least 10 nm and at most 10 μm .

Other preferable lower limits include the aforementioned values; and as discussed above, even smaller particles may become detected. Other preferable upper limits include the aforementioned values (for the particle separator 240).

5

The term “particle size” refers to the aerodynamic size, more specifically aerodynamic diameter, of the particles. The aerodynamic diameter of an irregularly shaped particle is defined as the diameter of the spherical particle with a density of 1000 kg/m^3 that has the same settling velocity as the
10 irregular particle. The settling velocity, on the other hand, refers to terminal settling velocity of the particle in a force field (such as gravity or electric force) and in a fluid (such as gas).

Figure 4 shows some examples of measurements using the system of Figs. 2
15 and 3. The system was arranged to measure the total electric charge of particles having the size from 10 nm to 8 μm . The current, I_{tot} , is shown on the vertical axis, and the time in horizontal axis.

The analyzer 250 comprised a Faraday cup 252 and a current meter 254.
20 Typically, a Faraday cup is a conductive (e.g. metal) cup (or plate) designed to catch charged particles in low pressure (e.g. vacuum). As the charged particles hit the conductive plate, an electric potential is generated to the plate. When the plate is electrically connected to electrical ground (e.g. via a current meter 254), resulting current can be measured. The current can be
25 used to determine the number (per unit time) of ions or electrons and/or the electric charge of the ions hitting the conductive plate.

Referring to Fig. 4, the electric current to be measured is reasonable small, e.g. in this case in the pico Ampere range. Thus, in an embodiment, the
30 current meter 254 arranged to measure at least electric currents that are less than 100 pA ($1 \text{ pA} = 10^{-12} \text{ A}$), preferably less than 10 pA, and more preferably less than 1 pA. The current meter 254 can, naturally, be arranged to measure also larger currents. However, the signal to noise ratio (S/N) of the current meter 254 should be so high, in particular in the small current regime, that
35 meaningful results can be obtained also for the small currents as discussed above. The aforementioned values for current refer to the absolute value of

current. As is conventional, the sign of the current (positive or negative) can be used to denote the direction of the current. As depicted in Fig. 4, the current may be positive or negative. Thus, in an embodiment, the current meter 254 arranged to measure at least electric currents, of which absolute value are less than e.g. 100 pA (or any other of the aforementioned values).

In an embodiment, the analyzer 250 is arranged to provide information indicative of the electric charge of at least some of the particles at instances of time, wherein a time interval is left between these time instances of time.

10 In some embodiments the time interval (or a time interval, if different time intervals are used) is less than 10 minutes. In a preferred embodiment, a time interval is less than 1 minute. This enables the real time control and/or optimization of the flow into or out of the thermal device. In an embodiment, the current meter 254 is arranged to measure the electric current at instances

15 of time, wherein a time interval is left between these time instances of time. What was said for the time interval of the analyzer 250 applies also for the time interval of the current meter 252.

In an embodiment of the method or the system, the analyzer 250 (and/or the second analyzer 250b) is/are arranged to detect the electric charge of particles as function of particle size. An embodiment of the thermal system 200 comprises, as part of the analyzer 250, a cascaded low pressure impactor suitable for determining the electric charge of at least some of the particles as function of particle size. The cascaded low pressure impactor

25 may comprise a number of subsequent Faraday cups. The case, where only one Faraday cup was used, was described above. The number of subsequent Faraday cups may be e.g. two, at least two, three, at least three, three, at least three, four, at least four, five, at least five, six, at least six, seven, at least seven, eight, at least eight, nine, at least nine, ten, or at least

30 ten.

The cascaded low pressure impactor may be comprised by an ELPI. The ELPI comprises, in addition to the cascaded low pressure impactor, an electric charger arranged to charge particles. When the electric charger of the ELPI is not used, the ELPI operates as a cascaded low pressure impactor.

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The operation principle of the cascaded low pressure impactor may be such that largest particles are adhered on the first Faraday cup. Thereafter, largest particles of the remaining particles are adhered on the second Faraday cup.

- 5 Thereafter, largest particles of the remaining particles are adhered on the third Faraday cup, and so on. This type of operation may be achieved using a meandering path for the particles in the cascaded low pressure impactor.

- 10 The operation principle of the cascaded low pressure impactor may be such that smallest particles are adhered on the first Faraday cup. Thereafter, smallest particles of the remaining particles are adhered on the second Faraday cup. Thereafter, smallest particles of the remaining particles are adhered on the third Faraday cup, and so on. This type of operation may be achieved using a straight path for the particles in the cascaded low pressure
15 impactor and using electrically pre-charged Faraday cups.

- As is evident, the number of Faraday cups in the cascaded low pressure impactor defines the accuracy for the particle size measurements. However, since the number of particles per a Faraday cup decreases by increasing the
20 number of Faraday cups, the electric current from each cup decreases. An optimal number of Faraday cups in the cascaded low pressure impactor may be e.g. from 1 to 20; from 2 to 16; or from 3 to 12. Specific examples include 1, 3, 4, 6, 8, 10, and 12 Faraday cups. It is noted, however, that a single Faraday cup is not suitable for determining the electric charge of at least
25 some of the particles as function of particle size.

- The cascaded low pressure impactor may be comprised in an electrical low pressure impactor (ELPI). The ELPI, however is, in general, also arranged to electrically (further) charge at least some of the particles. When measuring
30 the electric charge of the particles, it is important to measure the electric charge of particles, at least at some point of time,

- (i) without further charging electrically the particles of which electric charge is to be measured, or
(ii) by electrically charging in a known way the particles of which
35 electric charge is to be measured, measuring the electric charge, by electrically charging in another known way the

- particles of which electric charge is to be measured, and measuring the electric charge, or
- (iii) without further charging electrically the particles of which electric charge is to be measured, measuring the electric charge, by electrically charging in a known way the particles of which electric charge is to be measured, and measuring the electric charge.

From the analyzer 250 information indicative of the electric charge of at least some of the particles of the gaseous compound comprising measurable particles is obtainable. The analyzer 250 is arranged to provide information indicative of the electric charge of at least some of the particles; e.g. to a controller 260. An embodiment of the method further comprises

- receiving reference information,
- comparing the information indicative of the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320 with the reference information to produce a comparison result, and
- controlling the feed using the comparison result.

The reference information may be e.g. a known electric current that would, in normal operational condition, be obtainable from the current meter 254. The reference information may be e.g. a known electric current distribution, i.e. the electric current as a function of particle size, that would, in normal operational condition, be obtainable from the current meter 254.

As depicted in Fig. 2 and discussed above, various different feeds can be controlled. Based on the comparison results, a first feed may be increased or decreased. Based on the comparison results, a second feed may be, e.g. simultaneously with the increase or decrease of the first feed, decreased or increased.

Referring to Fig. 2, an embodiment of the method comprises

- diluting at least one of (i) the gaseous compound 300, (ii) the gaseous compound comprising particles 310, and (iii) the gaseous compound comprising measurable particles 320 by mixing it with a dilute gas 232 such that

- the volumetric flow of the dilute gas 232 is V_1 ,
- the volumetric flow of the gaseous compound 300, the gaseous compound comprising particles 310, or the gaseous compound comprising measurable particles 320, whichever is diluted, is V_2 , and
- 5 - the ratio of the volumetric flows, V_1/V_2 , is from 1 to 1000; preferably from 10 to 1000.

Preferably the gas (300, 310, or 320) is diluted in such a way the temperature of the gas entering the analyzer 250 is at most 500 °C; more preferably at
10 most 300 °C. In some embodiments, the temperature of the gas entering the analyzer 250 is from 0 °C to 200 °C; preferably from 50 °C to 150 °C. In an embodiment, the dilute gas comprises air. In an embodiment, the dilute gas consists of air. In an embodiment, the dilute gas consists of filtered air. The air may be supplied in the form of pressurized instrument air, often available
15 in a boiler plant, which instrument air may be clean enough as such. The air may be supplied in the form of pressurized air, also often available in a boiler plant, which air may be cleaned before using as the dilute gas. In an embodiment, the dilute gas comprises nitrogen (N_2). In an embodiment, the dilute gas consists of nitrogen. In an embodiment, the dilute gas comprises at
20 least 75 %, least 80 % or at least 95 % nitrogen, by volume.

A corresponding system comprises means 230 for feeding dilute gas 232. The means 230 may comprise at least one of a pipe, a pump, and an opening. Referring to Fig. 2, the means 230 for feeding dilute gas 232 may
25 be arranged to dilute at least one of (i) the gaseous compound 300, the (ii) the gaseous compound comprising particles 310, and the (iii) the gaseous compound comprising measurable particles 320. The means 230 for feeding dilute gas may comprise an opening, from which dilute gas 232 may be fed, and, optionally, a pump for pumping dilute gas 232 to the thermal system
30 200. However, the analyzer 250 may be a low pressure analyzer 250, whereby the atmospheric pressure of air may be sufficient for feeding the air into the system as the dilute gas 232. The system may comprise means for controlling the dilute ratio V_1/V_2 , which was discussed above. These means may include at least one valve.

The temperature can be affected by the aforementioned ratio of the volumetric flows. For example, the temperature of the gaseous compound 300 may be up to about 1000 °C, whereby a ratio 1:1 may cool (and optionally also condense a part of) the gaseous compound to a temperature of about 500 °C. However, a much higher diluting ratio, as discussed above, may be beneficial, as this decreases the maintenance, e.g. cleaning, needs of the analyzer 250. The ratio of the volumetric flows, V_1/V_2 , may be e.g. at least 50 or at least 100.

10 An embodiment of the method comprises “receiving reference information”, as discussed above. The reference information may be obtained by observing normal operation conditions of the system. However, other reference information may be obtained e.g. by pre-charging the particles before measurements. However, as information on the electric charge of the particles is used in process control, in addition to the measurements of the charged particles, also measurements of (i) particles that are not further charged and/or (ii) particles that are further charged in another way, are needed. These two different measurements may be obtained using a periodically (in time) changing charging current (Fig. 5a), and/or by splitting the flow of a gas such that two flows of gaseous compound comprising measurable particles are formed (Fig. 5b).

Referring to Fig. 5a, a thermal system 200 comprises

- an electric charger 400 arranged to periodically charge at least some gaseous compound such that at least some of the particles of the gaseous compound comprising measurable particles are electrically charged.

The term “periodically” refers to periods in time. Moreover, the term “periodically” refers charging in one way during a first period, and either not charging or charging in another way during a second period.

The expression “charge at least some gaseous compound such that at least some of the particles of the gaseous compound comprising measurable particles are electrically charged” refers to the options of charging the gaseous compound comprising particles 310 and/or charging the gaseous compound comprising measurable particles 320. That is, the particles can, in

principle, be electrically further charged before particle the separator 240 (as for the system) or the separation of particles (as for the method). Thus, some gaseous compound may be charged, at a first time, in a first way; and at a second time, in a second way.

5

The corresponding method comprises, at a first period of time,

- further charging electrically, using an electric charger, (i) at least some of the particles of the gaseous compound comprising particles 310 and/or (ii) at least some of the particles of the gaseous compound comprising measurable

10 particles 320, in a first way, and

- detecting the electric charge of at least some of the further charged particles of the gaseous compound comprising measurable particles 320, e.g. to obtain a reference charge distribution.

15 This corresponds to the situation of Fig. 5a, wherein the electric charger 400 is used in a first way, e.g. by charging at least some of the particles using a first voltage.

The method comprises, at a second period of time,

20 (i) detecting the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320 without further charging at least some of the particles. This corresponds to the situation of Fig. 5a, wherein the electric charger 400 is not used, or the charging voltage is set zero. OR

25 (ii) further charging electrically, using the electric charger 400, (a) at least some of the particles of the gaseous compound comprising particles 310 and/or (b) at least some of the particles of the gaseous compound comprising measurable particles 320, in a second way; and detecting the electric charge of at least some of
30 the further charged particles of the gaseous compound comprising measurable particles 320; wherein the second way is different from the first way.

35 This corresponds to the situation, wherein the electric charger 400 is used in a second way, e.g. by charging at least some of the particles using a second voltage, wherein the second voltage is different from the first voltage. As is

evident, when particles are further charged, the corresponding voltage is non-zero. Therefore, the ratio of the second voltage to the first voltage is defined (even if the second voltage is exactly zero). The ratio of the second voltage to the first voltage may be e.g. (i) negative; (ii) less than 0.95 or more than 1.05; (iii) less than 0.8 or more than 1.2; or (iv) less than 0.5 or more than 2.

Fig. 5b shows another way of measuring reference information. The periodic charging, as described above, may be used also in this embodiment. A method corresponding to Fig. 5b comprises

- generating a first part 320a of gaseous compound comprising measurable particles and a second part 320b of gaseous compound comprising measurable particles. This can be done e.g. by splitting the stream of the gaseous compound comprising measurable particles 320. This could be done by splitting the stream of the gaseous compound 300 or by splitting the stream of gaseous compound comprising particles 310, and, optionally, proper post processing as discussed above.

The corresponding method comprises

- further charging electrically, using an electric charger 400a, some gaseous compound such that at least some of the particles of the first part 320a are electrically charged in a first way,
- detecting the electric charge of at least some of the further charged particles of the first part 320, e.g. to obtain a reference charge distribution.

The method further comprises

(i, in case a second charger 400b is not used)

- detecting the electric charge of at least some of the particles of the second part 320b without further charging electrically at least some of the particles of the second part 320b, or

(ii, in case the second charger 400b is used)

- further charging electrically, using another electric charger 400b, some gaseous compound such that the particles of the second part of gaseous compound comprising measurable particles 320b are further charged, in a second way, and

- detecting the electric charge of at least some of the particles of the second part 320b, wherein
- the second way is different from the first way.

5 In the above, the expression "further charging electrically some gaseous compound" refers to the possibility of splitting one of the gaseous compound 300, the gaseous compound comprising particles 310, and the gaseous compound comprising measurable particles 320 to two parts. The electrical charging of particles refers to (a) electrically charging particles originating
10 from the first part of that splitting (cf. charger 400a, Fig. 5b) or (b) electrically charging particles originating from the second part of that splitting (cf. charger 400b, Fig. 5b). The particles originating from the first part of that splitting are comprised by the first part 320a. The particles originating from the second part of that splitting are comprised by the second part 320b.

15

The system of Fig. 5b comprises

- means generating a first part 320a of gaseous compound comprising measurable particles and a second part 320b of gaseous compound comprising measurable particles, as discussed above,
- 20 - an electric charger 400a arranged to charge some gaseous compound such that at least some of the particles of the first part 320a are electrically charged in a first way, wherein
 - the analyzer 250 is arranged to detect the electric charge of at least some of the particles of the first part 320a, and the thermal system comprises
- 25 - a second analyzer 250b arranged to detect the electric charge of at least some of the particles of the second part 320b.

The thermal system further comprises

- (i, when the second electric charger 400b is not present or not used) means
30 for conveying the second part 320b to the second analyzer 250b without further charging electrically the particles of the second part 320b, or
- (ii, when the second electric charger 400b is present) another electric charger 400b arranged to charge to charge some gaseous compound such that at least some of the particles of the second part 320b are electrically
35 charged in a second way, wherein the second way is different from the first way.

It is noted that in the method or the system of the option (i) above, i.e. in the case wherein the second part 320b is conveyed to the second analyzer 250b without further charging electrically the particles of the second part 320b, the system comprises an electric charger 400a arranged to charge some gaseous compound such that at least some of the particles of the first part 320a are electrically charged in a first way. In this embodiment, of the method or the system, this charger is 400a is used in such a way that the particles of the second part 320b are not further charged. I.e. charging of the particles of the first part should occur after splitting some gas to two parts. Thus, this embodiment of the method may comprise

- further charging electrically, using an electric charger, some gaseous compound such that at least some of the particles of only the first part are electrically charged in a first way.

Thus, this embodiment of the system may comprise

- an electric charger arranged to charge some gaseous compound such that at least some of the particles of only the first part are electrically charged in a first way,

In case also the particles of the second part are further charged, this may not be necessary, even if preferred.

Figures 6a and 6b show measurements from a system of Fig. 5a. Moreover, the system comprised, in the analyzer 250, a cascaded low pressure impactor. More specifically, the electric charger 400 and the cascaded low pressure impactor 252 were both comprised by an ELPI. Figure 6a shows a measurement of electric current as function of particle size, when the electric charger 400 is on. Thus, during these measurements, the electric charger 400 was used to further charge electrically at least some of the particles of the gaseous compound comprising measurable particles 320, in a first way. As depicted, the resulting currents are of the order of tens of pico Amperes. The measured current is denoted in the Figure by $I_{ch,on}$.

At a second period of time, the electric charger 400 was not used. During this period of time, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320 was detected without further charging at least some of the particles. The resulting current is

denoted by $I_{ch,off}$ in Fig. 6b. The scale of the current is on the left hand side of the Figure 6b. The ratio of these currents is denoted by $I_{ch,off}/I_{ch,on}$ and is depicted also in Fig. 6b. The scale of the ratio is shown on the right hand side of Fig. 6b. The ratio varies, depending of particle size, from -2 % to 2 %.

5

In addition, the method may comprise receiving further reference data. For example, the detected ratio as function of size, as depicted in Fig. 6b, may be compared with the further reference data. Alternative, the total current could be measured (i.e. not as function of particle size), and a ratio of the total
10 current as measured while not charging the particles to the total current while charging the particles could be determined. Alternatively or in addition this ratio could be compared with the further reference data.

15 In a preferred embodiment of the method and/or the thermal system 200, the thermal device 100 is a boiler. In the preferred embodiment, the means for controlling a flow is arranged to control the feed of the additive material into the boiler. The additive materials and their function were discussed above.

Moreover, since the particles may collide in the gaseous compound comprising particles 310 and/or in the gaseous compound comprising measurable particles 320, and the collision may neutralize two particles having different electric charge, the electric charge of the particles may diminish as function of time. Therefore, preferably the sample gas is taken
20 out of the thermal device and/or the thermal process from such a location that the time between the generation of electrically charged particles and the time of their measurement is reasonably small. In spatial terms, the location of the generation of electrically charged particles is reasonably close to the location of the analyzer 250, wherein the analyzer 250 is used to detect the electric charge of at least some of the particles of the gaseous compound
25 comprising measurable particles 320.
30

As recited above, the location, wherein the electrically charged particles are formed (i.e. generated) is largely defined by the spatial temperature distribution in the thermal device during its use. Since the saturated vapor
35 pressure of e.g. alkali chlorides is heavily dependent on the temperature, condensing (or solidifying) occurs when temperature decreases. In typical

thermal devices, the partial pressures are such that condensing occurs in the temperature range from 500 °C to 700 °C.

In some embodiments, the time between the generation of electrically charged particles and the time of their measurement is less than 1 minute, less than 15 seconds, or less than 5 seconds. Even more preferably the time may be less than 1 second, but this may be hard to achieve in some types of thermal devices. In some embodiments, the distance between (i) the location of the generation of electrically charged particles and (ii) the analyzer 250 is less than 50 m, less than 15 m, or less than 5 m. Even more preferably the distance may be less than 1 m, but this may be hard to achieve in some types of thermal devices. The distance may be measured e.g. along the flow path of the gas (300, 310, 320). As for the location of the generation of electrically charged particles, a point of feeding a feedstock material can be used as a reasonable approximation. E.g. one the point of feeding air, the point of feeding the material to be burnt, and the point of feeding the additive material can be used as the location of the generation of the particles. Preferably, the point of feeding the additive material can be used as the location of the generation of the particles. Alternatively, the spatial temperature distribution in the thermal device may provide indications of the location of formation of the particles, as discussed above, and further discussed below.

In the aforementioned preferred embodiment (as also shown in Fig. 2), the boiler (i.e. the thermal device 100), comprises an outlet for letting out at least some of at least one of: the gaseous compound 300, the gaseous compound comprising particles 310, and the gaseous compound comprising measurable particles 320. In Fig. 2, the outlet is located below the superheater area 114 of the boiler. In Fig. 3, the outlet is located in the superheater area 114 of the boiler. In a boiler, the outlet could be located in the furnace of the boiler. The outlet may be comprised by a tubular probe, e.g. tube 222, arranged to convey some of the gaseous compound 300, some of the gaseous compound comprising particles 310, or some of the gaseous compound comprising measurable particles 320 to the analyzer 250, optionally through a particle separator 240.

- In an embodiment, the probe (e.g. the pipe 220) is located in the thermal device 100 in such a location that, during the use of the thermal device 100, the temperature $T_{\text{at probe}}$ in the thermal device 100, and at the location of the end of the probe (cf. Fig. 3) is at least 500 °C. In this way, the time between measuring the electric charge of some of the particles and the formation of the particles remains reasonable short. However, it may be beneficial, that the particles are generated *in situ*, whereby it may be beneficial that particles are generated before the probe 220. Therefore, preferably the probe is located in such a way that the temperature $T_{\text{at probe}}$ is also less than 950 °C.
- More preferably the probe is located such that the temperature $T_{\text{at probe}}$ is from 650 °C to 900 °C. These temperatures refer to temperatures when the thermal device operates. In a preferred embodiment, the thermal device 100 is a fluidized bed boiler, such as a bubbling fluidized bed boiler or a circulating fluidized bed boiler, since the temperature distribution in an operating fluidized bed boiler is typically such that a location having this specific temperature can be found. In addition, a fluidized bed boiler having a feed or feeds for at least two materials comprised by the fuel mix is a preferred embodiment, since the fuel mix composition affects the composition of flue gases. The electric charge of particles is indicative of the composition of flue gases as discussed above, and can therefore be used to control the composition of the fuel mix used in the fluidized bed boiler. In addition or alternatively to two different fuel materials, additives (i.e. additional materials) can be used, as discussed above.
- As probably implicitly clear, an aspect of the invention is the use of an electric low pressure impactor (ELPI) for controlling a thermal device 100. The use comprises
- producing, in the thermal device 100, some gaseous compound 300, some gaseous compound comprising particles 310, or some gaseous compound comprising measurable particles 320,
 - optionally, producing from the gaseous compound 300 or from the gaseous compound comprising particles 310 some gaseous compound comprising measurable particles 320,
 - conveying at least part of the gaseous compound comprising measurable particles 320 to the electric low pressure impactor (ELPI),

- detecting, using the ELPI, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320,
- providing information indicative of the electric charge of at least some of the particles, and
- 5 - controlling, by a flow controller and by using the information indicative of the electric charge of at least some of the particles, a flow into or out of the thermal device 100.

As discussed above, aspects of the use include:

- 10 (1) detecting, using the ELPI and without further charging the particles, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320;
- (2) (i) detecting, using the ELPI and further charging the particles in a first way, a first electric charge of at least some of the particles of the
15 gaseous compound comprising measurable particles 320; and (ii) detecting, using the ELPI and further charging the particles in a second way, a second electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320;
- (3) (i) detecting, using the ELPI and without further charging the particles,
20 a first electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320; and (ii) detecting, using the ELPI and further charging the particles, a second electric charge of at least some of the particles of the gaseous compound comprising measurable particles 320;
- 25 (4) using the ELPI to detect the electric charge of at least some of the particles as function of particle size; and
- (5) using the ELPI to provide information indicative of the electric charge of at least some of the particles, and controlling the flow of an additive material, such as include ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$), ferrous sulphate (FeSO_4), aluminum sulphate ($\text{Al}_2(\text{SO}_4)_3$), ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$), ammonium bisulphate ($(\text{NH}_4)\text{HSO}_4$), sulphuric acid (H_2SO_4), and/or elemental sulfur into the thermal device, especially
30 into a fluidized bed boiler.

Still further, the use may comprise using such an ELPI that has at least an aforementioned property regarding the analyzer 250 (e.g. regarding the particle size).

Claims:

1. A method for controlling a thermal process, wherein the thermal process produces energy and/or fuel in a thermal device, the method comprising
 - 5 - producing gaseous compound comprising particles,
 - conveying at least part of the gaseous compound comprising particles to a particle separator,
 - separating some particles from the gaseous compound comprising particles such that particles having a size of at most 10 μm are passed and some
 - 10 particles are arrested, to produce gaseous compound comprising measurable particles,
 - conveying at least part of the gaseous compound comprising measurable particles to an analyzer that is arranged to detect the electric charge of particles having the size of at least 10 nm and at most 10 μm ,
 - 15 - detecting, using the analyzer, the electric charge of at least some of the particles of the gaseous compound comprising measurable particles,
 - providing information indicative of the electric charge of at least some of the particles, and
 - controlling, by a flow controller and by using the information indicative of the
 - 20 electric charge of at least some of the particles, a flow into or out of the thermal device.
2. The method of claim 1, wherein said producing gaseous compound comprising particles comprises
 - 25 - producing, as a product or a side product, the gaseous compound comprising particles, and/or
 - producing, as a product or a side product, a gaseous compound and condensing at least part of the gaseous compound to particles; thereby producing the gaseous compound comprising particles.
 - 30
3. The method of claim 1 or 2, wherein the flow controller is arranged to control at least one of
 - the air feed into the thermal device,
 - the flow of the fuel mix into the thermal device,
 - 35 - the composition of the fuel mix flow,

- the feed of an additive material into the thermal device, wherein examples of the additive material include ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$), ferrous sulphate (FeSO_4), aluminum sulphate ($\text{Al}_2(\text{SO}_4)_3$), ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$), ammonium bisulphate ($(\text{NH}_4)\text{HSO}_4$), sulphuric acid (H_2SO_4), and elemental sulfur,
- the flow of the gaseous compound and/or the gaseous compound comprising particles out of the thermal device, and
- the flow of energy out of the thermal device, e.g. by controlling the circulation of a heat transfer medium in the system or by controlling the temperature of the heat transfer medium in the system.

4. The method of any of the claims 1 to 3, wherein

- the thermal device is a boiler.

5. The method of claim 4, wherein
- the flow controller is arranged to control the feed of an additive material into the boiler, wherein examples of the additive material include ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$), ferrous sulphate (FeSO_4), aluminum sulphate ($\text{Al}_2(\text{SO}_4)_3$), ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$), ammonium bisulphate ($(\text{NH}_4)\text{HSO}_4$), sulphuric acid (H_2SO_4), and elemental sulfur.

6. The method of claim 4 or 5, wherein

- the boiler comprises

- o a furnace,
 - o a superheater area, and
 - o an outlet for letting out at least one of gaseous compound, gaseous compound comprising particles, and gaseous compound comprising measurable particles, and
- the outlet is located in the furnace of the boiler or in the superheater area of the boiler.

7. The method of any of the claims 1 to 6, comprising

- receiving reference information,

- comparing the information indicative of the electric charge of at least some of the particles of the gaseous compound comprising measurable particles with the reference information to produce a comparison result, and

- controlling a flow into or out of the thermal device using the comparison result.

8. The method of any of the claims 1 to 7, comprising

- 5 - diluting at least one of the gaseous compound, the gaseous compound comprising particles, and the gaseous compound comprising measurable particles by mixing it with a dilute gas such that
- the volumetric flow of the dilute gas is V_1 ,
- the volumetric flow of the gaseous compound, the gaseous compound
- 10 comprising particles, or and the gaseous compound comprising measurable particles is V_2 , and
- the ratio of the volumetric flows, V_1/V_2 , is from 1 to 1000; preferably from 10 to 1000.

15 9. The method of any of the claims 1 to 8, comprising
(A)

- at a first period of time,

- 20 ○ further charging electrically, using an electric charger, (a) at least some of the particles of the gaseous compound comprising particles and/or (b) at least some of the particles of the gaseous compound comprising measurable particles, in a first way, and
- detecting the electric charge of at least some of the further charged particles of the gaseous compound comprising measurable particles, and

25 (B)

- at a second period of time,

(B,i)

- 30 ○ detecting the electric charge of at least some of the particles of the gaseous compound comprising measurable particles without further charging at least some of the particles to be detected, or

(B,ii)

- 35 ○ further charging electrically, using the electric charger, (a) at least some of the particles of the gaseous compound comprising particles and/or (b) at least some of the particles of the gaseous compound comprising measurable particles, in a second way, and

- detecting the electric charge of at least some of the further charged particles of the gaseous compound comprising measurable particles, wherein
- the second way is different from the first way.

5

10. The method of any of the claims 1 to 9, comprising

(A)

- generating a first part of gaseous compound comprising measurable particles and a second part of gaseous compound comprising measurable particles,

10

- further charging electrically, using an electric charger, some gaseous compound such that at least some of the particles of the first part are electrically charged in a first way,

- detecting the electric charge of at least some of the further charged particles of the first part, and

15

(B,i)

- detecting the electric charge of at least some of the particles of the second part without further charging electrically at least some of the particles of the second part, or

20

(B,ii)

- further charging electrically, using another electric charger, some gaseous compound such that at least some of the particles of the second part of gaseous compound comprising measurable particles are further charged, in a second way, and

25

- detecting the electric charge of at least some of the particles of the second part, wherein
- the second way is different from the first way.

11. The method of any of the claims 1 to 10, wherein the analyzer is suitable for determining the electric charge of at least some of the particles as function of particle size.

30

12. The method of any of the claims 1 to 11, wherein the analyzer comprises a cascaded low pressure impactor.

35

13. A thermal system suitable for the production of energy and/or fuel, the thermal system comprising

- a thermal device, suitable for the production of energy and/or fuel, arranged to produce, as a product or a side product, a gaseous compound and/or a gaseous compound comprising particles,

- optionally, a condenser arranged to condense at least part of the gaseous compound to particles, thereby producing gaseous compound comprising particles,

- a particle separator arranged to pass particles, comprised by the gaseous compound comprising particles, having a size of at most 10 μm , and to arrest some particles, to produce gaseous compound comprising measurable particles, and

- an outlet for conveying at least a part of the gaseous compound or at least part of the gaseous compound comprising particles to the particle separator;

whereby the thermal system is arranged to produce gaseous compound comprising measurable particles, the thermal system further comprising

- at least one flow controller for controlling a flow into or out of the thermal device,

- a controller for controlling the flow controller,

- an analyzer that is arranged to detect the electric charge of particles having the size of at least 10 nm and at most 10 μm , and

- means for conveying at least part of the gaseous compound comprising measurable particles to the analyzer, wherein

- the analyzer is arranged to detect the electric charge of at least some of the particles of the gaseous compound comprising measurable particles,

- the analyzer is arranged to provide information indicative of the electric charge of at least some of the particles, and

- the controller is arranged to control the flow controller using the information indicative of the electric charge of at least some of the particles.

14. The thermal system of claim 13, wherein

- the analyzer comprises a Faraday cup and a current meter.

15. The thermal system of claim 14, wherein

- the signal to noise ratio of the current meter is such that the current meter is arranged to measure at least currents that are less than 100 pA (1 pA = 10^{-12} A), preferably less than 10 pA, and more preferably less than 1 pA.

5 16. The thermal system of any of the claims 13 to 15, comprising
- an electric charger arranged to periodically charge at least some gaseous compound such that at least some of the particles of the gaseous compound comprising measurable particles are electrically charged.

10 17. The thermal system of any of the claims 13 to 16, comprising
(A)
- means generating a first part of gaseous compound comprising measurable particles and a second part of gaseous compound comprising measurable particles,

15 - an electric charger arranged to charge some gaseous compound such that at least some of the particles of the first part are electrically charged in a first way, whereby
- the analyzer is arranged to detect the electric charge of at least some of the particles of the first part, and the thermal system comprises

20 (B)
- a second analyzer arranged to detect the electric charge of at least some of the particles of the second part, and the thermal system further comprises
(B,i)

25 ○ means for conveying the second part to the second analyzer without further charging electrically the particles of the second part,
or

(B, ii)

30 ○ another electric charger arranged to charge some gaseous compound such that at least some of the particles of the second part are electrically charged in a second way, wherein
○ the second way is different from the first way.

18. The thermal system of any the claims 13 to 17, wherein the analyzer is suitable for determining the electric charge of at least some of the particles
35 as function of particle size.

19. The thermal system of any the claims 13 to 18, wherein the analyzer comprises a cascaded low pressure impactor.

20. The thermal system of any of the claims 13 to 19, wherein the flow controller is arranged to control at least one of

- the air feed into the thermal device,
- the flow of the fuel mix into the thermal device,
- the composition of the fuel mix flow,
- the feed of an additive material into the thermal device, wherein examples of the additive material include ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$), ferrous sulphate (FeSO_4), aluminum sulphate ($\text{Al}_2(\text{SO}_4)_3$), ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$), ammonium bisulphate ($(\text{NH}_4)\text{HSO}_4$), sulphuric acid (H_2SO_4), and elemental sulfur,
- the flow of the gaseous compound and/or the gaseous compound comprising particles out of the thermal device, and
- the flow of energy out of the thermal device, e.g. by controlling the circulation of a heat transfer medium in the system or by controlling the temperature of the heat transfer medium in the system.

21. The thermal system of any of the claims 13 to 20, wherein

- the thermal device is a boiler.

22. The thermal system of any claim 21, wherein

- the flow controller is arranged to control the feed of an additive material into the boiler, wherein examples of the additive material include ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$), ferrous sulphate (FeSO_4), aluminum sulphate ($\text{Al}_2(\text{SO}_4)_3$), ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$), ammonium bisulphate ($(\text{NH}_4)\text{HSO}_4$), sulphuric acid (H_2SO_4), and elemental sulfur.

23. The thermal system of claim 21 or 22, wherein

- the boiler comprises
 - o a furnace
 - o a superheater area, and
 - o an outlet for letting out at least one of gaseous compound, gaseous compound comprising particles, and gaseous compound comprising measurable particles, and

- the outlet is located in the furnace of the boiler or in the superheater area of the boiler.

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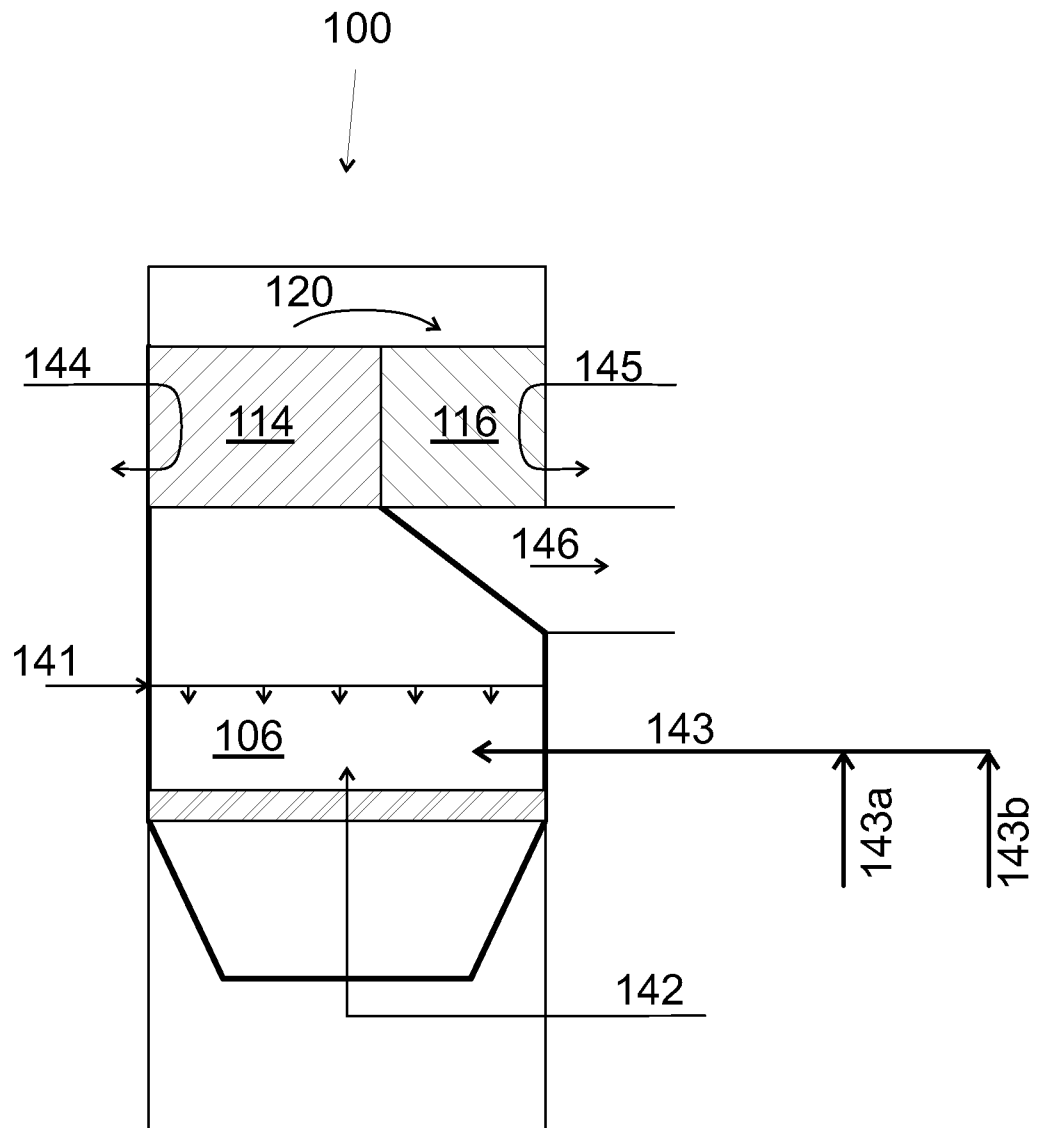


Fig. 1

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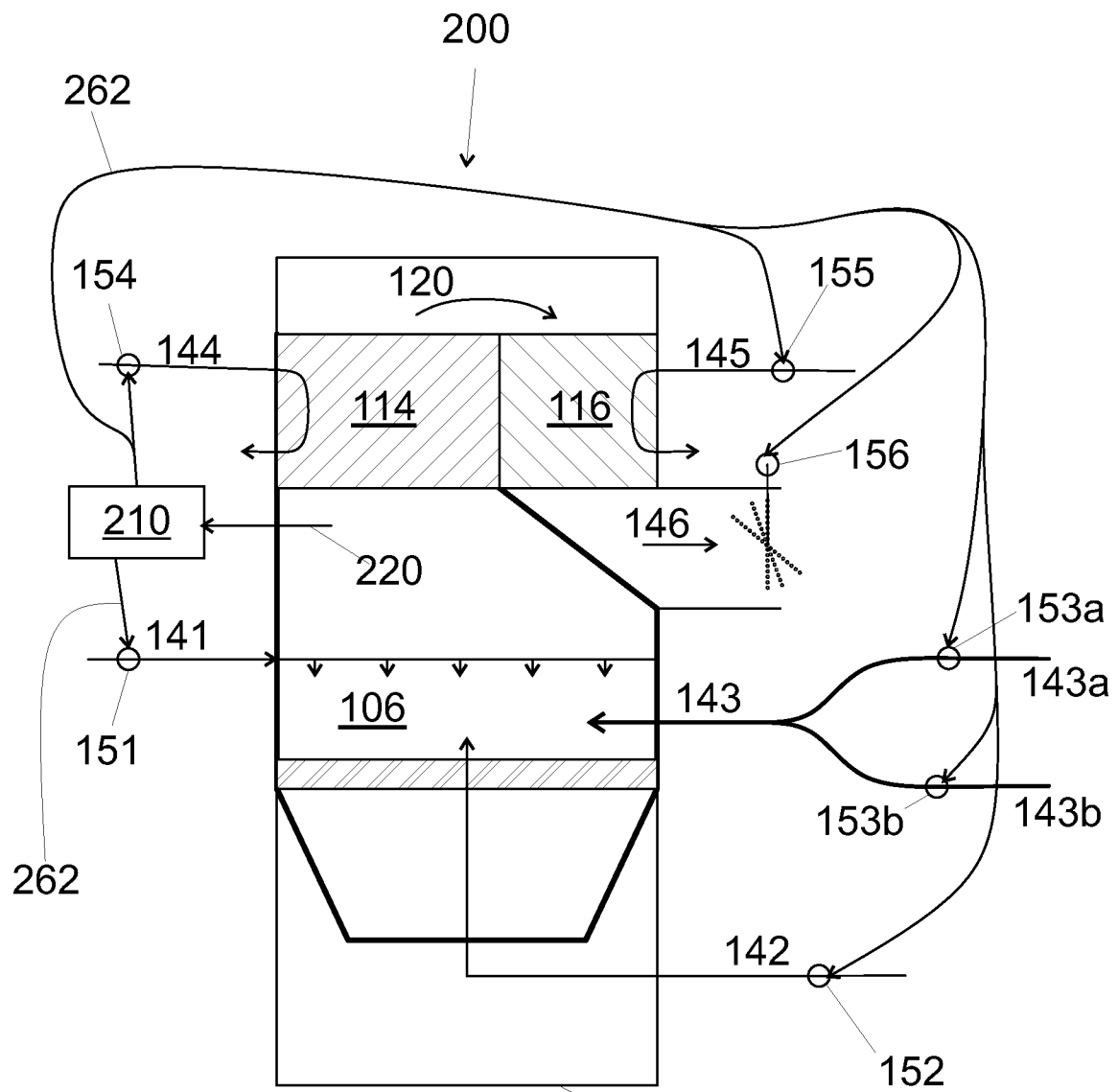


Fig. 2

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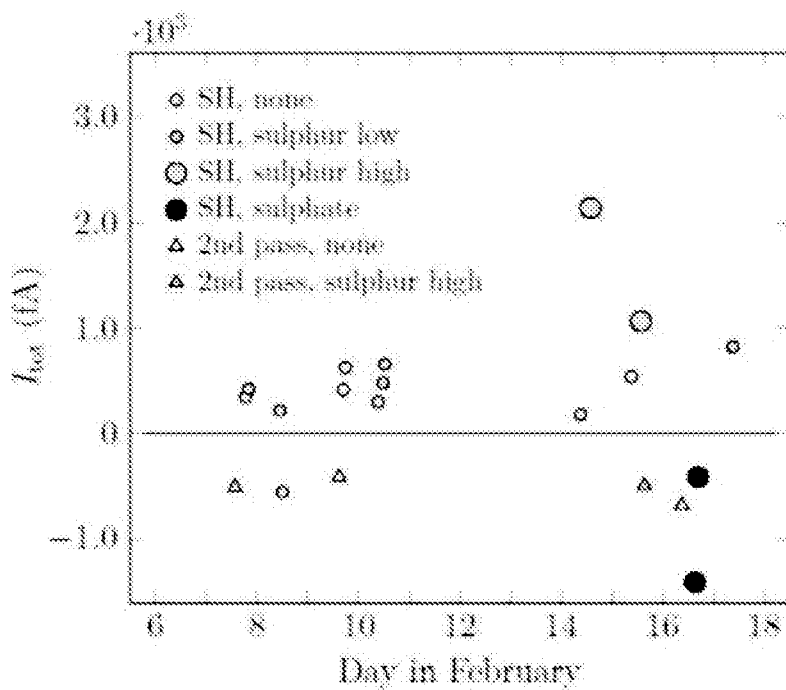
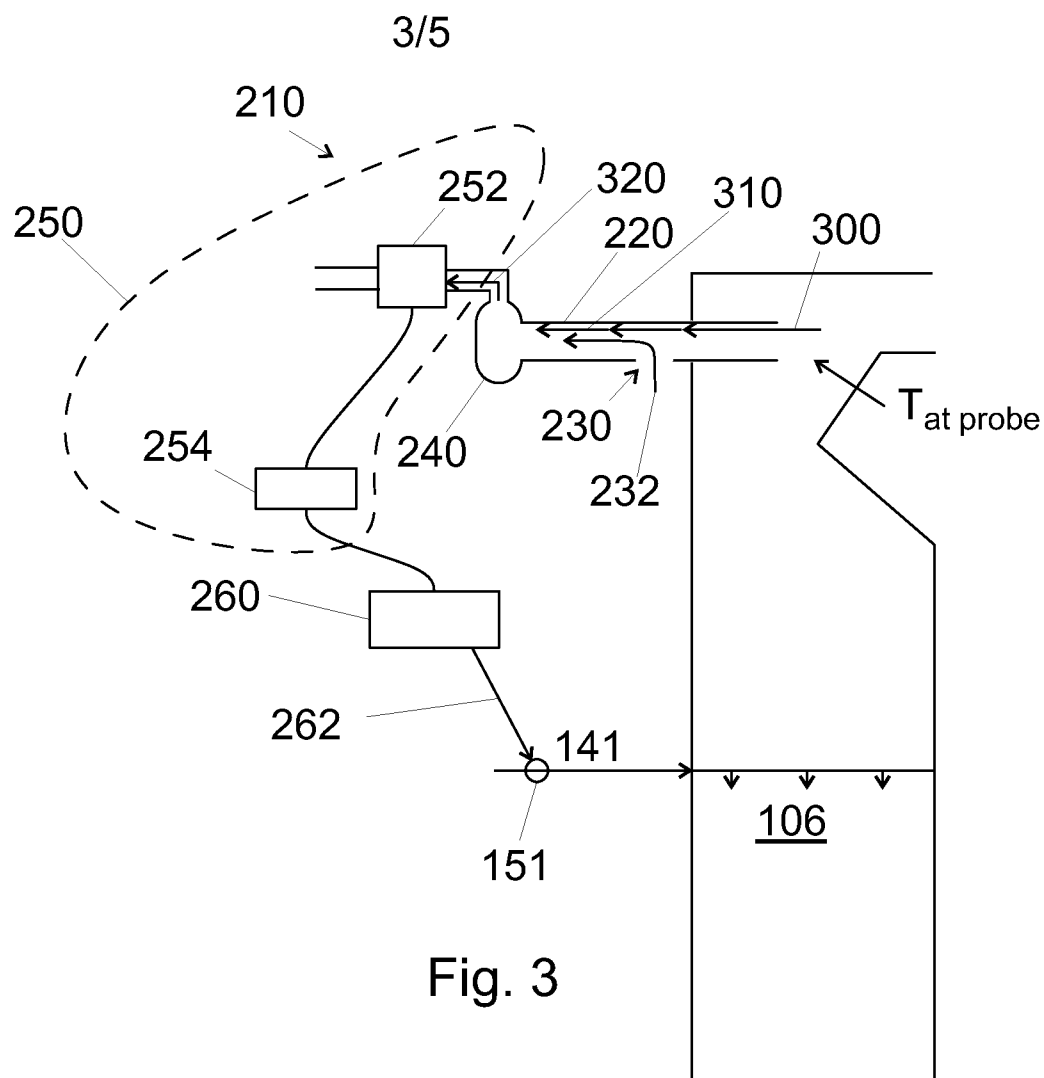


Fig. 4

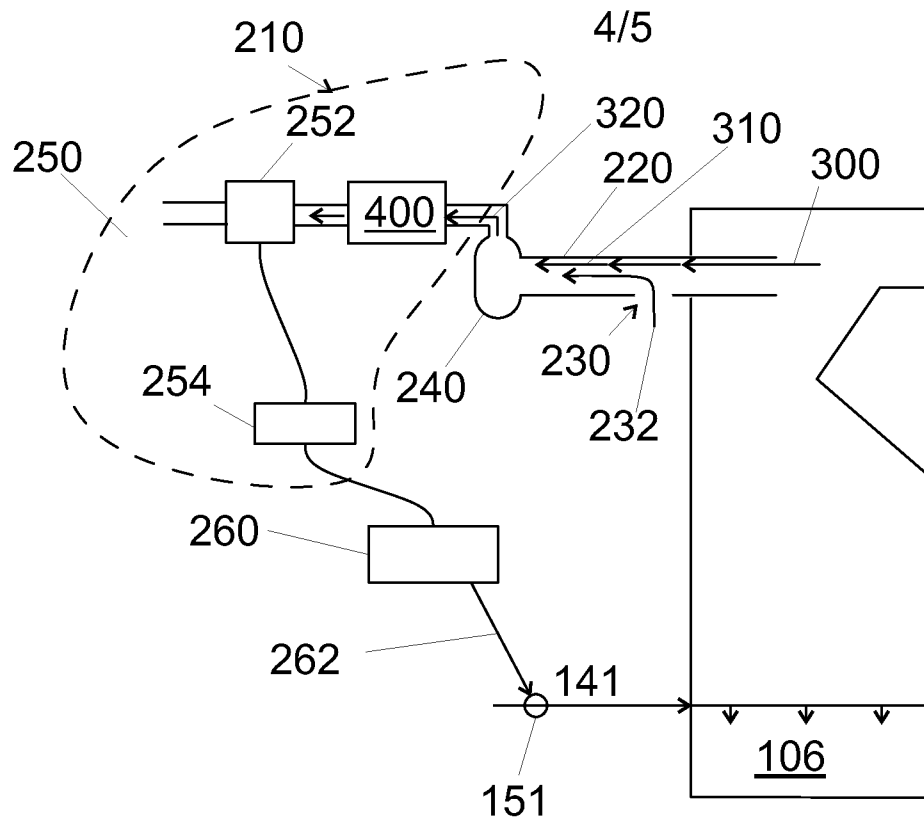


Fig. 5a

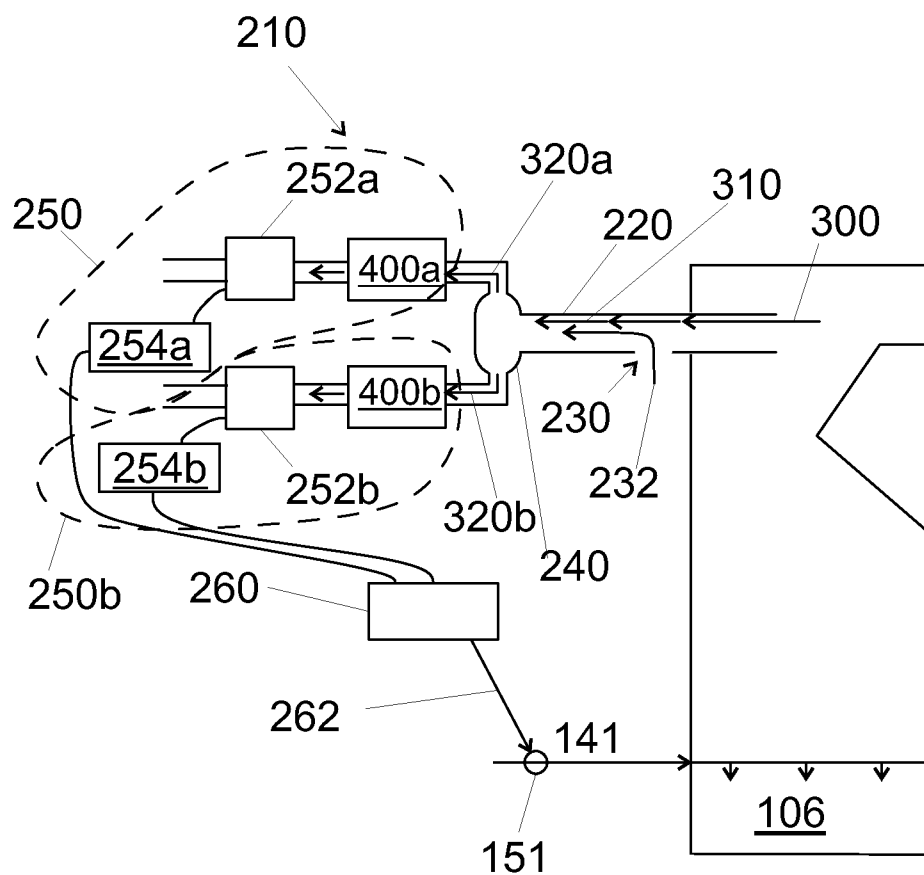


Fig. 5b

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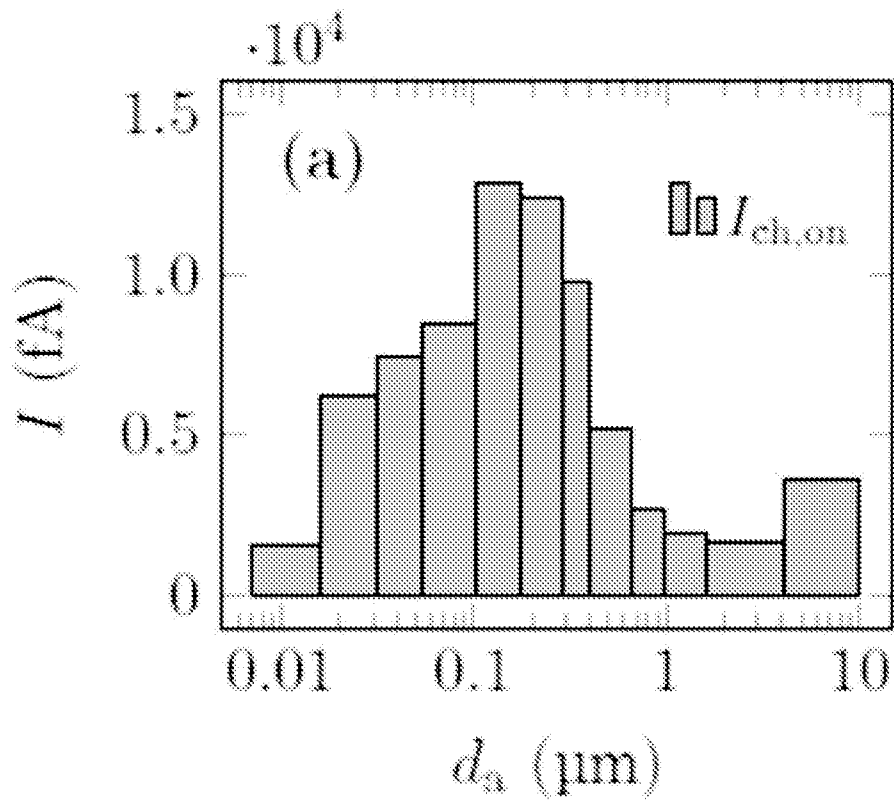


Fig. 6a

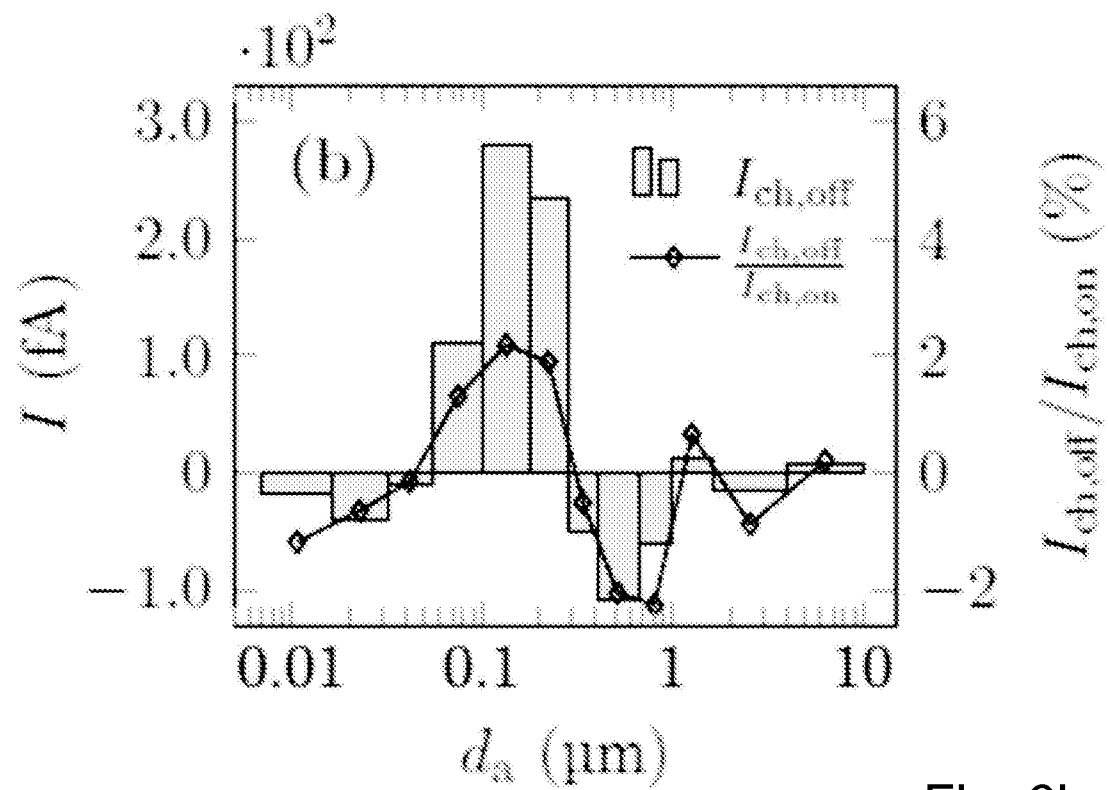


Fig. 6b

INTERNATIONAL SEARCH REPORT

International application No

PCT/FI2014/050364

A. CLASSIFICATION OF SUBJECT MATTER

INV. F23N5/00 G01N27/62
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)

F23N G01N

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 959 010 A (BURTSCHER HEINZ [CH] ET AL) 25 September 1990 (1990-09-25)	1-10, 13-16, 20-23
A	column 2, line 14 - column 6, line 55; claims 1,4,8,9; figure	17
A	----- EP 0 128 630 A1 (TNO [NL]) 19 December 1984 (1984-12-19) page 5, line 3 - page 6, line 4; figure	1,13
A	----- US 4 055 075 A (ALLAN THOMAS T ET AL) 25 October 1977 (1977-10-25) the whole document	1,13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

22 July 2014

Date of mailing of the international search report

04/08/2014

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2014/050364

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