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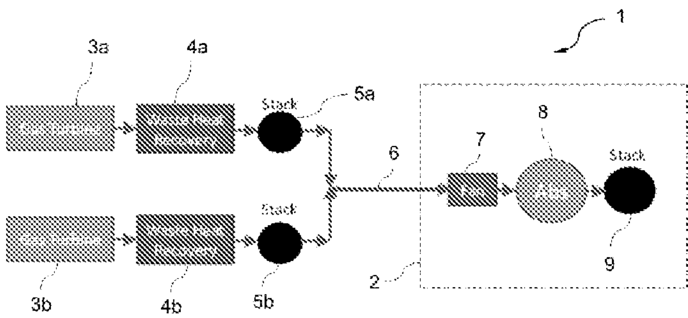
(54)	Title	**Plant and Method of Controlling an Industrial Plant having a Flue Gas Processing System**
(56)	References Cited:	EP 2722093 A1, TW 2013/37179 A, WO 2010/141346 A2, US 2014/144355 A1, US 2009/075219 A1
(57)	Abstract	

An industrial plant (1) having a flue gas processing system (2), the plant (1) comprising: a flue gas stack (5,5a-b) arranged to receive flue gases from an industrial process (3,4), the stack having a discharge outlet (5') open to the atmosphere;
a suction line (6) connected to the flue gas stack (5,5a-b) and to a flue gas processing unit (8);
a fan (7) operatively arranged in the suction line (6); a sensor (12,12');
and a controller (11,11a-b) arranged to regulate the flow through the suction line (6) based on a measured signal (13,13') from the sensor (12,12').
There is also provided a method of controlling the operation of an industrial plant (1) having a flue gas processing system (2).



Plant and Method of Controlling an Industrial Plant having a Flue Gas Processing System

<u>Field</u>

The present disclosure relates to an industrial plant having a flue gas processing system and method of controlling the operation of such a plant, in particular for control of flue gas handling from the industrial plant into a flue gas treatment plant.

<u>Background</u>

In industrial plants, such as power plants or other types of plants producing flue gases, there is often a need to process the flue gases before discharge to the environment. This may, for example, be the case if it is required or desirable to clean or remove parts from the flue gas stream. One relevant example in this respect is CO2 capture from flue gases, in order to reduce CO2 emissions.

EP2722093 discloses an oxy fuel boiler system with a CO_2 capture unit. The boiler is connected to a stack via a flue gas conditioning system, a condenser, a compressor and a CO_2 separator. A fan is provided to draw flue gas from the boiler into the flue gas conditioning system.

<u>Summary</u>

In an embodiment, there is provided an industrial plant having a flue gas processing system. The plant comprises a flue gas stack arranged to receive flue gases from an industrial process, the stack having a discharge outlet open to the atmosphere; a suction line connected to the flue gas stack and to a flue gas processing unit; a fan operatively arranged in the suction line; a sensor; and a controller arranged to regulate the flow through the suction line based on a measured signal from the sensor.

In an embodiment, there is provided a method of controlling the operation of an industrial plant having a flue gas processing system, the method comprising the steps: operating an industrial process to produce a flue gas; flowing the flue gas to a flue gas processing unit via a suction line which is fluidly connected to a flue gas stack having a discharge outlet open to the atmosphere; operating a controller to control the flow rate of flue gas through the suction line in response to a measured signal.

The detailed description below and the appended claims outline further embodiments.

Brief descriptions of the drawings

The above objects, as well as additional objects, features and advantages of the present disclosure, will be more fully appreciated by reference to the following illustrative and non-limiting detailed description of example embodiments of the present disclosure, when taken in conjunction with the accompanying drawings.

Figure 1 shows a schematic illustration of an industrial plant having a flue gas processing system.

Figure 2 shows a schematic illustration of an industrial plant having a flue gas processing system.

Figure 3 shows a schematic illustration of an industrial plant having a flue gas processing system.

Figure 4 shows a schematic illustration of an industrial plant having a flue gas processing system.

Detailed description

Figures 1 and 2 illustrate, in a schematic manner, an industrial plant 1 having a flue gas processing system 2. The flue gas processing system 2 is configured to receive flue gases from an industrial process, here illustrated as a gas turbine 3,3a-b. The gas turbine 3,3a-b produces flue gases (exhaust) which are optionally led through a waste heat recovery heat exchanger 4,4a-b and subsequently to a flue gas stack 5,5a-b. As can be seen from Figs 1 and 2, in Fig. 1 two industrial processes are illustrated in the form of two gas turbines 3a-b, while in Fig. 2 only one gas turbine 3 is illustrated. The plant 1 may, alternatively, have more than two industrial processes, or have two or more industrial processes of different types, such as different types of power plants producing flue gas.

In Fig. 1, the two gas turbines 3a,3b each have a dedicated flue gas stack 5a,5b, however alternatively two or more industrial processes, such as gas turbines 3a,3b, may be connected to a common flue gas stack 5,5a-b.

The flue gas stack 5,5a-b is arranged to receive flue gases from the industrial process(es), in this case from the gas turbine(s) 3,3a-b via the waste heat recovery heat exchanger 4,4a-b, and the stack 5,5a-b has a discharge outlet 5’ (see Fig. 2) open to the atmosphere.

A suction line 6 is connected to the flue gas stack 5,5a-b and to a flue gas processing unit 8, such that the suction line 6 can transfer flue gases from the stack 5,5a-b to the processing unit 8. The suction line 6 may be in the form of a duct, however may alternatively be formed by any suitable flow channel or pipe. A fan 7 is operatively arranged in the suction line 6 for generating a flow of flue gas to the processing unit 8. The fan 7 is controllable via a regulator 11 such as to control the flow rate through the suction line 6 and/or the pressure(s) in the suction line 6. In this manner, a flue gas flow rate out of the stack 5,5a-b through the suction line 6 can be generated and/or controlled. It may, for example, often be desirable to control this flow rate so that substantially all the flue gas from the industrial process is led to the flue gas processing unit 8 for treatment. This means that the flow at the stack outlet 5’ is substantially zero and that the stack is being “balanced”. (This is hereafter referred to as “stack balancing control”.) Alternatively, it may be an objective to maintain a supply to the processing unit 8 which matches its treatment capacity, in order to maximize utilization and/or to provide stable operating conditions for the flue gas processing unit 8.

The flue gas processing unit 8 may, for example be a CO2 removal plant.

In some applications, there may be a need for the flue gas stack 5,5a-b to remain permanently open to atmosphere, in order to prevent pressure build-up and disturbance of the industrial process. As the flue gas stack 5,5a-b, and thus also the suction line 6, then has an open connection to atmosphere via the stack 5,5a-b (specifically, via the discharge outlet 5’), the pressure levels in the stack 5,5a-b and the suction line 6 will be close to the atmospheric pressure, generally a few mbar below the atmospheric pressure to allow flow into and through the suction line 6. (1 atm = approximately 1.01325 bara).

As the pressure at the stack outlet 5’ may vary with rapid variations in wind velocities around the stack 5,5a-b and the plant 1, the pressure in the stack 5,5a-b may, however, in certain applications experience dynamic variations. This can be particularly prevalent in offshore plants, where wind velocities can be higher, and/or in areas which experience more gusts and variations in wind conditions around the plant 1. If using pressure levels in the stack 5,5a-b and/or suction line 6 as a control parameter in the system, for example to control the pressure levels or flow rates, one may experience poorer control performance due to such disturbances.

Referring to the embodiment illustrated in Fig. 2, a controller 11 is arranged to regulate the flow through the suction line 6 based on a signal 13 from a temperature sensor 12 and indicative of a temperature or temperature change in the suction line 6. In Fig. 2, the controller 11 is arranged to regulate an operating speed of the fan 7 based on the signal 13 indicative of a temperature or temperature change in the suction line 6. In this manner, a cooling effect and/or sudden temperature change which may follow if the stack 5,5a-b starts sucking in colder air with ambient temperature via the outlet 5’ can be rapidly identified, and appropriate control action can be taken. The flue gas will normally be more than 200 deg C, hence only small amount of atmospheric air entering the flue gas flowing into the suction line 6 will create significant temperature drops which are detectable via the temperature sensor 12. In this manner, the suction rate through the suction line 6 can be adjusted so that no ambient air is drawn into the flue gas processing unit 8 via the discharge outlet 5’. This control setup therefore allows the flow rate of flue gas provided to the processing unit 8 to be adjusted according to variations in the supply rate of flue gas coming from the industrial process (here: the gas turbine 3), and thereby reduce the risk that the processing unit 8 is unintentionally supplied with flue gas which is diluted with ambient air. When such a change in temperature is detected, the flowrate from the stack 5,5a-b into the suction line 6 and further to the processing unit 8 can thus be reduced until the temperature is re-normalized by not sucking in air via the outlet 5’.

The temperature sensor 12 is in Fig. 2 illustrated as being placed near an inlet part of the suction line 6. Alternatively, the temperature sensor 12 may be placed in the stack 5,5a-b, for example, in a position in the stack 5,5a-b which is close to the suction line 6 connection, or at another position in the stack 5,5a-b which would experience a temperature change if ambient air is drawn into the stack 5,5a-b.

Fig. 3 illustrates another embodiment, having several equivalent components as those illustrated in Figs 1 and 2, which are given the same reference numerals. In Fig. 3, the controllers 11a-b are operatively connected to variable flow restrictions 21a-b in the suction line 6. The flow restrictions 21a-b may, for example, be control dampers arranged in the suction line 6 and operable to vary the flow resistance and/or effective cross-sectional flow area in the suction line 6. Butterfly dampers are one type of common flow restrictions which may be suitable for this purpose.

The controller 11a can then be configured to, in response to a reduction in flue gas temperature measured by temperature sensor 12a, reduce the flow rate by adjusting the flow restriction 21a. Similarly, controller 11b can be configured to regulate the flue gas flow rate via flow restriction 21b.

A suitable pressure is maintained in the suction line 6 by the fan 7, such as to allow flow of flue gases to the processing unit(s) 8. The fan 7 may have its own control arrangement for this purpose, as indicated at 22, in order to maintain a desirable pressure in the suction line 6. The control arrangement 22 may, for example, be a standard feedback control loop regulating the speed of the fan 7 based on a reading from a pressure sensor 22a. Advantageously, the pressure sensor 22a providing the control signal for the control arrangement 22 is arranged in a manifold 6’ being part of the suction line 6. The flue gas flow control is then effectuated by adjusting the flow restrictions 21a-b, while the fan 7 is controlled to maintain the desired pressure in the suction line 6.

Fig. 3 illustrates two flue gas sources (here: gas turbines 3a-b) but as will be appreciated, the plant 1 may comprise a single industrial process making up a flue gas source, or more than two industrial processes making up flue gas sources.

Fig. 4 illustrates a similar plant 1 as shown in Fig. 3, but with two flue gas processing units 8. Each flue gas processing unit 8 may have its own fan 7. The embodiment in Fig. 4 makes up an alternative implementation to that shown in Fig. 3 and otherwise functions in the same way as described above. Optionally, yet further flue gas processing units 8 may be used. Advantageously, when having more than one industrial process and/or more than one flue gas processing unit 8, each industrial process and each flue gas processing unit 8 can be fluidly connected to the manifold 6’ such that the manifold 6’ receives and distributes all flue gas in the system.

In alternative embodiments, the temperature sensor(s) 12,12a-b described above may be a different type of sensor. Particularly, in any of the embodiments described herein the sensor(s) 12,12a-b may be (an) oxygen sensor(s) operable to measure an oxygen content of the gas stream passing by the sensor(s) 12,12a-b. A measured increase in oxygen content can be taken as an indication of influx of atmospheric air through the discharge outlet 5’. Control actions similarly as described above may be initiated based on such a sensor signal. Alternatively, in any of the embodiments described herein, the sensor(s) 12,12a-b may be combined temperature and oxygen sensor(s), whereby control action is taken by the controller 11 on the basis of both a temperature signal and an oxygen level signal. This can in some embodiments increase accuracy or otherwise improve control performance.

Alternatively, or additionally, the plant 1 may comprise a flow sensor 12' (such as one or more flowmeter(s)) arranged in the stack 5. The flow sensor 12' (see Fig. 2) produces a signal 13' indicative of a gas flow rate through (i.e. into and/or out of) the discharge outlet 5'. The signal 13' can be provided to the controller 11 and used to generate control actions similarly as described above. In any of the embodiments described herein, the plant 1 can use a flow sensor 12' and flow sensor signal 13' in conjunction with a signal from the sensor(s) 12,12a-b or independently, i.e. without the sensor(s) 12,12a-b.

In any of the embodiments described herein, the controller 11 can be configured to regulate the flow through the suction line 6 such that the flow rate through the discharge outlet 5' remains at zero, close to zero, or with a positive outflow of gas from the stack 5 through the discharge outlet 5'. In this manner, an inflow of atmospheric air through the discharge outlet 5' and into the processing unit 8 can be avoided, or at least the risk thereof can be reduced. Alternatively, in some cases, it may be acceptable that some atmospheric air reaches the processing unit 8 but it is more important to avoid untreated flue gas to exit to atmosphere. In such a case, the controller 11 can be configured to regulate the flow through the suction line 6 such that the flow rate through the discharge outlet 5' remains at or close to zero, or with some inflow of gas from the stack 5 through the discharge outlet 5'.

The sensor(s) used in the plant 1 may be of any suitable type for measuring temperature, oxygen and/or flow. In one embodiment, the temperature sensor may be an IR-camera operable to generate an image or heat map measuring the temperature distribution of gas at a location in the stack 5 or the suction line 6. The image or heat map may, for example, be generated on an outside surface of the stack, and thereby reflect a change in gas temperature on the inside of the stack. A control signal 13,13' can then be calculated based on the image, for example by generating a parameter for example based on the lowest temperature visible in the image or map, or based on a calculated average temperature across defined point in (or the entire) image or map.

According to embodiments described herein, an open flue gas suction system is provided with improved handling of incoming flue gas from a stack, and with lower risk of pulling in ambient air, such as to provide a robust control that can handle wind gust and high wind velocities around the stack creating variation in the outside air pressure at the stack outlet.

CLAIMS

1. An industrial plant (1) having a flue gas processing system (2), the plant (1) comprising:
   a flue gas stack (5,5a-b) arranged to receive flue gases from an industrial process (3,4), the stack having a discharge outlet (5’) open to the atmosphere; and
   a sensor (12, 12’);
   characterised in that the plant (1) further comprises:
   a suction line (6) connected between the flue gas stack (5,5a-b) and a flue gas processing unit (8);
   a fan (7) operatively arranged in the suction line (6) and operable to draw flue gas from the flue gas stack (5, 5a-b) to the flue gas processing unit (8); and
   a controller (11,11a-b) arranged to regulate the flow through the suction line (6) based on a measured signal (13,13’) from the sensor (12,12’).

2. The industrial plant (1) of claim 1, wherein the measured signal (13,13’) from the sensor (12,12’) is indicative of:
   - a gas temperature or change in gas temperature in the flue gas stack (5,5a-b) or in the suction line (6),
   - an oxygen content or change in oxygen content in the flue gas stack (5,5a-b) or in the suction line (6), and/or
   - a gas flow rate through the discharge outlet (5’).

3. The industrial plant (1) of any preceding claim, wherein the controller (11) is arranged to regulate an operating speed of the fan (7) based on the signal (13,13’).

4. The industrial plant (1) of any preceding claim, wherein the controller (11) is arranged to regulate a flow restriction (21a-b) in the suction line (6) based on the signal (13,13’).

5. The industrial plant (1) of the preceding claim, wherein the flow restriction (21a-b) is arranged upstream the fan (7).

6. The industrial plant (1) of any preceding claim, wherein the fan (7) comprises a control arrangement (22) configured to control a pressure in the suction line (6) upstream the fan (7).

7. The industrial plant (1) of the preceding claim, wherein the control arrangement (22) is configured to maintain the pressure in the suction line (6) upstream the fan (7) at a substantially constant level.

8. The industrial plant (1) of any of the two preceding claims, wherein the control arrangement (22) is configured to control the pressure in the suction line (6) upstream the fan (7) and downstream the flow restriction (21a-b).

9. The industrial plant (1) of any preceding claim comprising a plurality of industrial processes (3,4), and wherein the suction line (6) comprises a flow restriction (21a-b) associated with each industrial process (3,4) and arranged to regulate the flue gas stream from the industrial process (3,4) independently of other industrial processes (3,4) in the plant (1).

10. The industrial plant (1) of any preceding claim, wherein the controller (11) is configured to maintain a zero gas flow rate through the discharge outlet (5') or to maintain a gas flow rate out of the stack (5) through the discharge outlet (5').

11. The industrial plant (1) of any preceding claim, wherein the flue gas processing unit (8) is a CO2 removal plant.

12. A method of controlling the operation of an industrial plant (1) having a flue gas processing system (2), the method comprising operating an industrial process (3,4) to produce a flue gas, characterised in that the method further comprises the steps of:
flowing the flue gas from a flue gas stack (5, 5a-b) to a flue gas processing unit (8) via a suction line (6),the flue gas stack (5,5a-b) having a discharge outlet (5') open to the atmosphere;
operating a controller (11,11a-b) to control the flow rate of flue gas through the suction line (6) in response to a measured signal (13,13').

13. The method of the preceding claim, wherein the measured signal (13,13’) is provided from a sensor (12,12’) and is indicative of:
    - a gas temperature or change in gas temperature in the flue gas stack (5,5a-b) or in the suction line (6),
    - an oxygen content or change in oxygen content in the flue gas stack (5,5a-b) or in the suction line (6), and/or
    - a gas flow rate through the discharge outlet (5’).

14. The method of any of claims 12-13, wherein the control the flow rate of flue gas through the suction line (6) is carried out with a fan (7) arranged in the suction line (6) and/or with a flow restriction (21a-b) in the suction line (6).

15. The method of any of claims 12-14, wherein the method comprises operating the controller (11) to maintain a zero gas flow rate through the discharge outlet (5’) or to maintain a gas flow rate out of the stack (5) through the discharge outlet (5’).

Patentkrav

1. Et industrianlegg (1) som har et røykgassprosesseringssystem (2), hvor anlegget (1) omfatter:

en røykgass stabel (5,5a-b) anordnet for å motta røykgasser fra en industriell prosess (3,4), hvor stabelen har et tømmeutløp (5') åpen til atmosfæren; og en sensor (12, 12');

karakterisert ved at anlegget (1) videre omfatter:

en sugeledning (6) forbunnet mellom røykgass stabelen (5,5a-b) og en røykgass prosesseringsenhet (8);

en vifte (7) operativt anordnet i sugeledningen (6) og operativ til å trekke røykgass fra røykgass stabelen (5, 5a-b) til røykgassprosesseringsenheten (8); og

en kontroller (11,11a-b) anordnet for å regulere strømningen gjennom suge-ledningen (6) basert på et målt signal (13,13') fra sensoren (12,12').

2. Industrianlegget (1) ifølge krav 1, hvor det målte signalet (13,13') fra sensoren (12,12') er indikativt for:

- en gasstemperatur eller endring i gasstemperatur i røykgass stabelen (5,5a-b) eller i sugeledningen (6),
- et oksygeninnhold eller endring i oksygeninnhold i røykgass stabelen (5,5a-b) eller i sugeledningen (6), og/eller
- en gass-strømningshastighet gjennom tømmeutløpet (5').

3. Industrianlegget (1) ifølge et hvilket som helst foregående krav, hvor kontrolleren (11) er anordnet for å regulere en driftshastighet av viften (7) basert på signalet (13,13').

4. Industrianlegget (1) ifølge et hvilket som helst foregående krav, hvor kontrolleren (11) er anordnet for å regulere en strømningsbegrensning (21a-b) i sugeledningen (6) basert på signalet (13,13').

5. Industrianlegget (1) ifølge det foregående kravet, hvor strømningsbegrensningen (21a-b) er anordnet oppstrøms av viften (7).

6. Industrianlegget (1) ifølge et hvilket som helst foregående krav, hvor viften (7) omfatter et kontrollarrangement (22) konfigurert til å kontrollere et trykk i sugeledningen (6) oppstrøms av viften (7).

7. Industrianlegget (1) ifølge det foregående kravet, hvor kontrollarrangementet (22) er konfigurert til å opprettholde trykket i sugeledningen (6) oppstrøms av viften (7) på et hovedsakelig konstant nivå.

8. Industrianlegget (1) ifølge et hvilket som helst av de to foregående kravene, hvor kontrollarrangementet (22) er konfigurert til å kontrollere trykket i sugeledningen (6) oppstrøms av viften (7) og nedstrøms av strømningsbegrensningen (21a-b).

9. Industrianlegget (1) ifølge et hvilket som helst foregående krav, som omfatter en flerhet av industrielle prosesser (3,4), og hvor sugeledningen (6) omfatter en strømningsbegrensning (21a- b) assosiert med hver industrielle prosess (3,4) og anordnet for å regulere røykgass-strømmen fra den industrielle prosessen (3,4) uavhengig av andre industrielle prosesser (3,4) i anlegget (1).

10. Industrianlegget (1) ifølge et hvilket som helst foregående krav, hvor kontrolleren (11) er konfigurert til å opprettholde en null gass-strømningshastighet gjennom tømmeutløpet (5') eller til å opprettholde en gass-strømningshastighet ut av stabelen (5) gjennom tømmeutløpet (5').

11. Industrianlegget (1) ifølge et hvilket som helst foregående krav, hvor røykgassprosesseringsenheten (8) er et CO_2-fjerningsanlegg.

12. En fremgangsmåte for å kontrollere driften av et industrianlegg (1) som har et røykgassprosesseringssystem (2), hvor fremgangsmåten omfatter å drifte en industriell prosess (3,4) for å produsere en røykgass, **karakterisert ved at** fremgangsmåten videre omfatter trinnene med å:

strømme røykgassen fra en røykgass stabel (5, 5a-b) til en røykgass prosesseringsenhet (8) via en sugeledning (6), hvor røykgass stabelen (5,5a-b) har et tømmeutløp (5') åpen til atmosfæren;

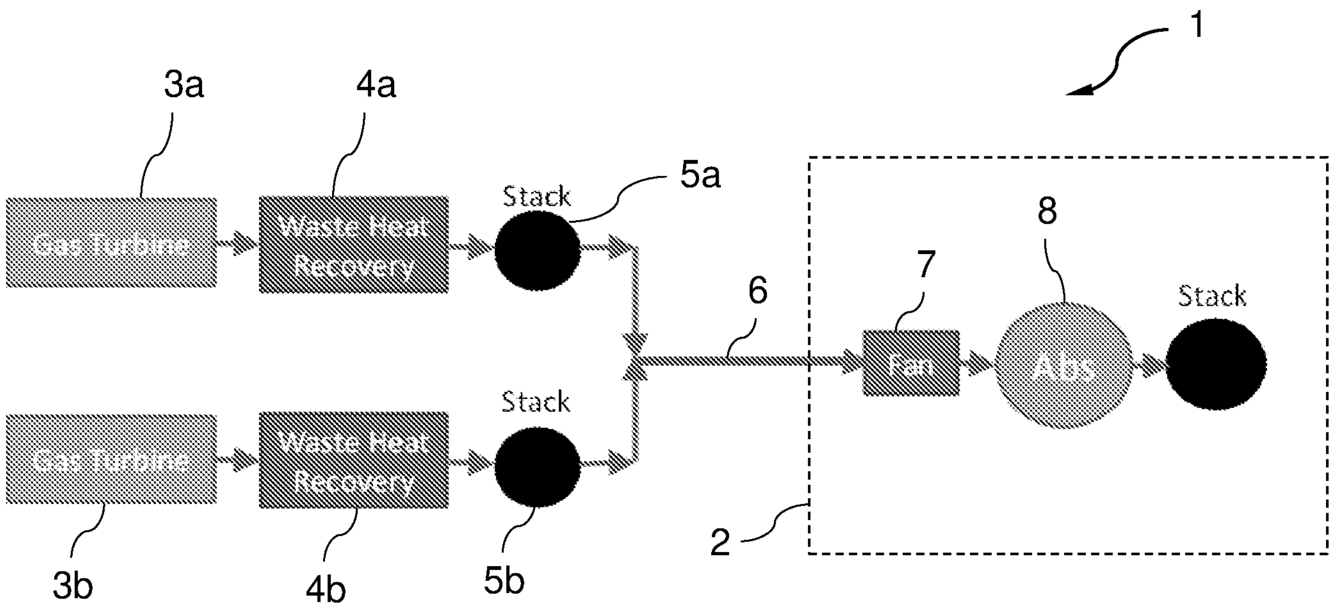
å drifte en kontroller (11,11a-b) til å kontrollere strømningshastigheten av røykgass gjennom sugeledningen (6) som respons på et målt signal (13,13').

13. Fremgangsmåten ifølge det foregående kravet, hvor det målte signalet (13,13') blir tilveiebragt fra en sensor (12,12') og er indikativt for:

- en gasstemperatur eller endring i gasstemperatur i røykgass stabelen (5,5a-b) eller i sugeledningen (6),
- et oksygeninnhold eller endring i oksygeninnhold i røykgass stabelen (5,5a-b) eller i sugeledningen (6), og/eller
- en gass-strømningshastighet gjennom tømmeutløpet (5').

14. Fremgangsmåten ifølge hvilket som helst av kravene 12-13, hvor kontrollen strømningshastigheten av røykgass gjennom sugeledningen (6) blir utført med en vifte (7) anordnet i sugeledningen (6) og/eller med en strømningsbegrensning (21a-b) i sugeledningen (6).

15. Fremgangsmåten ifølge hvilket som helst av kravene 12-14, hvor fremgangsmåten omfatter å drifte kontrolleren (11) til å opprettholde en null gass-strømningshastighet gjennom tømmeutløpet (5') eller til å opprettholde en gass-strømningshastighet ut av stabelen (5) gjennom tømmeutløpet (5').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4b
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Fig. 1

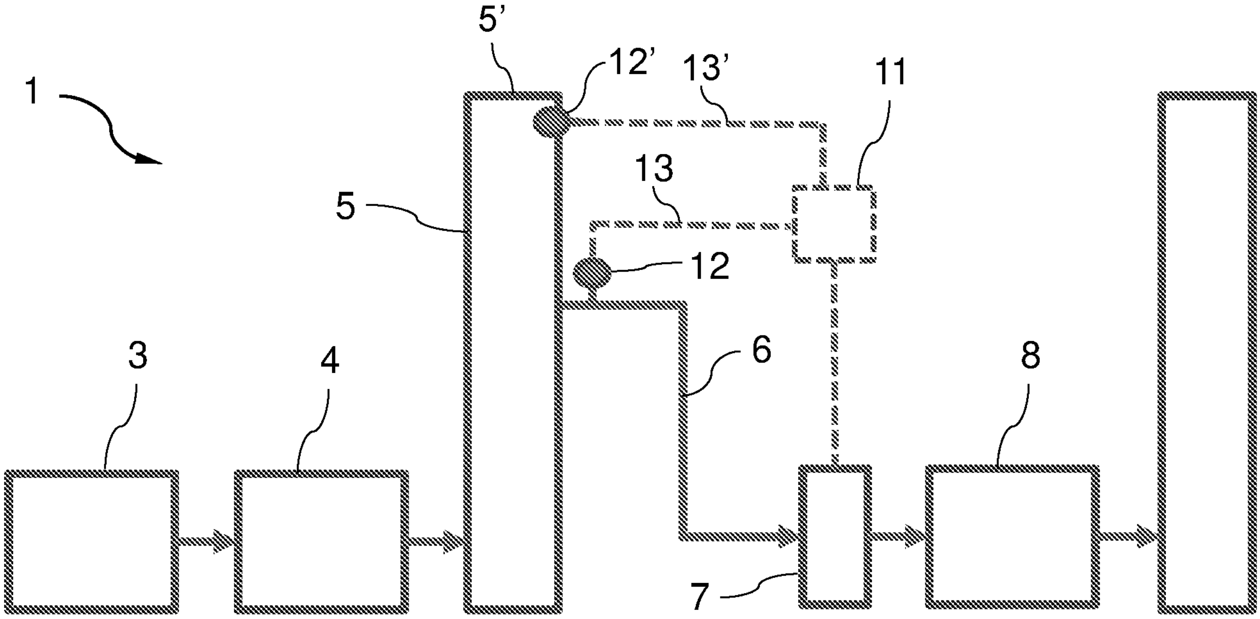
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Fig. 2

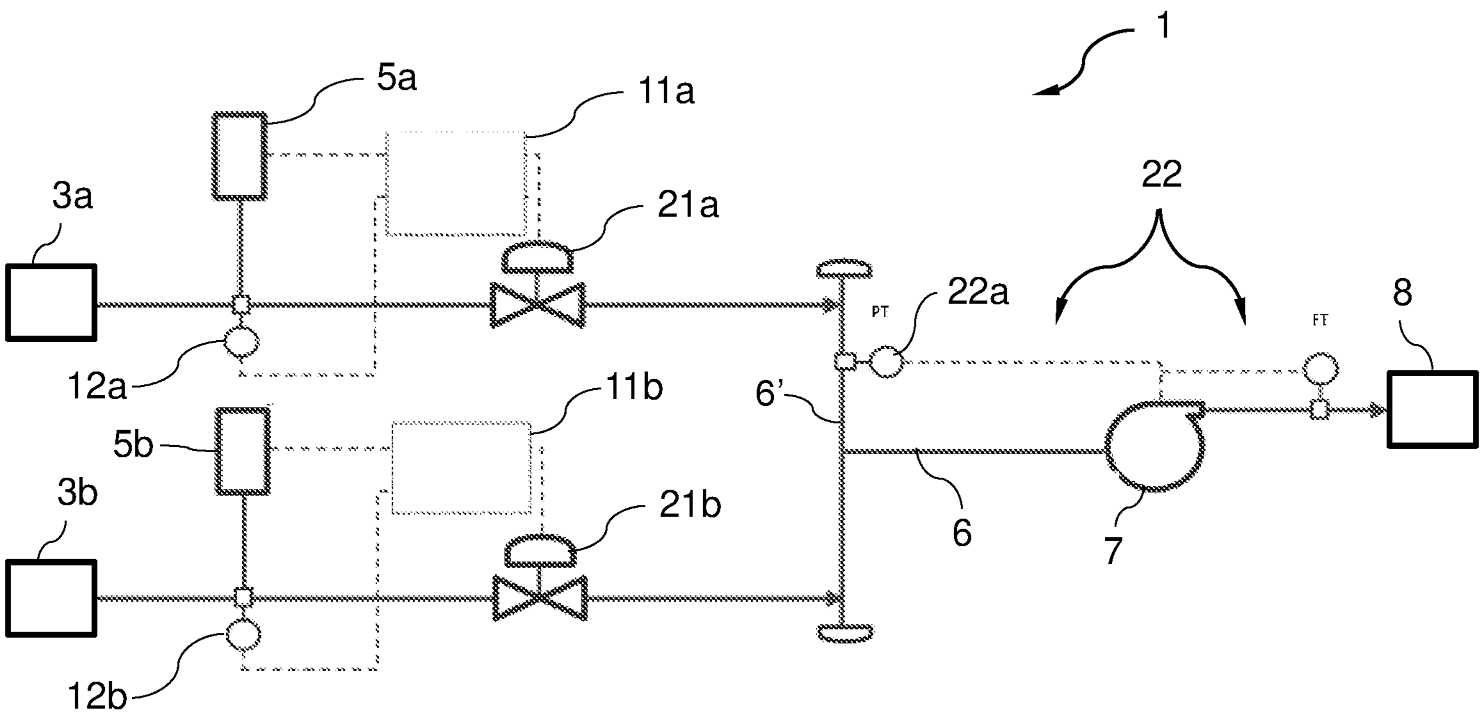
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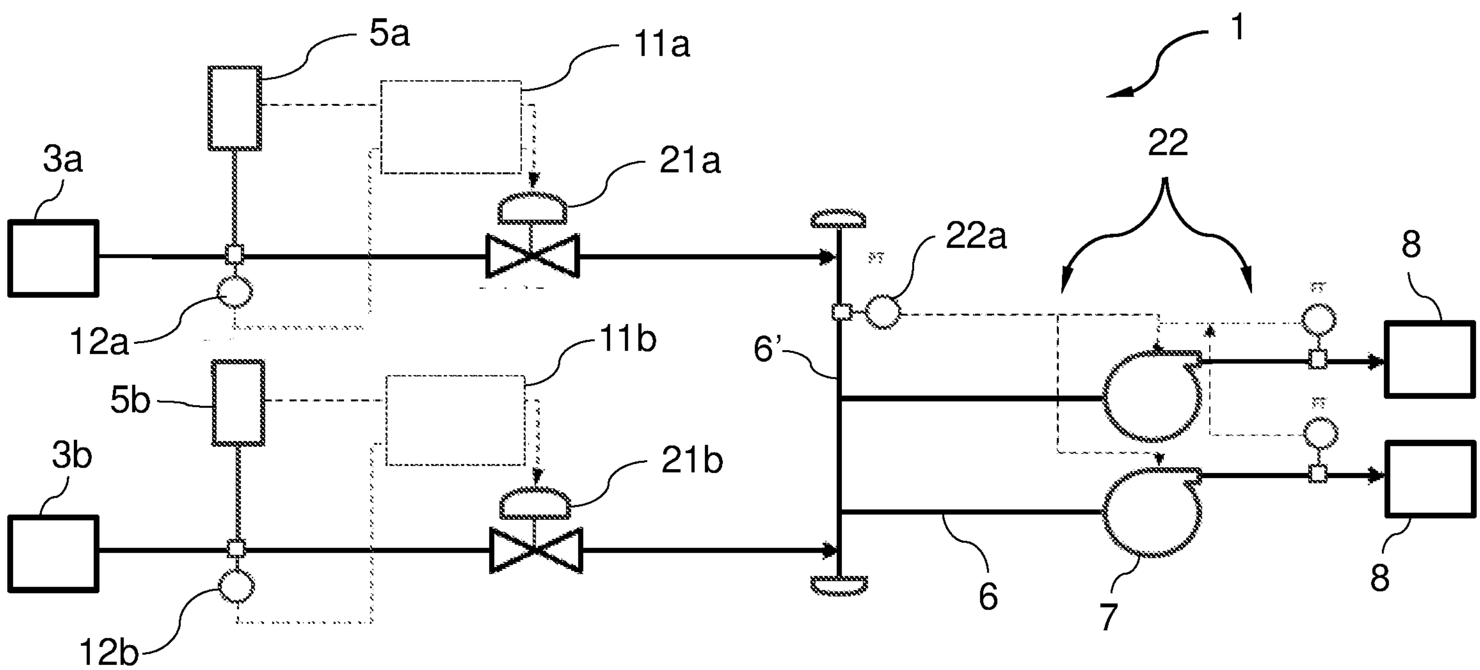
Fig. 3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12b

Fig. 4