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(71) Applicant: **bCheck NV**
1000 Brussel (BE)

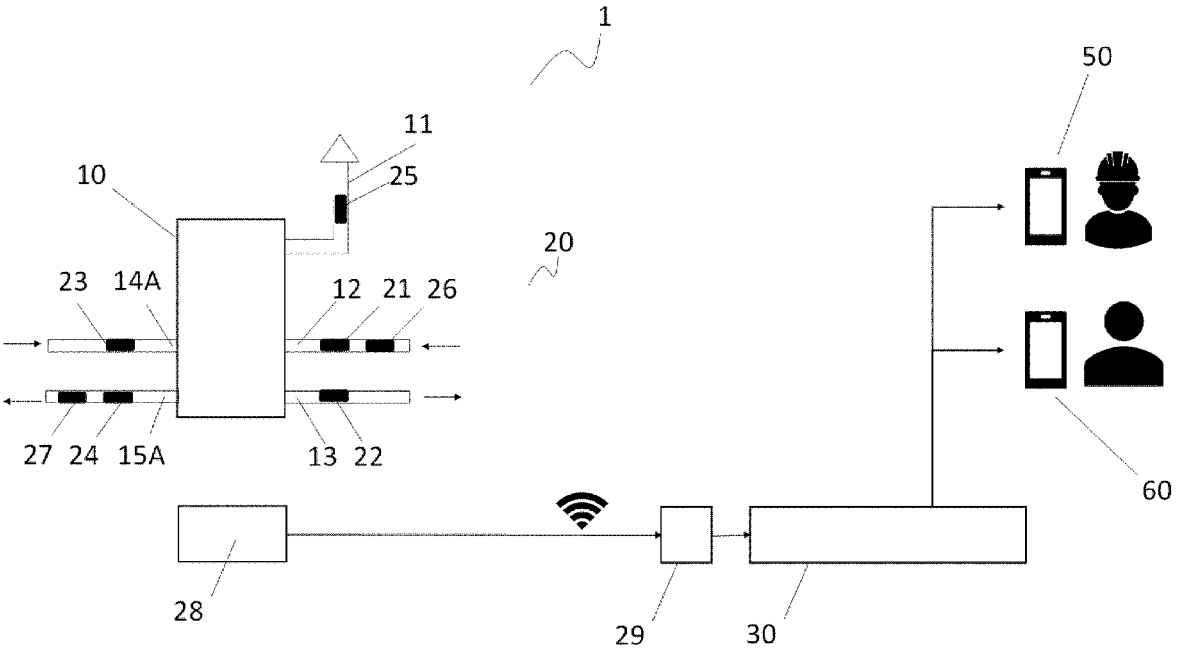
(72) Inventors:
- **DIRIX, Eric**
  3500 Hasselt (BE)
- **DIRIX, Pieter**
  3010 Leuven (BE)

(74) Representative: **IPLodge bv**
Technologielaan 9
3001 Heverlee (BE)

(54) BOILER PERFORMANCE MONITORING AND BREAKDOWN PREDICTION SYSTEM

(57) The invention relates to a system for monitoring boiler performance and for anticipating boiler breakdown, said system comprising: a device having a set of sensors, comprising at least one of a first pair of temperature sensors, comprising a first temperature sensor, for being applied to a central heating circuit (CHC) inlet and a second temperature sensor for a CHC outlet; a second pair of temperature sensors comprising a third temperature sensor, for being applied to a domestic hot water (DHW) inlet and a fourth temperature sensor for a DHW outlet; said device further comprising a fifth temperature sensor, for being applied to a flue gas outlet; an accelerometer for said CHC inlet; and a transmission module for sending data to a controller unit, and the controller unit configured to receive and analyse data for boiler component anomalies.

Fig.1



EP 3 663 671 A1

Description

Field of the Invention

[0001] The present invention relates to a system for monitoring the performance of and for predicting the breakdown of a boiler. The invention also relates to a corresponding method for use in same.

Background

[0002] Boilers play a central part in central heating systems for buildings and housing. In many countries, both heating and domestic hot water (DHW) are generated by use of the heat produced by one single boiler. In the Flemish part of Belgium, 67% of households produce DHW with a boiler connected to the central heating system (Eurostatenquete_samenvatting, retrieved from https://www.energiesparen.be/marktonderzoek on 25 September 2018).

[0003] In a traditional market, the owner of a house also owns the house boiler. In such markets, a homeowner whose boiler is in need of repair, will call upon the services of a boiler maintenance company and pay per delivered service, meaning that the majority of the offered services are *ad hoc.* Since repairing a boiler costs significantly less than installing a new one, many boiler owners prefer to have their boilers repaired until replacement has become the economically better option. As a result, a traditional boiler market will be characterized by the fact that a substantial group of boilers are quite old. In the specific case of Belgium, which in 2018 can be identified as such a traditional market, it is assumed that 30% of the installed boilers are older than 15 years. According to Belgian law, every boiler needs to be maintained on a regular basis (e.g., annually or biennially) by a registered and licensed professional. Most professionals are independent or SME's.

[0004] Boiler markets in West European countries are characterized by a variety of market models. An emerging trend is that third parties become the owner of a "fleet" of boilers and take control thereof, offering a range of services to their customers, being the individual boiler users.

In several countries, market consolidation is taking place with energy providers and insurance companies entering the boiler market in the role of such third-party owners, the former as part of a strategy of offering a total energy solution to customers, including maintenance of heating equipment in their homes.

[0005] Market entry by insurance providers can be seen as part of a bigger global shift from providing mere financial compensation for damage suffered, to preventing damage from happening in the first place. Exemplary of this shift is the development of systems by insurance related companies wherein sensors and devices such as cameras are installed in housing, which are connected to a smart phone or other personal device of the home owner. The sensors and cameras are capable of detecting motion, smoke and water leaks in an early stage, the presence of intruders, open windows or doors, and the like.

For entering the boiler market, third parties such as energy providers and insurance companies create their own local network of skilled technicians, such as electricians or plumbers, or collaborate with an already existing network.

One variant of this business model is based on the pooling of financial risks, wherein the customer pays a (typically monthly) subscription fee, covering maintenance and repair costs. In the most popular variant of this model, said subscription fee also covers the purchase and the installation of a boiler. As a consequence, the customer pays for a service, being the continuous use of a boiler, leaving all technical and maintenance worries to said third party, who purchased and installed the boiler at the customer's premises.

[0006] So far, boiler owners or boiler service providers are confronted with the problem that whenever boiler breakdown occurs, technical assistance will only be requested when the breakdown is detected. Often, boiler breakdown is only detected when residents notice a decrease in room temperature or DHW temperature. Valuable time for requesting assistance is thus wasted, the effects of which may go from merely troublesome to potentially detrimental for persons living in the building that is heated by the boiler, as well as goods stored therein. It is thereby to be noted that damage caused by a malfunctioning boiler can lead to compensation claims. Such events are not to be underestimated as the chance of boiler breakdown can be estimated at around 10%, meaning that each year about 10% of all installed boilers will suffer breakdown.

Furthermore, boiler service providers have noticed that customers who subscribe to a service via e.g. a monthly subscription fee, show the tendency to contact the service provider for minor issues which can easily be solved by the customer himself or which may even be the result of an action by the customer. For instance, the customer may have forgotten that he has opened a window somewhere in the building, subsequently notice a drop in room temperature and call for assistance of the service provider. Lacking the capacity to monitor the performance of the heating system of the customer from a distance, the provider will have no other choice than to schedule a technical intervention, typically on the site. Such unnecessary technical interventions will obviously affect the profitability of the service provider.

[0007] It is clear from the above that the capability of monitoring boiler performance allows service providers in providing customer assistance from a distance as well as keeping boiler owners informed about the state of their device. Furthermore, the capability of predicting and anticipating an imminent boiler breakdown allows boiler owners or service providers to request or provide assistance in time, thus avoiding the inconveniencies of boiler

breakdown or failure.

[0008] Devices and systems for monitoring boilers have been proposed.

[0009] CN 201177381 proposes a data acquisition device for a safe-operation assessment of a boiler as well as a monitoring system therefor. For this purpose, a variety of sensors are introduced into the boiler, the collected data of which are used to provide a better safety analysis and thus to decide whether the boiler is operating in a safe manner. The device does not provide an assessment of boiler performance and cannot predict the occurrence of an eventual upcoming boiler breakdown.

[0010] There is therefore a need for a boiler monitoring system for monitoring boiler performance for a functioning boiler and for predicting upcoming boiler failure. Furthermore, there is a need that such a boiler monitoring system is installable on a plurality of boilers which are already in operation, wherein the boilers of such a plurality may differ in age, brand, size, design and the like. In view of installing such a system on a plurality of boilers, and for economic reasons, there is furthermore a need to provide a boiler monitoring system which is composed of inexpensive components.

Summary of the Invention

[0011] According to an aspect of the present invention, there is provided a system for monitoring boiler performance and for anticipating boiler breakdown, said system comprising:

- a device having a set of sensors, comprising at least one of
    - ◦ a first pair of temperature sensors, comprising a first temperature sensor, for being applied to a central heating circuit (CHC) inlet of said boiler and a second temperature sensor, for being applied to a CHC outlet of said boiler;
    - ◦ a second pair of temperature sensors comprising a third temperature sensor, for being applied to a domestic hot water (DHW) inlet of said boiler and a fourth temperature sensor, for being applied to a DHW outlet of said boiler;

      said device having a set of sensors further comprising;
    - ◦ a fifth temperature sensor, for being applied to a flue gas outlet of said boiler;
    - ◦ an accelerometer for being applied to said CHC inlet of said boiler or to said DHW inlet of said boiler; and
- a transmission module which is configured to send data representing measurements by said set of sensors to a controller unit, and
- the controller unit which is configured to receive and analyze said data for boiler component anomalies.

[0012] It is an advantage of embodiments of the present invention that boiler performance of a boiler in operation can be monitored in a continuous manner. It is a further advantage that the above described sensor combinations allow anticipating upcoming boiler failures, wherein such failures may be originated by various causes. Furthermore, it has been found that combinations of sensors as described here above allow anticipating such failures for boilers, regardless of whether the boiler provides both DHW and central heating or only one of these. Even more, the set of sensors allows for predicting boiler failure, regardless of the age, brand, power as well as the design of the plumbing system of which the boiler is part. As a consequence, property managers or boiler maintenance companies can install the boiler performance monitoring and breakdown prediction system on existing circuits and thus retrofit existing plumbing systems. It is a further advantage that said sensors are inexpensive components, turning the process of providing a large fleet of boilers with said monitoring system in an economically feasible operation.

[0013] In an embodiment of the system according to the present invention, said accelerometer is applied to said CHC inlet of said boiler under the condition that said device having a set of sensors comprises said first pair of temperature sensors.

[0014] It is an advantage of this embodiment that the accelerometer is applied to the CHC inlet of the boiler, in the event that the boiler is connected to a central heating circuit. For other cases, e.g. when the boiler only provides domestic hot water, the accelerometer will be applied to the DHW inlet of the boiler.

[0015] In an embodiment of the system according to the present invention, said device has a set of sensors further comprising a sensor for measuring electromagnetic interference.

[0016] It is an advantage of this embodiment that a wider range of boiler breakdowns can be predicted. More in particular, it has been found that boiler breakdowns relating to DHW supply can be anticipated by including said sensor for measuring electromagnetic interference.

[0017] In an embodiment of the system according to the present invention, said transmission module transmits said data to said controller unit by use of a gateway which is in contact with an internet router.

[0018] It is an advantage of this embodiment that the performance of a boiler can be monitored by a controller unit from a distance.

[0019] In a particular embodiment of the system according to the present invention, Long Range (LoRa) is used by said transmission module for sending data to said gateway.

[0020] It is an advantage of this embodiment that LoRa enables long range transmissions with low power consumption, so that data can be transmitted to said controller unit, preferably by use of said gateway, even when said boiler and said gateway are separated by e.g. concrete walls.

[0021] In an embodiment of the system according to the present invention, said controller unit is configured to retrieve from said received data a reference standard for each of said set of sensors, said reference standard being indicative of a normal operating boiler.

[0022] It is an advantage of this embodiment that for each sensor a standard is obtained which represents a boiler operating in a regular fashion. As such, sensor values which are obtained after such a standard is retrieved can be evaluated with regard to a reference for said sensor as being the result of a normal request to the boiler or as abnormal behaviour.

[0023] In a particular embodiment of the system according to the present invention, said controller unit is configured to analyse a data stream representing measurements by said set of sensors for boiler component anomalies, having regard to said reference standards retrieved for each of said set of sensors.

[0024] In an embodiment of the system according to the present invention, said controller unit is configured to analyse said data stream provided by said set of sensors by use of machine learning techniques.

[0025] It is an advantage of this embodiment that past experiences can be applied to increase insight into the emergence of a technical problem of a boiler. As such, these techniques can be employed to define a probability for boiler failure and to increase the reliability of such predictions. Preferably, data mining techniques are applied to said data stream, uncovering new links between sensor values.

[0026] In an embodiment of the system according to the present invention, said controller unit is configured to report the results of said comparison to third parties by use of a communication means.

[0027] It is an advantage of this embodiment that the warning of a probable upcoming boiler breakdown can be brought to the attention of technicians or boiler owners and the like in time.

[0028] In an embodiment of the system according to the present invention, said sensors are applied in a non-invasive manner to the boiler.

[0029] It is an advantage of this embodiment that already installed boilers can be provided with the system according to the invention without the hassle of drilling holes in piping or any other intrusive operation which may be costly. Existing boiler system can therefore be retrofit in a minimum amount of time.

[0030] According to an aspect of the present invention, there is provided a method for monitoring boiler performance and for anticipating boiler breakdown, said method comprising the following steps:

- retrieving from data representing measurements by a set of sensors from a device having a set of sensors a reference standard for each of said set of sensors, said reference standard being indicative of a normal operating boiler, and
- analysing by use of a controller unit a data stream representing subsequent measurements by said set of sensors for boiler component anomalies, having regard to said reference standards retrieved for each of said set of sensors.

[0031] In an embodiment of the method according to the present invention, said method further comprises the step of analysing said data stream by use of machine learning techniques.

[0032] According to an aspect of the present invention, there is provided a kit of parts for monitoring boiler performance and for predicting boiler breakdown, the kit comprising at least one of

- a first pair of temperature sensors, comprising a first temperature sensor, for being applied to a central heating (CHC) inlet of a boiler and a second temperature sensor, for being applied to a CHC outlet of said boiler;
- a second pair of temperature sensors comprising a third temperature sensor, for being applied to a domestic hot water (DHW) inlet of said boiler and a fourth temperature sensor, for being applied to a DHW outlet of said boiler;

the kit further comprising a fifth temperature sensor, for being applied to the flue gas outlet of said boiler; and an accelerometer for being applied to said CHC inlet or to said DHW inlet of said boiler.

[0033] In an embodiment according to the present invention, said kit further comprises a transmission module (28) for sending said data measured by said set of sensors to a controller unit (30).

[0034] According to an aspect of the present invention, there is provided a computer program product comprising code means configured to cause a processor to perform the functions of said boiler performance monitoring and breakdown prediction system as described here above.

[0035] The technical effects and advantages of embodiments of the computer program product and the system according to the present invention correspond *mutatis mutandis* to those of the corresponding embodiments of the system according to the invention.

Brief Description of the Figures

[0036] These and other features and advantages of embodiments of the present invention will now be described in more detail with reference to the accompanying drawings, in which:

- Figure 1 schematically illustrates a boiler performance monitoring and breakdown predicting system according to an embodiment of the present invention;
- Figure 2 schematically illustrates a boiler performance monitoring and breakdown predicting system according to another embodiment of the present in-

vention;

- Figure 3 schematically illustrates monitoring the boiler by evaluating sensor output, thus observing an upcoming boiler failure.

Detailed Description of Embodiments

[0037] Figure 1 schematically illustrates a system **1** for monitoring boiler performance and/or for predicting boiler breakdown according to an embodiment of the invention.

[0038] A specific application of the system **1** according to embodiments of the invention is a system for monitoring, preferably in a continuous manner, the performance of a boiler **10**, and/or for predicting an upcoming breakdown of a boiler **10**. Typically, said boiler **10** is a boiler in a residential building which is used for providing central heating to the building, for providing domestic hot water (DHW) or for providing a combination of both. Where appropriate, the invention will be described with reference to such an application, without the intent to limit the scope of the invention thereto. The system **1** is provided to inform the boiler owner or boiler service provider about boiler performance, typically by both providing an overview of instantaneous boiler performance and an overview of any recent evolutions in boiler performance. For the purpose of the invention, the wording "boiler performance" refers to the capacity of the boiler to successfully transfer generated heat to a desired application, such as to a central heating circuit of a building or the generation of DHW. Boiler performance can therefore be evaluated by calculating or measuring the share of generated energy that is effectively being used for e.g. producing domestic hot water, compared to the total amount of generated energy. Typically, such a heat transfer can be influenced by wear of boiler components or poor adjustment of components, resulting in high fuel consumption with regard to the delivered heat.

[0039] Moreover, the system **1** is provided to inform about an upcoming event, such as an upcoming boiler breakdown or boiler failure, the source of which may e.g. be the failure of a component.

[0040] It should be understood that predicting or anticipating a failure or breakdown of a boiler refers to a situation wherein a failure has not yet occurred when at a certain point in time, the system **1** determines on the basis of a single event or a combination of, preferably simultaneous, events that there is significant potential or probability for an upcoming failure. Such a decision can be made on the basis of past experiences. The accuracy of such a predicted probability can be assessed statistically for a large number of predictions made in a large number of systems according to the invention.

[0041] According to a preferred embodiment of the invention, the boiler **10** is a boiler serving a one-family dwelling house. The boiler **10** can also be a central boiler, serving the needs of a plurality of residential units, such as apartments, or of other edifices, such as office buildings, government buildings, public or semi-public buildings, school buildings, factories, farms and the like.

[0042] It is an advantage of embodiments of the present invention, that a system **1** can be provided that is applicable to an existing boiler **10**, regardless the brand, age, type or model of the boiler **10**. In other words, the system **1** according to embodiments of the invention can be retrofit to an existing boiler. It is a further advantage that the system **1** can be applied to a boiler **10** in a non-intrusive manner, e.g. without the need for drilling holes in tubes or containers, thus without the need for introducing or inserting sensors and/or wires on the inside of the plumbing. It is a further advantage that the system **1** is composed of a limited number of simple components and sensors, thereby providing an economically advantageous way of monitoring the boiler performance and of predicting breakdown.

[0043] For the purposes of the present invention, the term "boiler" refers to a device, typically a closed vessel, in which a liquid is heated, without producing saturated or superheated vapor or steam. For the purpose of the invention, the boiler **10** is used for providing central heating to a building, for providing domestic hot water (DHW) or for providing a combination of both.

Typically, the boiler **10** is designed to operate at a temperature of at least 35°C, preferably at least 40°C, more preferably at least 45°C, and most preferably at least 50°C. It is further understood that the boiler **10** is designed to operate at a temperature of at most 90°C, preferably at most 85°C, more preferably at most 80°C, even more preferably at most 75°C, more preferably at most 70°C, and most preferably at most 65°C.

[0044] The boiler **10** as referred to in the present invention typically comprises a burner (not shown on the figure), wherein a fuel is transformed in heat, and a heat exchanger (not shown on the figure) for transferring said produced heat to a liquid such as water. The heat exchanger is typically inside the boiler **10** and transfers the generated heat to the liquid, which subsequently heats up.

[0045] Depending on the demand, fuel is drawn into the boiler **10** and is directed to the burner or burners of the boiler. The fuel burned by the boiler **10** may be natural gas (containing primarily methane), or a petrol-based product, such as fuel oil. It will however be clear that the system 1 according to embodiments of the invention is independent of the type of fuel source. Carbon dioxide and steam are produced upon burning the fuel. The boiler is therefore provided with a flue gas outlet, flue vent or a channel **11** for conveying said exhaust gases or flue gases to the outer air, as well as with at least one fan (not shown on the figure) for pushing said flue gases out of the flue.

[0046] A central heating system (not shown on the figure) comprises a first closed circuit, usually containing water or a water-based composition which can flow through said closed circuit. It will be clear that also other liquids may be used for this purpose. The water in said first closed circuit passes through the boiler **10**, where it

can be heated, and delivers said acquired heat further on in the circuit, typically via radiators. The boiler **10** therefore plays an important role in the central heating system.

[0047] According to embodiments of the present invention, the boiler **10** provides central heating to a building. The boiler **10** then comprises a central heating circuit (CHC) inlet **12**, for returning water from said first closed circuit into the boiler **10**, and a central heating circuit (CHC) outlet **13**, for entering water that has possibly been heated by the activity in the boiler **10** into the first closed circuit.

[0048] According to embodiments of the present invention, the boiler **10** provides DHW.

[0049] As shown on Figure **1**, boilers may have the shape of a single compact unit, without requiring a separate hot water cylinder. For the production of DHW in such a configuration, water will typically be drawn from a main water supply into the boiler **10**, receive heat by use of the heat exchanger for reaching a certain temperature and leave the boiler **10** towards its point of use. The advantage of this compact unit is that it saves space within the property.

The boiler then comprises a domestic hot water (DHW) inlet **14A** for entering water from a main water supply (not shown on the figure) into the boiler **10**, and a domestic hot water (DHW) outlet **15A** for conducting water heated by the boiler **10** to its point of use in the building (not shown on the figure).

[0050] Referring now to Figure 2, the boiler **10** can further be connected to a vessel **100** or tank for storing DHW (such a combination is sometimes known as a system boiler).

According to a preferred configuration, water can be drawn from the main water supply into said separate vessel, where it is heated by a heating fluid that is circulating in a second closed circuit between the boiler **10** and the separate vessel **100.** A representation of this configuration can be found in Figure 2.

In such a configuration, a domestic hot water (DHW) inlet **14B** can be defined which enters water from a main water supply (not shown on the figure) into said separate vessel **100**, and a domestic hot water (DHW) outlet **15B** for conducting water heated in the vessel **100** to its point of use in the building.

[0051] Alternatively, water is drawn from the main water supply into the boiler **10** by use of a DHW inlet **14C**, heated in the boiler **10** via the heat exchanger and subsequently transported to said separate vessel, which is typically thermally isolated to reduce heat loss. The heated water is then stored in the separate vessel until use, when it is transported to its point of use by a DHW outlet **15C.**

[0052] In all configurations, a DHW inlet **14** can be defined for entering water from a main water supply into a boiler or a vessel for heating water prior to use, as well as a DHW outlet **15** for conducting heated water from the boiler or the vessel to a point of use. For the purpose of the invention, both a single unit boiler as the combination of boiler and separate vessel **100** as described here above will be referred to as boiler **10.**

[0053] According to preferred embodiments, boiler **10** provides both heat for a central heating system as well as domestic hot water (DHW). Priority will normally be given to the production of DHW. Such boilers will subsequently have a CHC inlet **12**, CHC outlet **13**, DHW inlet **14** and DHW outlet **15** as described here above.

[0054] The boiler **10** is further provided with at least one circulating pump (not shown on the figure), e.g. for pumping heated water or liquid through the first closed circuit of the central heating system or through the second closed circuit. Such a pump is typically electrically powered.

[0055] The boiler **10** may further be in contact with an expansion tank (not shown on the figure) for protecting the DHW hardware from excessive pressure caused by thermal expansion as well as water hammer.

[0056] Water demand is typically regulated by use of valves (not shown on the figure), which are present on at least the CHC outlet **12** and the DHW outlet **14**.

[0057] According to an aspect of the invention, a system **1** for monitoring boiler performance and/or for predicting boiler breakdown is provided. For this purpose, said system **1** comprises a device **20**, having a set of sensors.

[0058] According to embodiments of the invention, the set of sensors of said device **20** comprises at least one of

- a first pair of temperature sensors, comprising a first temperature sensor **21**, for being applied to a central heating circuit (CHC) inlet **12** of a boiler **10** and a second temperature sensor **22**, for being applied to a central heating circuit (CHC) outlet **13** of the boiler **10**; and
- a second pair of temperature sensors comprising a third temperature sensor **23**, for being applied to a domestic hot water (DHW) inlet **14** of the boiler **10** and a fourth temperature sensor **24**, for being applied to a domestic hot water (DHW) outlet **15** of the boiler **10**.

[0059] The set of sensors of said device **20** further comprises a fifth temperature sensor **25**, for being applied to the flue gas outlet **11**, and an accelerometer **26.**

[0060] According to embodiments of the present invention, boiler **10** is a boiler for providing heat in the form of a heated liquid to the central heating of a building. It will be clear that for these embodiments, the device **20** will not contain the second pair of temperature sensors **23**,**24** or will not have this pair installed and/or activated, meaning that this second pair remains idle.

[0061] According to embodiments of the present invention, boiler **10** is a boiler for providing domestic hot water (DHW) to a building. It will be clear that for these embodiments, the device **20** will not contain the first pair of temperature sensors **21,22** or will not have this pair installed

and/or activated, meaning that this first pair remains idle.

[0062] According to embodiments of the present invention, boiler **10** is a boiler for providing both heated water to the central heating to the building and domestic hot water (DHW). In these cases, the device **20** will contain both pairs of temperature sensors and both pairs will be installed and activated.

[0063] For the purpose of the present invention, an accelerometer **26** is a device for measuring acceleration or for detecting and measuring vibrations. The accelerometer **26** can measure vibrations in three dimensions and can as such be used for measuring the effect of water flowing through a pipe or a fan venting the combustion chamber.

[0064] The accelerometer **26** can in principle be applied to any of the in- or outlets **12-15.** According to embodiments of the invention, the accelerometer **26** is applied to the CHC inlet **12** of the boiler **10** in the event that the boiler **10** is connected to a central heating circuit. Preferably, the device **20** comprises a housing (not shown on the figures), which housing further houses said accelerometer **26.** If the boiler only provides for DHW, the accelerometer **26** is preferably applied to the DHW inlet **14.**

[0065] According to preferred embodiments, the set of sensors of said device **20** further comprises a sensor for measuring electromagnetic interference **27** (EMI sensor herein after). When used, said EMI sensor **27** is preferably applied to the DHW outlet **15**. It has been found by the inventors that the inclusion of said EMI sensor **27** allows for a more complete prediction of boiler failures related to the supply of DHW. As such, by including the EMI sensor **27** in the device **20**, the range of predictable boiler failures is further extended.

[0066] According to preferred embodiments, the sensors of said set are waterproof.

[0067] According to embodiments of the present invention, the device **20** is powered in a way known in the state of the art. Preferably, the device **20** is powered by use of a standard micro USB cable.

[0068] According to embodiments of the present invention, device **20** further comprises a transmission module **28**, which is connected to the set of sensors by means known in the state of the art, such as wiring (not shown on the figure) or wireless communication protocols and which receives data provided by said set of sensors. Said transmission module **28**, which may or may not be housed by said housing of said device **20**, is configured to transfer data provided by said set to a controller unit **30**.

[0069] Data measured by said set of sensors may be communicated to the controller unit **30** by said transmission module **28** by use of communication protocols known to the skilled in the art.

[0070] According to a preferred embodiment, use is made of a gateway **29** which is in contact with a router (not shown on the figure) connected to the internet and which can send said data to the controller unit **30** by use of said internet connection. Transmitters according to IEEE Std 802.11 ("Wi-Fi") can be used for transferring data from the transmission module **28** to said gateway **29**. However, it has been found that in many cases Wi-Fi signals are not recommended due to a limited range, which may further be hampered by the presence of e.g. concrete walls near the boiler **10**. Preferably, wireless communication technologies such a LoRa (Long Range) are used. LoRa is a digital wireless data communication technology which enable long range transmissions with low power consumption.

[0071] The controller unit **30** is configured to receive data measured by said set of sensors and preferably transmitted by said transmission module **28**.

[0072] According to embodiments of the present invention, the controller unit **30** is also configured to analyze said data provided by said set of sensors. Preferably, said analysis is performed on a continuous basis using the constant input of measurements provided by the set of sensors.

[0073] The inventors have found that for a normally functioning boiler, the constant data stream which is provided by said set of sensors reveals a regular pattern of behavior for every single sensor, said pattern being a consequence of the requests of the boiler users or of automatic operations. In other words, the combination of sensors in said set of sensors allows for a close follow-up of the regular actions of the boiler **10**. Such boiler actions are defined by a limited number of requests (e.g. central heating on or off; a request for sanitary water from a limited number of taps), wherein said requests often relate to specific time slots (e.g. a request for hot water from a shower tap may occur in the morning or at the end the day). As a consequence, said pattern is defined by recurring automatic operations by the boiler **10** for generating hot water for heating or sanitary use, as well as by the actions of the user of the building, such as requesting hot water by opening a water tap or demanding an increase or decrease in room temperature by changing the thermostat.

Said operations and actions may influence more than one sensor, so that measurements of combinations of sensors may have to be observed for determining a certain boiler action. As such, the values measured by the sensors are in function of the action which is performed at that moment by the boiler **10**.

It was found that the specific and limited combination of sensors described herein allowed deriving and defining said regular pattern.

[0074] According to embodiments of the invention, the controller unit **30** is further configured to retrieve from said received data a reference standard indicating normal behavior of the boiler and its components. A functioning and normally solicited boiler will be characterized by recurring and regular patterns for the measured data of each single sensor. Therefore, in view of comparing any anomalies with regular behavior a reference standard has to be defined for every sensor of said plurality. Typically, the controller unit is configured to determine

such a reference standard for every single sensor, e.g. upon initiating or applying the system **1** to the particular boiler, meaning that during a limited period of time after applying the system **1** to a particular boiler, data will be recorded with the aim of deriving a standard form of behavior for every sensor of the system **1**. Such an initialization phase usually takes several days, typically 5 days, but no more than 10 days. It is however assumed that during this initialization phase, the boiler **10** will function in a normal way and will be solicited accordingly.

[0075] During the initialization phase and when the boiler is supposed to be operating in a normal manner, said controller unit **30** is configured to identify and store reference data and patterns derived therefrom in the form of a reference standard for each sensor of said set of sensors. The reference standards are stored in a database and indicate a normal operating boiler. The database therefore contains values and patterns for individual sensors which may be measured when the boiler **10** is operating normally.

[0076] Advantageously, the system **1** allows deducing regular patterns from measurements by sensors applied to normal-functioning boilers **10**, regardless the type or manufacturer of the boiler. Said patterns, reflecting "normal behaviour" have been found to differ between boilers **10**.

[0077] Particularly, patterns reflecting "normal" behaviour have been found to differ between different types of boiler **10** from the same manufacturer, whereas boilers **10** from different manufacturers may show similar patterns. However, it will be clear that the system **1** can retrieve, from data measured by the set of sensors, regular patterns for every single sensor, reflecting that the boiler is operating in a normal manner.

[0078] According to embodiments of the invention, the controller unit **30** is further configured to analyze subsequent data provided by said set of sensors in search for boiler component anomalies by comparing said subsequent data with the retrieved reference standards. Indeed, upon having established a reference standard indicating normal functioning behavior for every single sensor of said plurality, consecutive measurements for said set of sensors, which measurements are obtained after determining the reference standard, can be weighed against these reference standards. As such, the controller unit **30** is configured to detect abnormal behavior or anomalies by comparing the instantaneous measurements of a single sensor with said regular patterns, or by the comparison of instantaneous measurements of combinations of sensors with normal patterns or combinations thereof.

[0079] According to embodiments of the invention, the controller unit **30** is further configured to calculate from said consecutive measurements, with respect to the retrieved reference standards, an instantaneous overall boiler performance for the boiler **10**. Such an overall boiler performance, which may also indicate the evolution of performance, may be expressed by use of a numerical value, a colour code and the like.

[0080] It has unexpectedly been found that the approximate values of the sensors **21-26** suffice for noticing a deterioration of boiler performance and may serve as a basis for the calculation of a probability of boiler failure. For the simplest of cases, a direct link can be made between a sensor measurement and the occurrence of a breakdown (e.g. a decreased temperature measurement for an outgoing flow to the central heating or DHW indicates a decrease in boiler efficiency). Furthermore, it may be the case that breakdown is not due to an abrupt change but to a gradual evolution.

[0081] According to preferred embodiments of the invention, said controller unit **30** is further provided, having regard to reference standards retrieved for each sensor of said plurality, for analysing the data stream provided by said set of sensors by use of data mining techniques. For the purpose of the invention, the term "data mining techniques" relate to techniques and methods for examining large pre-existing databases in order to generate new information.

[0082] Furthermore, according to preferred embodiments of the invention, said controller unit **30** is further provided, having regard to reference standards retrieved for each sensor of said plurality, for analysing the data stream provided by said set of sensors by use of machine learning techniques and/or pattern recognition models.

[0083] The machine learning approach involves the step of computing, based on the input of the data stream of sensor measurements and possibly by use of insights obtained through data mining, an algorithm or a mathematical function that represents a probability of boiler breakdown.

Said machine learning approaches may include, but are not limited to, supervised or unsupervised analysis: classification techniques (e.g. naive Bayes, Linear Discriminant Analysis, Quadratic Discriminant Analysis Neural Nets, Tree based approaches, Support Vector Machines, Nearest Neighbour Approaches), Regression techniques (e.g. linear Regression, Multiple Regression, logistic regression, probit regression, ordinal logistic regression ordinal probit regression, Poisson Regression, negative binomial Regression, multinomial logistic Regression, truncated regression), Clustering techniques (e.g. k-means clustering, hierarchical clustering, PCA), Adaptations, extensions, and combinations of the previously mentioned approaches.

According to preferred embodiments of the invention, said machine learning approach makes use of Bayesian change point detection, which is aiming at the identification of changes of the probability distribution of sensor measurements.

[0084] It has been found that the combination of the sensors described here above, with a continuous analysis of measured data by the controller unit **30**, preferably by use of data mining and/or machine learning techniques, allows for observing evolutions in boiler performance as well as providing a reliable probability regarding

boiler breakdown.

[0085] According to embodiments of the invention, the controller unit **30** is further configured to communicate the results of said analysis to a network by use of a communication means (not shown on the figure).

[0086] If the analysis performed by the controller unit **30** infers that all measurements by the set of sensors point at normal boiler behavior, the results of the analysis are stored by the controller unit 30 and no further action is taken. Preferably, said analysis is performed in a continuous manner. If the result of the analysis hint at an upcoming boiler breakdown or a decrease in boiler performance beyond a certain predefined level, said result is further communicated to a network by use of a communication means. Said network can contain the owner of the boiler, a boiler technician and/or further third parties.

[0087] According to embodiments of the invention, the controller unit **30** is further configured to retrieve from the analysis a set of possible causal factors for the defect, breakdown or decreased performance, and communicate said diagnosis to the boiler owner, boiler technician and/or any other third parties by use of said communication means.

[0088] As a result, intermittent boiler breakdown can be noticed for boilers of different types and manufacturers, meaning that the system of the invention can be applied independently of the brand of the boiler **10**. The independency of any brand and the possibility to retrofit existing boiler installations are among the advantages of system **1**.

[0089] The inventors have found that the analysis of the measurements of a limited selection of sensors applied to the boiler **10** at various specific positions may lead to reliably predicting boiler breakdown, thus allowing the boiler owner or boiler service provider to anticipate said breakdown by appealing to technical assistance in time. It has been noticed that signals indicating an upcoming or imminent boiler breakdown can be noticed up to 48 hours before breakdown occurs. For certain issues, such signals were noticed 96 hours before the actual breakdown.

[0090] The inventors have further found that it is possible to obtain said pattern for normal boiler behaviour as well as upcoming boiler breakdown by contacting said set of sensors to parts of the boiler **10**, such as plumbing, in a non-invasive way with regards to the existing hardware. Sensors **21-27** can be fixed to plumbing or vessels by use of means known by the skilled in the art. Such means include clamps, cable ties, tape, glue and the like. No sensors are therefore inserted into any channels, tubes or tanks and no alterations such as drilling a hole are needed for these parts. Although the exact temperature of the water in any of the inlet or outlets is largely unknown and merely estimated, it was found that such temperature estimations suffice for deducting upcoming boiler breakdown. The non-invasive setup has as a consequence that the system of the invention is applicable to older or already existing boiler installations. Existing boilers can therefore be retrofit with the system of the invention.

[0091] Furthermore, no digital or electrical connections have to be made between the device **30** and the boiler **10**. The only condition is that some specific parts of the boiler **10** need to be accessible to a technician, such as the plumbing and the fluke.

[0092] According to preferred embodiments of the invention, the controller unit **30** is not present in the residential building housing the boiler **10**. Unit **30** is typically a centrally placed unit configured to monitor a plurality of boilers **10**, having a different age, brand, type and the like.

[0093] It is an advantage of the present invention that for every brand of boiler **10**, a standard pattern may be defined which reflects normal boiler behavior and which subsequently allows determining boiler performance and predicting an upcoming boiler breakdown.

[0094] The system **1** comprises components such as sensors which are low in cost. It is therefore an advantage of the present invention to provide for a system for predicting an upcoming boiler breakdown and to monitor boiler performance in an economically advantageous manner.

[0095] According to preferred embodiments of the invention, the system **1** is furthermore provided with a communication means, said means being provided to communicate the analysis results as well as the retrieved set of causal factors to the users of the network by use of data transfer protocols known in the state of the art.

[0096] According to preferred embodiments of the present invention, a quantified report is provided on a regular basis to parties such as the boiler owner on the basis of the measurements of said set of sensors.

[0097] The results of the analysis by the controller unit **30** may be shared by the communication means to a plurality of parties, such as the boiler owner, boiler technician and the like.

According to embodiments of the present invention, said communication means makes thereby use of an application programming interface (API). API stands for Application Programming Interface and is used to allow interaction between software applications and to integrate different software applications.

More in particular, an API is used to transfer data contained in software program A to another environment under the control of a second processor which runs software program B and store said data in a second non-volatile memory.

[0098] Advantageously, an API may be used to communicate said data to a software program used by a boiler technician. Typically, technicians move from customer to customer during the day, making use of a mobile device **50** provided with a GUI providing information about the repairs that have to be carried out.

[0099] As used herein, the term "mobile device" generally refers to any computing device that is made for

portability. Mobile devices include laptop computer, a mobile phone, a personal digital assistant (PDA), a data tablet, a digital camera, a video camera, and the like.

[0100] By use of an API, the system **1** can report an upcoming breakdown as well as already suggest some causes for the defect, which can save the technician valuable time, independently of the software program or system the technician is using.

[0101] According to preferred embodiments of the present invention, said communication means is further provided to communicate with a software program at the disposal of the boiler owner, thereby informing the boiler owner of the boiler performance and of any upcoming boiler breakdowns. Preferably, such information is transferred to a mobile device **60** of the boiler owner. The information provided by the communication means may help the customer to solve the problem by him- or herself. Alternatively, the program may propose to book an intervention by a technical team.

A specific point in time can be proposed to the boiler owner for the boiler to be repaired. The boiler owner can be requested to give his explicit confirmation and approval to such a message.

[0102] According to another aspect of the invention, there is provided a method for monitoring boiler performance and for anticipating boiler breakdown, said method comprising the following steps:

- retrieving from data representing measurements by a set of sensors **21-26** from a device as described here above a reference standard for each of said set of sensors **21-26**, said reference standard being indicative of a normal operating boiler, and
- analysing by use of controller unit **30** as described here above a data stream representing subsequent measurements by said set of sensors **21-26** for boiler component anomalies, having regard to said reference standards retrieved for each of said set of sensors.

[0103] According to embodiments of the method, the set of sensors further comprises an electromagnetic interference sensor **37**.

[0104] According to preferred embodiments of the method, said method further comprises the step of analysing said data stream by use of machine learning techniques.

[0105] According to another aspect of the invention, a kit of parts is provided, said kit comprising the following elements:

at least one of

◦ a first pair of temperature sensors, comprising a first temperature sensor **21**, for being applied to a central heating circuit (CHC) inlet **12** of a boiler **10** and a second temperature sensor **22**, for being applied to a CHC outlet **13** of said boiler **10**;

◦ a second pair of temperature sensors comprising a third temperature sensor **23**, for being applied to a domestic hot water (DHW) inlet **14** of said boiler **10** and a fourth temperature sensor **24**, for being applied to a DHW outlet **15** of said boiler **10**;

the kit further comprising

- a fifth temperature sensor **25** for being applied to a flue gas outlet **11** of said boiler **10**;
- an accelerometer **26** for being applied to said CHC inlet **12** or to said DHW inlet **14** of said boiler **(10).**

[0106] According to embodiments of the present invention, the kit of parts further comprises a transmission module **28** configured to receive data measured by said set of sensors and to send said data to a controller unit **30**.

[0107] According to embodiments of the present invention, the kit of parts further comprises an electromagnetic interference sensor **37**.

[0108] The present invention also pertains to a computer program, optionally stored on a computer-readable medium, comprising code means adapted to cause a processor to perform the functions of the controller unit **30** as described above.

[0109] While the invention has been described hereinabove with reference to specific embodiments, this is done to illustrate and not to limit the invention, the scope of which is defined by the accompanying claims. The skilled person will readily appreciate that different combinations of features than those described herein are possible without departing from the scope of the claimed invention.

Examples

[0110] A Junkers TOP 30-3 ZWB boiler was provided with a system **1**, said system having a device **20** provided with both a first and second pair of temperature sensors. The boiler was subsequently monitored for a period of 55 days. Fig. 3 illustrates the data stream provided by the set of sensors. Analysis by the controller unit **30** indicated at point of time A (leftmost vertical line) an increased probability for an imminent breakdown, leading to alert to the boiler owner. While being allowed to continue further functioning without any noticeable changes for the boiler user, an effective boiler breakdown was measured at point of time B (rightmost vertical line).

Claims

1. A system (1) for monitoring boiler (10) performance and for anticipating boiler (10) breakdown, said system (1) comprising:

- a device (20) having a set of sensors, comprising at least one of

◦ a first pair of temperature sensors, comprising a first temperature sensor (21), for being applied to a central heating circuit inlet (12) of said boiler (10) and a second temperature sensor (22), for being applied to a central heating circuit outlet (13) of said boiler (10);
◦ a second pair of temperature sensors comprising a third temperature sensor (23), for being applied to a domestic hot water inlet (14) of said boiler (10) and a fourth temperature sensor (24), for being applied to a domestic hot water outlet (15) of said boiler (10);
said device (20) having a set of sensors further comprising
◦ a fifth temperature sensor (25), for being applied to a flue gas outlet (11) of said boiler;
◦ an accelerometer (26) for being applied to said central heating circuit inlet (12) of said boiler (10) or to said domestic hot water inlet (14) of said boiler (10); and

- a transmission module (28) which is configured to send data representing measurements by said set of sensors to a controller unit (30), and
- the controller unit (30) which is configured to receive and analyze said data for boiler component anomalies.

2. The system (1) according to claim 1, wherein said accelerometer (26) is applied to said central heating circuit inlet (12) of said boiler (10) under the condition that said device (20) having a set of sensors comprises said first pair of temperature sensors.

3. The system (1) according to claim 1 or claim 2, said device (20) having a set of sensors further comprising a sensor (27) for measuring electromagnetic interference.

4. The system (1) according to any one of previous claims, wherein said transmission module (28) transmits said data to said controller unit (30) by use of a gateway (29) which is in contact with an internet router.

5. The system (1) according to claim 4, wherein Long Range (LoRa) is used by said transmission module (28) for sending data to said gateway (29).

6. The system (1) according to any one of previous claims, wherein said controller unit (30) is configured to retrieve from said received data a reference standard for each of said set of sensors, said reference standard being indicative of a normal operating boiler (10).

7. The system (1) according to claim 6, wherein said controller unit (30) is configured to analyse a data stream representing measurements by said set of sensors for boiler component anomalies, having regard to said reference standards retrieved for each of said set of sensors.

8. The system (1) according to claim 7, wherein said controller unit (30) is configured to analyse said data stream provided by said set of sensors by use of machine learning techniques.

9. The system (1) according to any one of previous claims, wherein said controller unit (30) is configured to report the results of said comparison to third parties by use of a communication means.

10. The system (1) according to any one of previous claims, wherein said sensors (21-27) are applied in a non-invasive manner to the boiler (10).

11. A method for monitoring boiler (10) performance and for anticipating boiler (10) breakdown, said method comprising the following steps:

- retrieving from data representing measurements by a set of sensors from a device (20) according to claims 1-3 a reference standard for each of said set of sensors, said reference standard being indicative of a normal operating boiler (10), and
- analysing by use of controller unit according to claims 1-10 a data stream representing subsequent measurements by said set of sensors for boiler component anomalies, having regard to said reference standards retrieved for each of said set of sensors.

12. The method according to claim 11, said method further comprising the step of analysing said data stream by use of machine learning techniques.

13. A kit of parts for monitoring boiler performance and for anticipating boiler breakdown, the kit comprising at least one of

◦ a first pair of temperature sensors, comprising a first temperature sensor (21), for being applied to a central heating circuit inlet (12) of a boiler (10) and a second temperature sensor (22), for being applied to a central heating circuit outlet (13) of said boiler (10);
◦ a second pair of temperature sensors comprising a third temperature sensor (23), for being applied to a domestic hot water inlet (14) of said boiler (10) and a fourth temperature sensor (24), for being applied to a domestic hot water outlet (15) of said boiler;

the kit further comprising a fifth temperature sensor (25), for being applied to the flue gas outlet (11) of said boiler (10); and an accelerometer (36) for being applied to said central heating circuit inlet (12) or to said domestic hot water inlet (14) of said boiler (10).

14. The kit of parts according to claim 13, said kit further comprising a transmission module (28) for sending said data measured by said set of sensors to a controller unit (30).

15. A computer program product comprising code means configured to cause a controller unit (30) to perform the functions according to any one of claims 1-14.

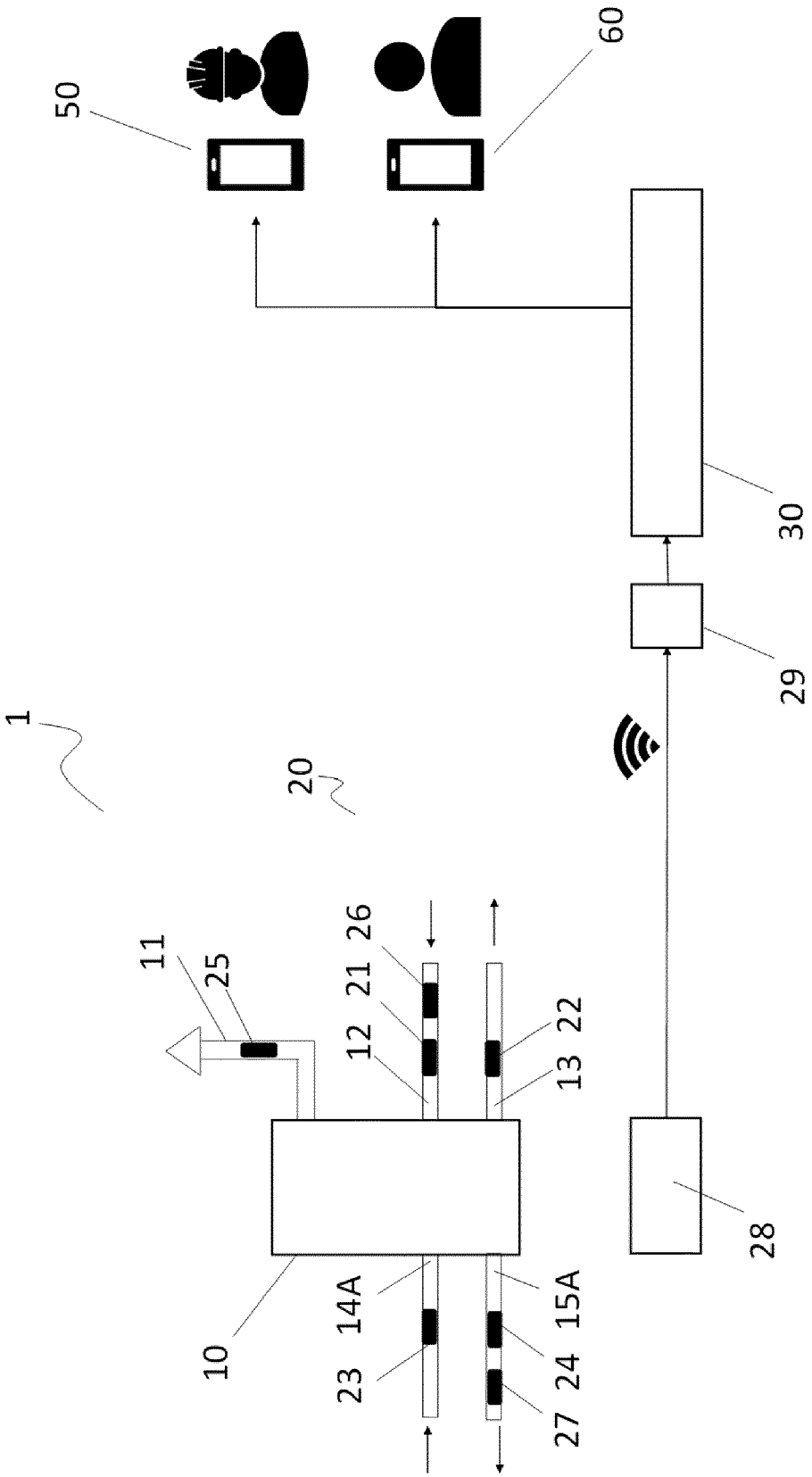


Fig.1

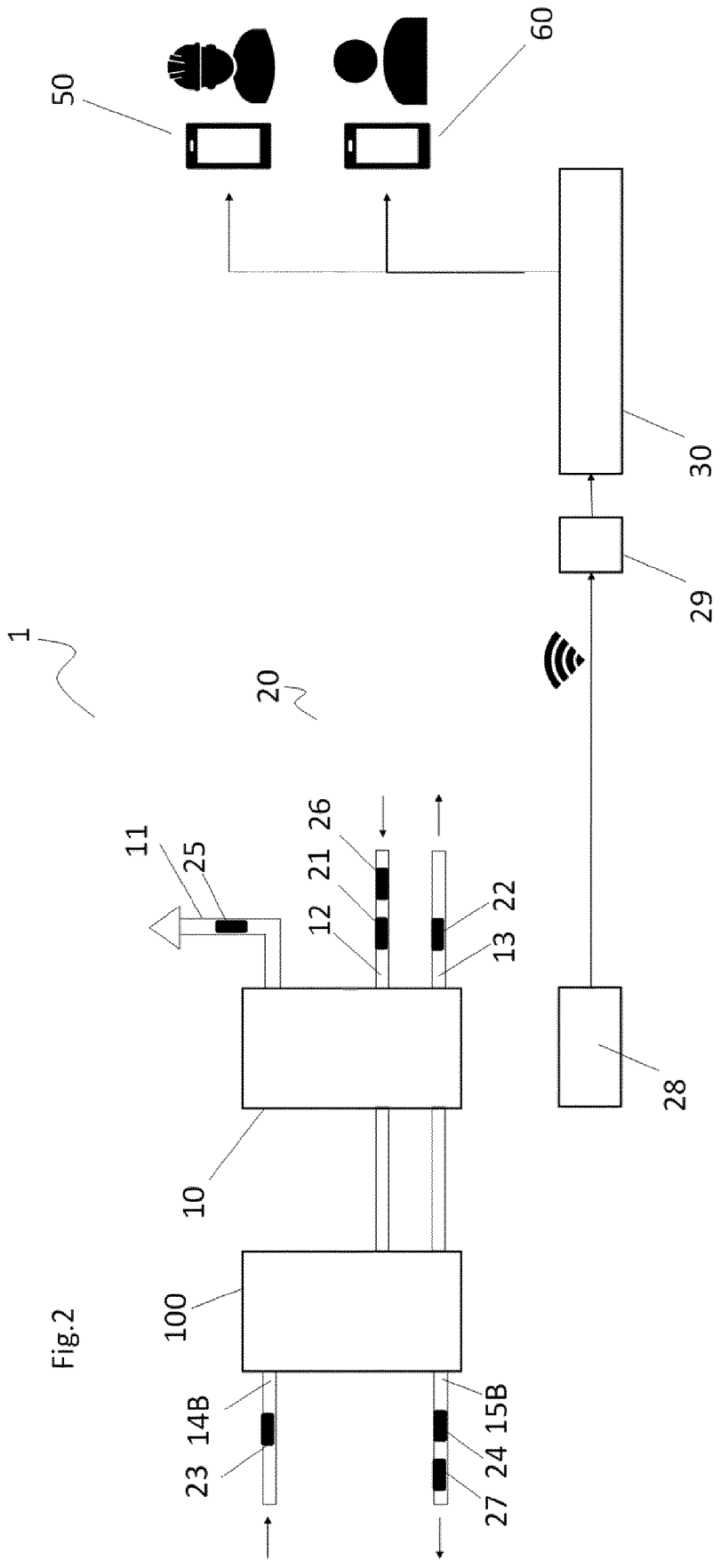


Fig.2

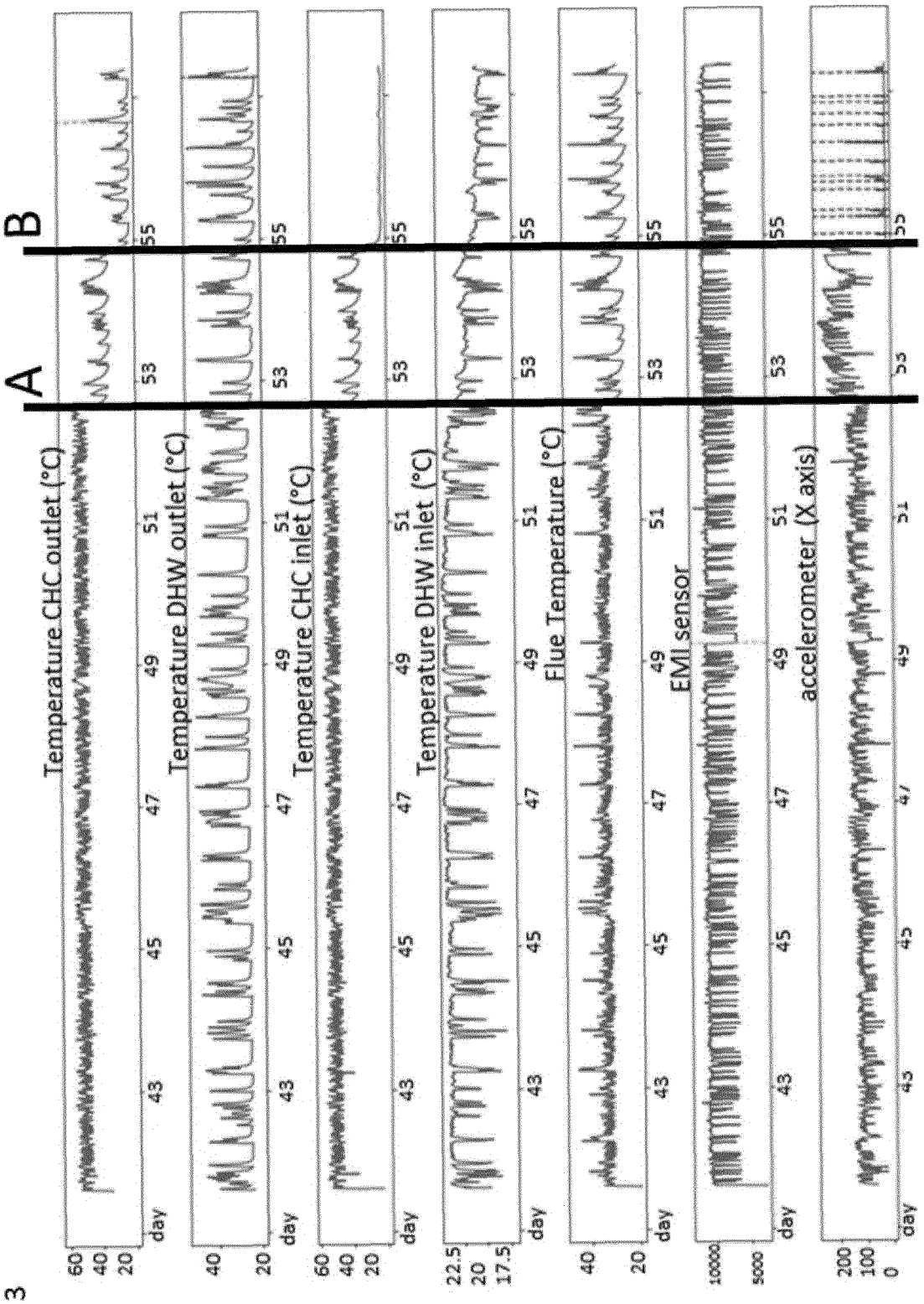

A
B
Temperature CHC outlet (°C)
Temperature DHW outlet (°C)
Temperature CHC inlet (°C)
Temperature DHW inlet (°C)
Flue Temperature (°C)
EMI sensor
accelerometer (X axis)
day

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 18 21 0288

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	US 2014/032137 A1 (GOGOANA MARIAN [US]) 30 January 2014 (2014-01-30) * page 3, paragraph 31 - page 6, paragraph 66; figures 1,2,3a *	1-15	INV. F24H9/20 F24D19/10
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A	CN 107 218 727 A (GUANGZHOU DEVOTION THERMAL FACILITY CO LTD) 29 September 2017 (2017-09-29) * the whole document *	1-15	
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F24H
F24D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	15 May 2019	Hoffmann, Stéphanie

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 21 0288

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15-05-2019

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

REFERENCES CITED IN THE DESCRIPTION

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