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(54) FLAME ACQUISITION SYSTEM AND METHOD OF RETROFITTING A COMBUSTION APPLIANCE WITH THE SYSTEM

(57) Flame acquisition system (1) for a combustion appliance (2) for combusting a combustion gas, in particular for a gas boiler, the system (1) comprising at least a flame sensor (4) to acquire the presence of a flame and for generating a flame signal, the flame sensor (4) being connectable to a control system (3) of the combustion appliance (2) for controlling the combustion appliance (2), and a converter (5) connectable to the flame sensor (4) to convert the flame signal generated by the flame sensor (4) into an electrical current used by the control system (3) for controlling the combustion appliance (2).

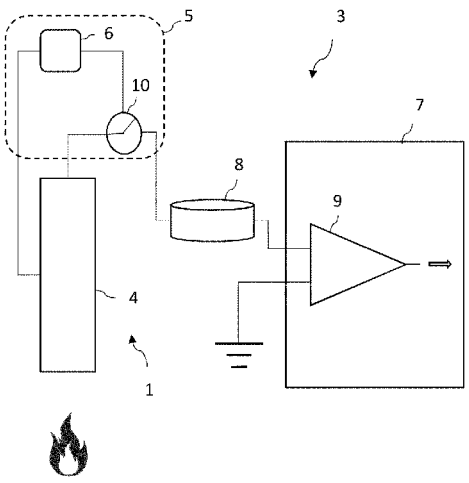

FIG. 3A

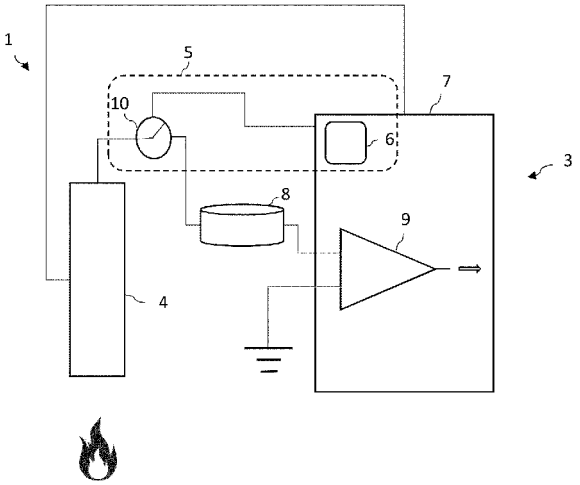

FIG. 3B

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Description

[0001] The invention relates to a flame acquisition system for a combustion appliance. Additionally, the invention relates to a combustion appliance comprising said flame acquisition system and the use of the flame acquisition system to convert a hydrocarbon gas boiler into a gas boiler for the combustion of pure hydrogen. Also, the invention relates to a method for retrofitting a combustion appliance.

[0002] The emission of carbon dioxide is one of the most relevant factors contributing to the pollution in environment. Since the contribution from the building sector is continuously increasing in the last decades, there is the need to reduce CO_2 emissions from this sector. Heating of spaces and heating of water are the two major causes of energy consumption and CO_2 emission from the building sector. Inefficient boilers and carbon-intensive power can further worsen this problem.

[0003] Nowadays, the majority of boilers are gas boilers and are designed for natural gas, using hydrocarbons as fuel gas. Gas boilers combust gas fuel to heat water for domestic use and/or central heating systems in buildings. The market is looking into cleaner alternatives for combusting natural gas. One of these alternatives is combusting pure hydrogen. It is noted that gas boilers combusting pure hydrogen (i.e. hydrogen boiler) are boilers to which fuel gas is supplied that comprises at least 90 mol% hydrogen. Currently, there are natural gas (or propane) boilers on the market which are only suitable to combust up to 20% hydrogen into the gas blend (according to the specifications). In other words, current boilers on the market are not directly suitable for combustion of hydrogen and important modifications are needed to possibly convert a standard natural gas boiler into a hydrogen boiler. These modifications are in most cases expensive and time consuming.

[0004] For example, a ionization signal is used to acquire the flame in a hydrocarbon (i.e. natural gas) boiler. When combusting pure hydrogen, there is no (or really little) hydrocarbon and/or carbon content in the fresh gas mixture and/or the combustion gases. Therefore the conventional applied ionization signal cannot be used anymore in hydrogen combusting boiler. In alternative, UV signal and/or temperature signal can used to acquire the flame in a hydrogen boiler. Therefore, for converting a natural gas boiler into a hydrogen boiler, a control unit must be modified (e.g. reprogrammed and/or changed from the structural point of view) or a new control unit must be installed to acquire the flame signal (UV or temperature).

[0005] It is therefore desirable to obtain an easy and relatively low-cost conversion between a standard natural gas boiler and a hydrogen boiler for the flame acquisition. It is also desirable that the conversion is carried out reducing to the minimum the components to be added or modified.

[0006] Prior art fails to address the problem of converting a gas boiler combusting a type of fuel gas, such as natural gas, into a gas boiler combusting another type of fuel gas, such as pure hydrogen as regards the flame acquisition mechanism. Also, the prior art documents are not suitable to provide a solution that is cost effective and safe.

[0007] The object of the invention is therefore to provide a flame acquisition system that is easy to implement, cost-effective, safe, and that is effective in converting a natural gas boiler into a hydrogen boiler.

[0008] The object is solved by a flame acquisition system for a combustion appliance for combusting a combustion gas, in particular for a gas boiler, the system comprising at least a flame sensor to acquire the presence of a flame and for generating a flame signal, the flame sensor being connectable to a control system of the combustion appliance for controlling the combustion appliance, and

a converter connectable to the flame sensor to convert the flame signal generated by the flame sensor into an electrical current used by the control system for controlling the combustion appliance.

[0009] Thanks to the present flame acquisition system, it is possible to upgrade a combustion appliance such as a conventional hydrocarbon (i.e. natural gas) gas boiler into a hydrogen boiler in a very easy and safe way. Also, the conversion is cost effective since it can be realized without changing the measurement circuit of the controller of the starting gas boiler. Upgrading the combustion appliance can be intended that a conventional hydrocarbon gas boiler can be provided with an additional functionality of detecting the presence of a flame also in case the fuel gas does not comprise carbon containing compounds.

[0010] It is noted that the control system is configured to control the settings of the combustion appliance based on a determined current flowing in its circuit. Specifically, this is a control system for an appliance combusting hydrocarbon gas (i.e. natural gas or LPG (CxHy)) and the current is a so called ionization current that is usually generated by an ionization electrode. In particular, the present flame acquisition system is used to convert the flame signal coming from the flame sensor (adapted to acquire a flame generated by the combustion of a gas different form a hydrocarbon gas, for example pure hydrogen) into an electrical current or ionization signal that is an imitation of a ionization current that can be used by the control system to control the combustion appliance. In this way, the control system can maintain the functionality of controlling the settings of the appliance by receiving an electrical signal derived by the acquisition of a flame that is not necessarily generated by the combustion of hydrocarbon gas.

[0011] The combustion gas comprises air and fuel gas. A fan for supplying air to the air combustion can be controlled based on the electrical current or ionization signal. Alternatively or additionally, a gas valve for supplying the fuel gas to the combustion appliance can be controlled

based on the electrical current or ionization signal.

[0012] The control system can control the fan of the combustion appliance and/or the gas valve of the combustion appliance on the basis of the flame signal.

[0013] Examples of combustion appliances can include furnaces, water heaters, boilers, direct/in-direct make-up air heaters, power/jet burners and any other residential, commercial or industrial combustion appliance. In many cases, a combustion appliance can be modulated over a plurality of burner loads, with each burner load requiring a different flow rate of fuel gas resulting in a different heat output. At higher burner loads, more fuel gas and more air are typically provided to the burner, and at lower burner loads less fuel gas and less air are typically provided to the burner.

[0014] As explained below more in detail the flame sensor is a sensor by means of which at least the presence of a flame is detected. However, the flame sensor can be configured to acquire further information by means of which it is possible to determine the air to fuel gas ratio of a mixture supplied to a burner of the combustion appliance and/or the fuel gas flow rate supplied to the burner.

[0015] In one example, the converter can comprise a flame acquisition control unit and a switch element located between the control system and the flame sensor, wherein the flame acquisition control unit is connected to the flame sensor and the switch element and is configured to trigger the switch element based on the acquisition of the flame by the flame sensor, thereby causing an electrical current to flow from the flame sensor to the control system.

[0016] The flame acquisition control unit can monitor the flame sensor to determine the acquisition of a corresponding flame signal and can control the switch element based on the acquisition of the flame signal. In particular, the switch element connects the flame sensor to the control system of the combustion appliance In a first configuration, the switch element is in an open position, meaning that no electrical current flows into the control system coming from the flame sensor. In a second configuration, the switch element is in a close position, meaning that there is an electrical current flowing into the control system. Once a flame signal is detected, the flame acquisition control unit triggers the switch element to pass from the first to the second configuration and causing an electrical current to flow into the control system. The flowing current is intended by the control system as an ionization current and the combustion appliance can be controlled accordingly.

[0017] In examples, the flame sensor can be at least one of:

- an optical sensor, in particular a UV sensor or IR sensor;
- a temperature sensor, in particular a thermocouple, located in a burner of the gas boiler (2);
- a temperature sensor, in particular a thermocouple, located in a combustion chamber of the gas boiler (2);
- a dynamic pressure sensor;
- a sound or vibration sensor; and
- a catalytic sensor.

[0018] All these sensors, properly located in the combustion appliance, can acquire the presence of the flame in the burner using different physical principles. Based on the characteristics of these sensors, it is possible to combine more of them for improving the performance of the flame acquisition system. In particular, it is possible by using for example the UV sensor to determine the amount of fuel gas and/or the air to fuel gas ratio of the mixture supplied into the burner of the combustion appliance.

[0019] In another example, the flame acquisition control unit can be part of an appliance control unit to control the combustion appliance or the flame acquisition control unit can be separated from said appliance control unit. In other words, the flame acquisition control unit can be integrated in the control board or printed circuit board of the combustion appliance. This can be the appliance control unit present to manage and control the functionalities of the appliance. In this way, the control board already installed in the original combustion appliance can be also used to control the flame acquisition system in the upgraded appliance. Alternatively, the flame acquisition control unit is not integrated in the control board or printed circuit board of the combustion appliance and is separated from that. In particular, the flame acquisition control unit can be part of another printed circuit board.

[0020] In a further example, the flame sensor can be suitable for detecting a flame generated by the combustion of hydrogen gas. In this case, it is intended a fuel gas that comprises at least 20 mol%, in particular at least 90 mol%, hydrogen.

[0021] In examples, the flame acquisition control unit can be configured to set an operating mode of the combustion appliance based on a flame acquisition signal acquired by the flame sensor. In this way, the appliance settings can be adapted to the presence of a combustion gas different from hydrocarbon gas, such as hydrogen gas. In many cases, a combustion appliance can be modulated over a plurality of burner loads, with each burner load requiring a different flow rate of fuel resulting in a different heat output. At higher burner loads, more fuel and more air are typically provided to the burner, and at lower burner loads less fuel and less air are typically provided to the burner. Accordingly, the acquisition of a flame generated by the combustion of a hydrogen gas can determine for example a reconfiguration of the modulation modes.

[0022] According to one aspect of the invention, a combustion appliance, in particular a gas boiler, is provided, the combustion appliance comprising an inventive flame acquisition system. Examples of combustion appliances can include furnaces, water heaters, boilers, direct/in-

direct make-up air heaters, power/jet burners and any other residential, commercial or industrial combustion appliance.

[0023] In particular, the appliance can be selectively configured to combust a gas comprising carbon containing compounds and/or a gas without carbon containing compounds. The present flame acquisition system can be used to acquire the flame generated by a combustion gas without carbon containing compounds, such as hydrogen.

[0024] In one example, the combustion appliance comprises a burner and a combustion chamber and the flame sensor can be located in the burner and/or the combustion chamber. In addition or alternatively, the combustion appliance can comprise a gas valve to control the inflow of the combustion gas, wherein the gas valve can be controlled electronically or pneumatically.

[0025] In case the gas valve is controlled electronically, a flame acquisition signal acquired by the flame sensor can be used to control an excess air factor. This is possible if the flame acquisition signal comprises information by means of which the fuel gas supplied to a burner of the combustion appliance can be determined. By adapting the gas valve position the air to fuel gas ratio of the mixture can be set

[0026] As mentioned above, the combustion appliance can be originally designed for the combustion of hydrocarbons. However, in an example, the combustion appliance including the present flame acquisition system can be used also when the combustion gas comprises at least 90 mol% hydrogen.

[0027] In another aspect of the invention, the use of the inventive flame acquisition system for converting a hydrocarbon gas boiler into a gas boiler for the combustion of pure hydrogen is provided. By using the present flame acquisition system, the gas boiler conversion can be easy to realize and can be safe and effective for a the operation of a hydrogen boiler.

[0028] In a further aspect of the invention, a method for retrofitting a combustion appliance, in particular a gas boiler is provided. The combustion appliance is designed for combusting a gas mixture including hydrocarbons and the method comprises:

installing the inventive flame acquisition system in the combustion appliance; and
updating the setting parameters of the combustion appliance for the combustion of pure hydrogen.

[0029] In one example, installing the flame acquisition system comprises connecting the flame sensor and the converter to the control system of the combustion appliance Also, updating the setting parameters can occur automatically by detecting a flame acquisition signal acquired by the flame sensor.

[0030] In the figures, the subject-matter of the invention is schematically shown, wherein identical or similarly acting elements are usually provided with the same reference signs.

Figure 1 shows a schematic representation of a flame acquisition system connected to the control system of a combustion appliance according to an example.

Figure 2 shows a schematic representation of a control system of a combustion appliance combusting carbon containing compounds.

Figures 3A-B show a schematic representation of a flame acquisition system connected to the control system according to two different examples.

Figure 4 shows a flow chart of a method for retrofitting a combustion appliance according to an example.

[0031] With reference to Figure 1, a flame acquisition system 1 is shown. The system 1 basically comprises a flame sensor 4 and a converter 5 connected to the flame sensor 4. The flame sensor 4 can be a UV sensor or a thermic sensor configured to acquire the presence of a flame generated at the burner of a combustion appliance 2 for starting the ignition process. The flame acquisition system 1 is connected to a control system 3 of the combustion appliance 2. The control system 3 is configured to control the settings of the combustion appliance 2 based on a determined current (ionization current) flowing in its circuit. The flame sensor 4 generates a flame signal upon detecting the flame and the converter 5 converts the flame signal generated by the flame sensor 4 into an electrical current (i.e. the ionization current) used by the control system to control the appliance 2.

[0032] For example, the combustion appliance 2 is a conventional hydrocarbon (i.e. natural gas or LPG (CxHy)) gas boiler. Therefore, the control system 3 is a ionization circuit for receiving a ionization current generated by an ionization electrode. By using the flame acquisition system 1, i.e. by connecting the system 1 to the control system 3 of the appliance 2, it is possible to convert the conventional combustion appliance 2 into an appliance using pure hydrogen as fuel gas. In fact, the flame sensor 4 is suitable to acquire a flame generated by the combustion of a fuel gas devoid of carbon containing compounds, such as pure hydrogen.

[0033] Figure 2 illustrates in detail the functioning of a control system 3 used in a conventional hydrocarbon gas boiler. The control system 3 comprise at least a ionization electrode 8 for detecting the flame generated by the combustion of a gas with carbon containing compounds. In particular, the ionization electrode 8 is used to acquire a ionization signal (ionization current) that the control system 3 can use to control the appliance 2. This current is present only if there is a flame and if the gas is a carbon

one e.g. natural gas or LPG (CxHy). Carbon containing compounds present in the gas reduces the resistance of the flame allowing the passage of an electrical current so that by measuring the electrical current it is known whether there is a flame and whether the combustion gas comprises carbon containing compounds. The control system 3 comprises an amplifier 9 for amplifying the ionization current and an appliance control unit 7 for managing the received ionization current and controlling the appliance 2 settings.

[0034] Figures 3A and 3B describe the application of the flame acquisition system 1 according to two examples. The converter 5 of the flame acquisition system 1 comprises a flame acquisition control unit 6 and a switch element 10, whereas in one example the flame acquisition control unit 6 is separated by the appliance control unit 7 of the control system 3 (figure 3A) and in the other example, the flame acquisition control unit 6 is part of the appliance control unit 7 of the control system 3 (figure 3B). It is noted that the flame acquisition control unit 6 is connected (directly or indirectly) to the switch element 10 and to the flame sensor 4. The switch element 10 is electrically connected to the ionization electrode 8 and is configured to open or to close the electrical connection with said electrode 8. When a flame is detected by the flame sensor 4, the flame acquisition control unit 6 detects a flame signal and the switch element 10 is triggered in a close position to allow the flowing of an electrical current in the control system 3. In other words, by triggering the switch element 10 in a close position, the flame signal is used as an electrical current passing through the ionization electrode 8. This electrical current (flame signal) is interpreted by the control system 3 as a ionization current and is used to control the combustion appliance 2 as if the ionization electrode 8 would have been detected a ionization signal generated by the ionization of a fuel gas with carbon containing compounds.

[0035] Figure 4 schematically illustrates the steps of a method 100 for retrofitting a combustion appliance 2. In particular, the method 100 can be used to convert a combustion appliance such as a natural gas boiler into a hydrogen boiler.

[0036] At step S101, the method 100 comprises the step of installing a flame acquisition system. For example, the flame sensor 4 and the converter 5 are connected to the control system 3. At step S102, the method 100 comprises updating the setting parameters of the combustion appliance 2 for the combustion of, in partiuclar pure, hydrogen.

[0037] It is noted that to control the functioning of a gas boiler, a control unit comprising a printed circuit board (PCB) is provided. Hydrogen combustion requires at least different parameter settings compared to natural gas combustion. Accordingly, the setting parameters of the combustion appliance must be updated when installing the present flame acquisition system 1, i.e. when converting the combustion appliance from a natural gas boiler to a hydrogen boiler. This can be done in different ways. In one example, the update can be performed by automatically detecting pure hydrogen in the gas mixture, for example using a hydrogen detector suitably located in the combustion appliance 2. Alternatively, the updating of parameters (or software) can be carried out by the installer operator or by replacing the control board (PCB).

Reference Signs

[0038]

1. Flame acquisition system
2. Gas boiler
3. Control system
4. Flame sensor
5. Converter
6. Flame acquisition control unit
7. Appliance control unit
8. Ionization electrode
9. Amplifier

Claims

1. Flame acquisition system (1) for a combustion appliance (2) for combusting a combustion gas, in particular for a gas boiler, the system (1) comprising:

at least one flame sensor (4) to acquire the presence of a flame and for generating a flame signal, the flame sensor (4) being connectable to a control system (3) of the combustion appliance (2) for controlling the combustion appliance (2); and

a converter (5) connectable to the flame sensor (4) to convert the flame signal generated by the flame sensor (4) into an electrical current used by the control system (3) for controlling the combustion appliance (2).

2. System (1) according to claim 1, **characterized in that** the converter (5) comprises a flame acquisition control unit (6) and a switch element (10) located between the control system (3) and the flame sensor (4), wherein the flame acquisition control unit (6) is connected to the flame sensor (4) and the switch element (10) and is configured to trigger the switch element (10) based on the acquisition of the flame by the flame sensor (4), thereby causing an electrical current to flow from the flame sensor (4) to the control system (3).

3. System (1) according to any one of claims 1 to 2, **characterized in that** the flame sensor (4) is at least one of:

an optical sensor, in particular a UV sensor and/or IR sensor;

a temperature sensor, in particular a thermocouple, located in a burner of the gas boiler (2);
a temperature sensor, in particular a thermocouple, located in a combustion chamber of the gas boiler (2);
a dynamic pressure sensor;
a sound or vibration sensor; and
a catalytic sensor.

4. System (1) of any one of claims 2 to 3, **characterized in that** the flame acquisition control unit (6) is part of an appliance control unit (7) to control the combustion appliance (2) or the flame acquisition control unit (6) is separated from said appliance control unit (7).

5. System (1) according to any one of claims 1 to 4, **characterized in that** the flame sensor (4) is suitable for detecting a flame generated by the combustion of hydrogen gas.

6. System (1) according to any one of claims 2 to 5, **characterized in that** the flame acquisition control unit (6) is configured to set an operating mode of the combustion appliance (2) based on a flame acquisition signal acquired by the flame sensor (4).

7. Combustion appliance (2) for combusting a combustion gas, in particular a gas boiler, comprising the flame acquisition system (1) of any one of claims 1 to 6.

8. Combustion appliance (2) according to claim 7, **characterized in that** the appliance (2) is selectively configured to combust a gas comprising carbon containing compounds and/or a gas without carbon containing compounds.

9. Combustion appliance (2) according to any one of claims 7 to 8, **characterized in that**

the combustion appliance (2) comprises a burner and a combustion chamber and the flame sensor (4) is located in the burner and/or the combustion chamber; and/or
the combustion appliance (2) comprises a gas valve to control the inflow of the combustion gas, wherein the gas valve can be controlled electronically or pneumatically.

10. Combustion appliance (2) according to claim 9, **characterized in that** in case the gas valve is controlled electronically, a flame acquisition signal acquired by the flame sensor (4) is used to control an excess air factor.

11. Combustion appliance (2) according to any one of claims 7 to 10, **characterized in that** the combustion gas comprises at least 90 mol% hydrogen.

12. Use of a flame acquisition system (1) according to any one of claims 1 to 6 for converting a hydrocarbon gas boiler into a gas boiler for the combustion of pure hydrogen.

13. Method (100) for retrofitting a combustion appliance (2), in particular a gas boiler, for combusting a gas mixture including hydrocarbons, the method comprising:

installing (S101) a flame acquisition system (1) according to any one of claims 1 to 6 in the combustion appliance (2); and
updating (S102) the setting parameters of the combustion appliance (2) for the combustion of pure hydrogen.

14. Method (100) according to claim 13, **characterized in that** installing (S101) the flame acquisition system (1) comprises connecting the flame sensor (4) and the converter (5) to the control system (3) of the combustion appliance (2).

15. Method (100) according to any one of claims 13 to 14, **characterized in that** updating (S102) the setting parameters occurs automatically by detecting a flame acquisition signal acquired by the flame sensor (4).

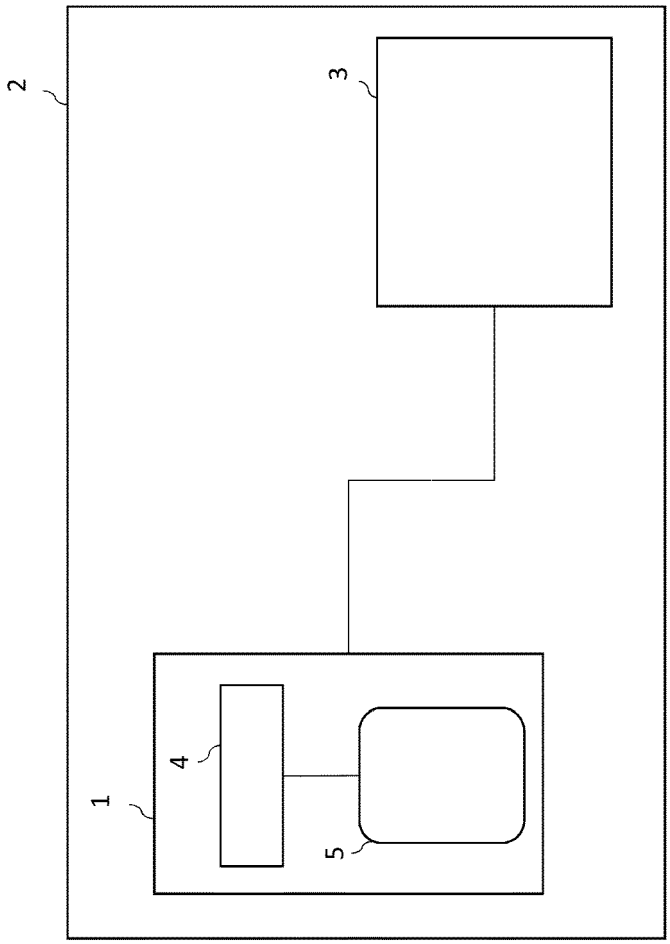

FIG. 1

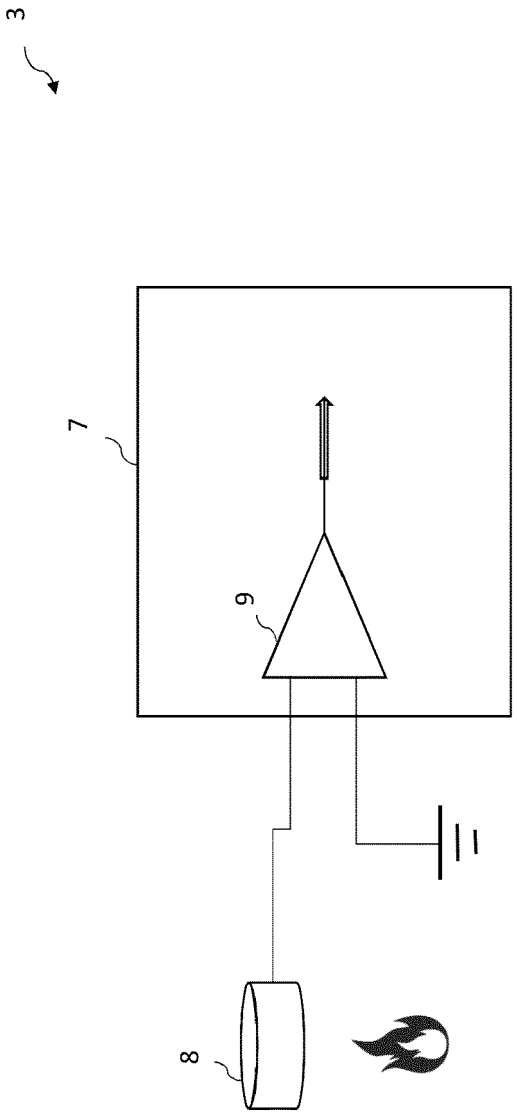

FIG. 2

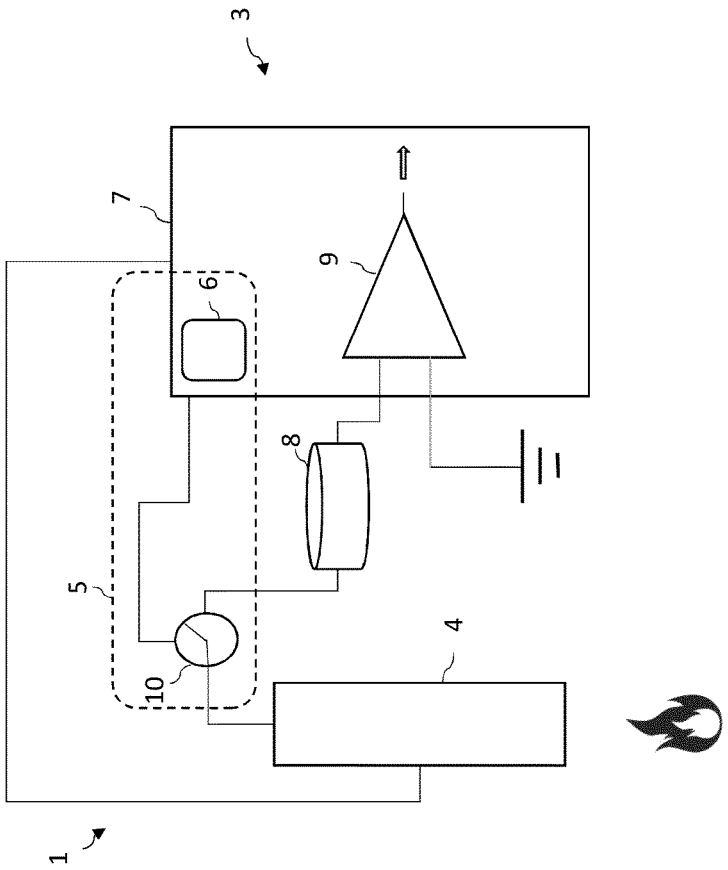

FIG. 3B

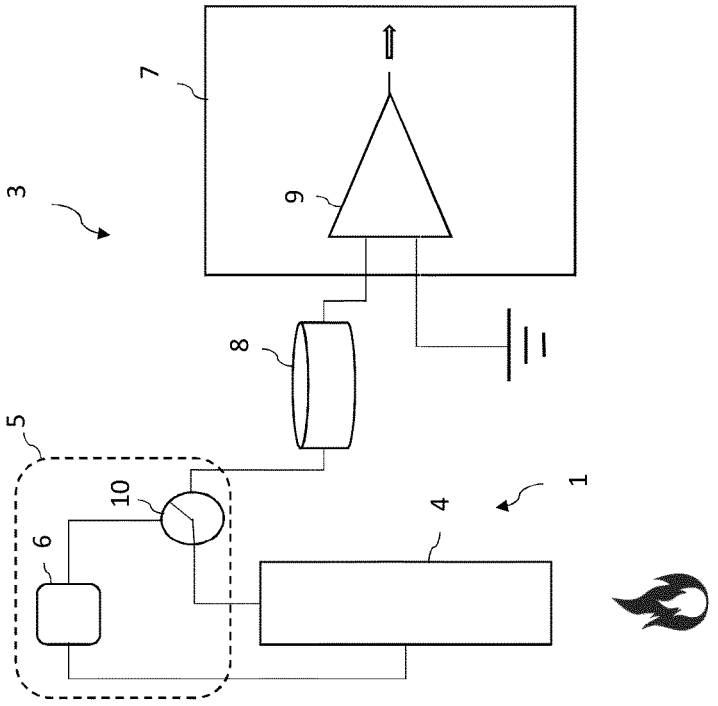

FIG. 3A

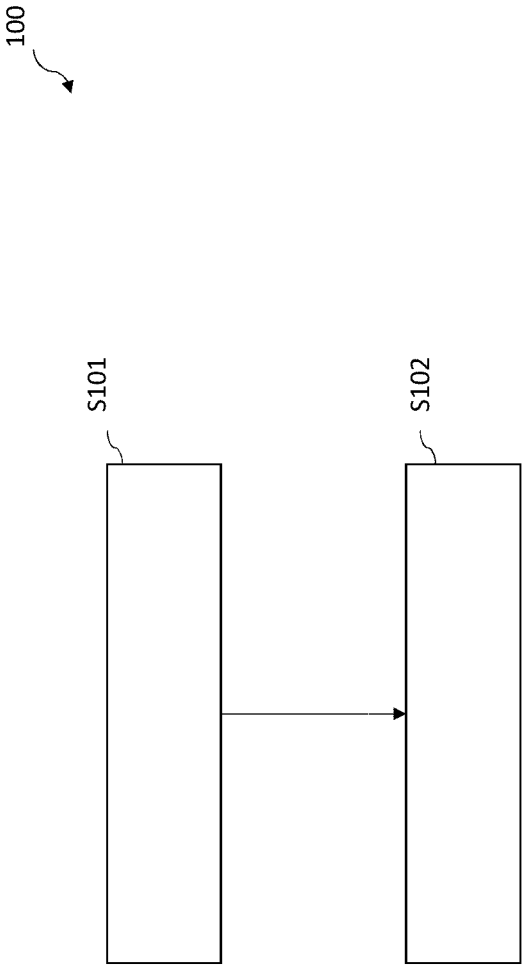

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 21 21 0342

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2021/165032 A1 (PITTWAY SARL [CH]) 26 August 2021 (2021-08-26) * pages 1-2 * * page 3, line 13 - page 7, line 26 * * figures 1-2 *	1-15	INV. F23N1/00 F23N5/08 F23N5/10 F23N5/16
X	JP 2010 071579 A (MITSUMI ELECTRIC CO) 2 April 2010 (2010-04-02) * figures 1-3 and the relating passages of the description *	1-9	
A	US 5 625 342 A (HALL GREGORY H [US] ET AL) 29 April 1997 (1997-04-29) * the whole document *	1-11	

TECHNICAL FIELDS SEARCHED (IPC)
F23N F23C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	9 May 2022	Rudolf, Andreas

CATEGORY OF CITED DOCUMENTS

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