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(54) **HYDROGEN RETROFIT KIT ASSEMBLY FOR A GAZ BURNER**

(57) The invention relates to a retrofit kit assembly (1) for converting a hydrocarbon gas combustion appliance (2), in particular a gas boiler, and more particularly for a condensing gas boiler, to a combustion appliance for combustion of fuel gas comprising more than 20 mol%, in particular 30 mol%, hydrogen, the kit assembly (1) comprising a frame structure (5) fixable to a housing

(3) of the combustion appliance (2) for, in particular fully, covering a burner chamber (18) of the combustion appliance (2); and
a control unit (23) configured to control a burner (6) configured for hydrogen combustion wherein the control unit (23) is, in particular firmly, connected to the frame structure (5).

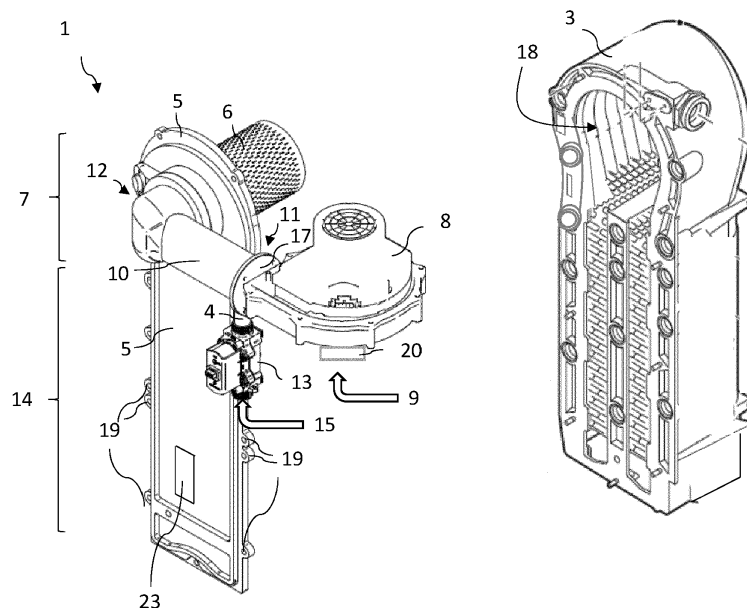


Fig. 2

Description

[0001] The invention relates to a retrofit kit assembly for converting a hydrocarbon gas combustion appliance, in particular a gas boiler, and more particularly for a condensing gas boiler, to a combustion appliance for combustion of fuel gas comprising more than 20 mol% hydrogen. Additionally, the invention relates to a combustion appliance comprising said retrofit kit assembly. Furthermore, the invention relates to the use of the retrofit kit assembly for converting a natural gas combustion appliance, in particular a natural gas boiler, into a combustion appliance, in particular boiler, for the combustion of pure hydrogen and 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 CO₂ emissions from this sector. Heating of spaces and heating of water are the two major causes of energy consumption and CO₂ 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 hydrocarbon gases 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 more sustainable alternatives with a lower CO₂-footprint to 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 98 mol% hydrogen. Currently, there are natural gas (or propane) boilers on the market which are only suitable to combust up to 20 mol% hydrogen into the gas blend (according to the specifications). In other words, current boilers on the market are not directly suitable for combustion of higher concentrations of hydrogen, in particular pure hydrogen, and important modifications are needed to possibly convert a standard natural gas boiler into a hydrogen gas boiler. These modifications commonly are expensive and time consuming. In addition, the converted natural gas boiler needs to run safely on hydrogen and needs to comply with safety critical requirements as safety defects can have serious consequences. Converting an existing natural gas appliance incorrectly can lead to defects of the resulting hydrogen appliance. One of the main sources of defects in a conversion is human error. There is a relationship between several types of human errors and defects in the appliance. Intentional errors, misunderstanding of instructions, forgetfulness, misidentification, inexperience, slowness, non-supervision, surprise. These human errors can lead to not following procedures, processing errors, errors in set up, missing parts, wrong parts, mis-operation, and adjustment errors. Therefore, one of the main problems to be solved is the

reduction or elimination of human errors in the conversion of natural gas boilers to hydrogen boilers.

[0004] Relying on training and work instructions to prevent errors alone is insufficient to reduce human error effectively. Available data indicates that no matter how much training a person receives or how well the process is documented, human error occurs. While application of standard work practices and training are valid methods for reducing the frequency of errors, they will not prevent errors from occurring. In addition, trying to rely only on training makes the conversion process slow, as there would need to be several safety checks.

[0005] Mistake-proofing or Poka-Yoke ideally ensures that the product or process design itself prevents mistakes before they occur. Good Poka Yoke devices in addition are simple and inexpensive. By converting a natural gas boiler to a hydrogen boiler, there is a risk of explosion if there is a human error in the part setup regarding safety critical parts for combustion of hydrogen. Such human error can lead to defects in operation of the converted hydrogen boiler.

[0006] It is therefore desirable to obtain an easy and relatively low-cost conversion between a standard natural gas boiler and a hydrogen boiler which helps in reducing human error in the conversion. It is also desirable that the conversion is carried out providing behavior shaping constraints which reduce safety critical part related human errors.

[0007] EP 3 524 884 A1 is directed to providing a retrofit assembly for a fuel gas boiler that that reduces polluting emissions and/or increases the yield and/or reduces problems in the ignition phase and discloses a retrofit assembly for a fuel gas boiler, the boiler comprising a fuel gas burner, a feeding assembly for supplying fuel gas to the burner, and a control unit for controlling the feeding assembly. In particular, the retrofit assembly comprises a processing unit configured to acquire a first control signal of the feeding assembly configured to control the feeding assembly, a second signal correlated to the exhaust gas or fuel gas composition, the processing unit being configured to define a third control signal of the feeding assembly configured to control the feeding assembly and based on the second signal and on the first signal. The retrofit assembly is configured to be installed in the boiler and to control the flow rate of the fuel gas by means of the third signal.

[0008] Although directed to a conversion system for a gas boiler for reducing the polluting emissions of the boiler, this document only discloses the retrofit of a control system, i.e. the modification of the setting parameters for increasing the yield of the boiler. EP 3 524 884 A1 does not disclose how to reduce or eliminate human errors in the conversion of a natural gas boiler to a hydrogen boiler.

[0009] Therefore, this and other prior art documents fail 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 hydrogen, in particular pure hydrogen.

[0010] The object of the invention is therefore to provide a retrofit kit assembly that is easy to implement and that is effective in converting a natural gas combustion appliance, in particular a boiler (hydrocarbon gas boiler), into a hydrogen combustion appliance, particular a hydrogen gas boiler while reducing human error.

[0011] The object is solved by a retrofit kit assembly for converting a hydrocarbon gas combustion appliance, in particular a gas boiler, and more particularly for a condensing gas boiler, to a combustion appliance for combustion of fuel gas comprising more than 20 mol%, in particular 30 mol%, hydrogen, the kit assembly comprising:

a frame structure fixable to a housing of the combustion appliance for, in particular fully, closing a burner chamber of the combustion appliance; and a control unit configured to control a burner configured for hydrogen combustion wherein the control unit is, in particular firmly, connected to the frame structure.

[0012] Connected in the accordance with the invention means that it can be connected structurally, directly, indirectly and/or functionally. For example, the control unit can be attached to the frame structure and/or to a manifold discussed below or another component of the kit assembly. In all cases the control unit is connected to the frame structure. Providing control unit for controlling the burner for hydrogen combustion has the advantage that the installer does not need to adapt and/or to exchange the control unit of the combustion appliance. Thus, there is no risk that hydrogen combustion will be controlled on the basis of control signals sued for hydrocarbon gas combustion avoiding risky situations. The connection of the control unit and the frame structure can be such that the control unit is moved when the frame structure is moved. A firmly connection between the control unit and the frame structure means that if one of said components is moved the other component is also moved.

[0013] Thanks to the retrofit kit assembly, it is possible to convert a combustion appliance such as a hydrocarbon gas boiler into a hydrogen gas boiler in a very easy and safe way while reducing human error by way of the concept of prevention through design. The retrofit kit assembly according to the invention is in addition simple and inexpensive. In other words, the conversion can be realized in a very short time and only requires replacing a minimum number of components. In particular, it is not necessary to connect or disconnect a plurality of cables and/or to attach or detach a plurality of sensors which can lead to defects such as errors in part setup, missing parts, wrong parts, adjustment errors, mis-operation, or not following procedures due to human errors connected to these defects, in particular forgetfulness, inexperience and misidentification and above all inadvertent error which is strongly connected to most of these defects. Thus, the retrofit kit assembly according to the invention reduces a number of human error sources such as inadvertent error, misunderstanding, forgetfulness, misiden-

tification, and inexperience by reducing the number of parts to be disconnected, replaced and connected to a minimum. In fact, the present retrofit kit assembly is ready to be mounted in a combustion appliance, in particular a (natural) gas boiler, by simply fixing the frame structure to a suitable housing of the combustion appliance. In addition, the modular nature of the assembly allows the possibility to provide a combination of different components suitable for a hydrogen gas combustion appliance depending on and optimized to the configuration and working principle of the respective (natural gas) combustion appliance to be converted. Thus, the retrofit-kit assembly according to the invention has overall lower skill-requirements for the conversion which leads to increased safety and reduced conversion time.

[0014] The retrofit kit according to the invention allows a constructively easy pre-determined orientation of the location of the manifold structure, in particular of the first and second connection, and thereby provides a technical behaviour-shaping constraint in view of safety critical parts for the combustion of hydrogen, thereby reducing safety risks, such as the incorrect connection of hydrogen and air.

[0015] Such an embodiment has the advantage that it also can ensure in an easy way that the requirements of the hydrogen-fire gas appliance guide PAS4444:2020 are fulfilled according to which a post blower mixing is needed. For this purpose, in the present retrofit kit assembly the manifold structure is provided with a connection for fuel gas (i.e. for a gas valve) that is located downstream the connection for receiving air (i.e. for a fan element). Downstream refers to the air flow in the manifold. The embodiment has the further advantage, that misidentification, forgetfulness, or inadvertent error are further reduced by way of product design, thus reducing defects caused by not following procedures, missing or wrong parts, improper setup, and errors in part setup itself.

[0016] In an alternative embodiment a pre blower mixing is possible. In that case the manifold structure is provided with a connection for fuel gas, in particular for a gas valve, that is located such that fuel gas is sucked by a fan. Thus, the fan has to consist of spark-free material.

[0017] In another embodiment, the burner can be connected or is connected to the manifold structure at the outlet portion for receiving a gas mixture to be combusted. Thus, a compact shape retrofit kit assembly is achieved. In addition, this embodiment has the advantage that relevant parts are pre-mounted in production, which allows for thorough quality testing and thus leads to a lower number of parts needing to be assembled and tested during conversion. This decreases set-up time even further with associated reduction in set-up errors and thus even further improved quality and safety. In this embodiment in addition, a functional connection can be by way of at least one signal of the control unit during setup which confirms the proper hydrogen parameter settings of the to the installer.

[0018] A gas burner configured for hydrogen needs be able to work at full power when there is a high heat demand. The gas burner should also be able to work at a lower power level, for example at 50% or 25% or 20% or 10% of the maximum power level, when there is only a low heat demand. another property of hydrogen is that the combustion temperature is about 300°C higher than the combustion temperature of methane. The burner deck temperature needs to stay below 585°C, the auto-ignition temperature of hydrogen at all times. In addition, a stable flame needs to be present taking account the high flame speed of hydrogen.

[0019] The burner deck geometry can be adapted such that the temperature stays below the auto-ignition temperature of hydrogen at all times and that avoids a flame lift off. This can be achieved for example by a burner deck that comprises a sheet enclosing a chamber and having at least one protrusion with a through hole. The through hole is fluidically connected with the chamber wherein the protrusion comprises a concave section and/or a convex section, in particular concave section and convex section.

[0020] Due to this configuration of the protrusion, i.e. the presence of a concave section and a convex section, the flame front is maintained not so far from the burner deck - under the limit of the lift flame - and at the same time not so anchored on the deck surface - over the limit of the back flame. In this way, the burner deck according to the present invention focuses on a reduction of the risk of flashback and facilitates the lift instead of maintaining the flame attached to the burner. This is especially useful when employing a highly reactive gas, such as hydrogen, as fuel gas.

[0021] The concave and convex sections determine a particular aerodynamic of the protrusion and the corresponding through hole. In particular, a sort of Venturi effect is created when the gas mixture passes through the protrusion from the chamber of the burner to outside the gas burner. This aerodynamic helps the mixed flow to pass with a reduced local pressure loss and the flow is guided towards the outside without any recirculation. Additionally, the gas mixture that passes through the through hole of the protrusion maintains the temperature below the auto-ignition of the fuel gas, i.e. hydrogen. There are no local pressure drops that could cause hot spots, like it happens with the thin edge of a natural gas burner deck that has an anchoring effect for the flame. In this way, a flame lifting behaviour is prioritized instead of an anchor-feature. Accordingly, using such burner deck, a better fluid dynamic and thermal behaviour is obtained when and where the gas expands due to the combustion.

[0022] Additionally or alternatively, the protrusion can protrude in a direction away from the chamber. In particular, the protrusion comprises a proximal portion close to the sheet, a distal portion away from the sheet and a middle portion located between the proximal and the distal portion. It is noted that the concave section of the

protrusion includes the proximal portion and can include a part of the middle portion, whereas the convex section includes the distal portion and can include another part of the middle portion. Specifically, the transverse cross section of the distal portion, in particular at an end distal to the middle portion, is larger than the transverse cross section of the middle portion, and preferably the transverse cross section of the distal portion, in particular at an end distal to the middle portion, is larger than the transverse cross section of the middle portion and/or proximal portion, in particular at an end distal to the middle portion.

[0023] In the concave section the area of the transverse cross section is decreasing in a direction away from the chamber. In the middle section, the area of the transverse cross section is, in particular essentially, constant in the direction away from the chamber. In the convex section, the area of the transverse cross section is increasing in the direction away from the chamber. The transverse cross section corresponds with a plane that is orthogonal to a central axis of the protrusion.

[0024] Advantageously, the protrusion can have a Venturi shape and/or a double truncated cone shape. This is advantageous for further limiting the flashback. The concave section and the convex section can be arranged coaxially. Additionally, the burner deck is configured such that the gas-air mixture can merely flow out through the protrusion from the chamber to a combustion chamber of the gas burner.

[0025] In a further embodiment, the protrusion can extend over a length comprised between 15% to 25%, preferably 20%, of a thickness value of the sheet of the burner deck, in particular in radial direction with respect to a burner central axis. In this way, the risk of flashback is further reduced.

[0026] In an embodiment, less than 20%, in particular less than 19%, or less than 15%, for example less than 12.0% or for example less than 10.0% of the surface area of the burner deck is formed by a combined surface area of the holes. More than 5.0% of the surface area of the burner deck is formed by a combined surface area of the holes. Less than 7.0%, for example less than 5.0% or for example less than 4.0% of the surface area of the burner deck is formed by a combined surface area of the holes. More than 1.0% of the surface area of the burner deck is formed by a combined surface area of the holes. By having less than 20% of combined surface area of the holes, a stable combustion of hydrogen can be achieved even when modulating the gas burner, i.e. when changing the power level. A preferred range of the combined surface area of the holes is less than 20% and more than 15%, in particular less than 19% and more than 16%.

[0027] By providing a combined surface area of the holes in the burner deck of less than 20%, in particular less than 19%, or less than 15%, but more than 1%, preferably more than 5%, low NO_x is generated when hydrogen is combusted.

[0028] In this matter it is to be mentioned that simply providing hydrogen to the known gas burner would not

be successful. One of the reasons that this would not be successful is because of a difference in flame speed. Thus, the flow rate of the air-hydrogen mixture through the openings has to be chosen such that the combustion of the hydrogen can be stabilized on the burner deck of the gas burner. Another property of hydrogen that has to be considered is that the combustion temperature is about 300°C higher than the combustion temperature of methane. Thus, the burner deck becomes much too hot for materials typically used in gas burners. In particular, the burner deck can reach a temperature of about 585°C, so that hydrogen can auto-ignite.

[0029] Saying the aforementioned changing the amount of flow of the air-hydrogen mixture through a known gas burner, would cause one of 3 situations: i) there is too little flow, so the flash-back occurs, ii) there is too much flow, so no stable flame is created, because the flame is pushed too far away from the burner deck, or iii) a stable flame is created on the burner deck, but the temperature becomes too high as described above

[0030] For example, the frame structure can be fixable to the housing of a heat exchanger present in a combustion appliance, in particular a (natural) gas boiler. Generally speaking, a heat exchanger facilitates the transfer of heat derived from the combustion of fuel gas and air present in circulating conduits. Therefore, the housing of the heat exchanger usually contains the burner of the combustion appliance, in particular gas boiler, for combusting the fuel gas. It is noted that the main factors distinguishing a natural gas combustion appliance from a hydrogen gas combustion appliance are related to the combustion aspects of the fuel gas and that the functioning of the heat exchanger itself remains basically the same. Therefore, the present retrofit kit assembly is used to replace fundamental components for the combustion, such as the burner or a flame detection means, in order to convert a natural gas combustion appliance to a hydrogen gas combustion appliance. For instance, the present retrofit kit assembly comprises a burner configured for hydrogen gas combustion.

[0031] Additionally, as is discussed below the retrofit kit assembly can comprise a UV-sensor for flame detection. The burner configured for hydrogen combustion can preferably be fixed to the frame structure. The retrofit kit assembly reduces the work amount for converting the combustion appliance to a hydrogen combustion appliance and reduces the danger that the retrofit kit assembly is assembled incorrectly.

[0032] The frame structure comprises a first portion and a second portion, wherein the burner is fixed to said first portion. The second portion extends longitudinally from the first portion. The frame structure being shaped as to cover at least partially, in particular fully, the housing, in particular a burner chamber, of the combustion appliance. In particular, the frame structure, and specifically the second portion of the frame structure is formed as a plate i.e. as a front cover for the internal housing of the combustion appliance.

[0033] In case the internal housing is the housing of a heat exchanger, the frame structure can work as a front cover of said heat exchanger. In particular, the first portion of the frame structure is interposed, in particular in flow direction of the air and fuel gas mixture, between the burner and the outlet portion of the manifold structure. This increases the compactness of the retrofit kit assembly. This has the additional advantage that it facilitates proper placement and detection of errors is simplified even further due to the fact that already the frame structure itself ensures proper placement of the retrofit kit assembly according to the invention and, thus, avoids misplacement by an installer. Given that the frame structure is a comparatively large structure, any misalignments or misplacements are at the same time made harder to do and at the same time makes detection very easy without requiring an in-depth analysis as would be required if all connections undone and done would need to be inspected to detect a defect in the conversion setup.

[0034] A further advantage is that fewer individual parts need to be connected and disconnected and thereby further reducing potential errors, in particular in making a proper connection, or connecting the right parts.

[0035] Fuel gas can comprise more than 20 mol% hydrogen. In particular, fuel gas can comprise more than 50 mol%, in particular more than 90 mol% hydrogen or be pure hydrogen. Pure hydrogen is defined as comprising at least 98 mol% hydrogen (hydrogen-fire gas appliance guide PAS4444:2020). Natural gas is a naturally occurring hydrocarbon gas mixture, comprising methane and commonly further comprising varying amounts of among others higher alkanes, carbon dioxide, nitrogen, hydrogen sulfide or helium. The hydrocarbon gas can also comprise or consist of propane.

[0036] The control unit can be a processor or comprise at least one processor. Additionally, the control unit can comprise printed circuit board.

[0037] According to an embodiment, the retrofit kit can optionally further comprise a burner configured for hydrogen combustion fixed to the frame structure. Thereby, more components can be mounted during production, further reducing the time needed for conversion and further reducing the risk of human error in assembly.

[0038] In a further embodiment, the retrofit kit comprises a manifold structure comprising means for providing an air/gas mixture and the manifold structure further comprising an inlet portion and an outlet portion, wherein the inlet portion is configured to receive the air/gas mixture and wherein the inlet portion comprises a first connection for receiving at least fuel gas, and a second connection located downstream from the first connection and wherein the outlet portion is arranged such that the air/gas mixture exits the manifold structure through the outlet portion and wherein the outlet portion is connected to the frame structure

[0039] The first connection can be integrally connected to the manifold structure and/or can protrude from the manifold structure. This has the additional advantage that

the retrofit kit assembly can be optimized either for mounting space or for further facilitation of the conversion by allowing for ease of access and recognition of the connection, e.g. in case of reduced visibility due to the original setup of the (natural) gas boiler to be converted.

[0040] According to an embodiment, the burner can be connectable or connected to the manifold structure at the outlet portion for receiving a gas mixture to be combusted.

[0041] According to an embodiment, the frame structure can cover the burner chamber in a sealing manner. Additionally or alternatively, the frame structure comprises a first portion and a second portion, wherein the burner is fixed to said first portion and the second portion extending longitudinally from the first portion, wherein the first portion of the frame structure is interposed between the burner and the outlet portion of the manifold structure.

[0042] According to the embodiment, the manifold structure can comprise a suppressor structure. The suppressor structure can be used to reduce the noise and/or the impact of flashback and/or can be an inlet silencer.

[0043] The first connection can be integrally connected to the manifold structure and/or can protrude from the manifold structure. This has the additional advantage that the retrofit kit assembly can be optimized either for mounting space or for further facilitation of the conversion by allowing for ease of access and recognition of the connection, e.g. in case of reduced visibility due to the original setup of the (natural) gas boiler to be converted.

[0044] The retrofit kit assembly can comprise a gas valve fixed at the first connection of the manifold structure and connectable to a gas conduit. This has the additional advantage that the safety is even further increased as even fewer connections need to be made as the gas valve will only have to be connected to the (natural) gas boiler to be converted. Therefore, even more connections can be quality controlled already during production of the retrofit kit assembly itself. This further reduces defects caused by human error, such as inadvertent error, inexperience, misidentification, or forgetfulness and thereby further reduces defects in the gas valve connection safety.

[0045] Additionally, the retrofit kit assembly can comprise a fan element fixed to the second connection of the manifold structure and connectable at least to an air conduit. This has the additional advantage that orientation and location of the fan element is predetermined such that the requirements of the hydrogen-fire gas appliance guide PAS4444:2020 are fulfilled by ensuring that ambient air is always sucked in in sufficient concentration / as needed. Additionally, it is prevented that an operator connects the fan element to wrong connection, namely the first connection resulting in pre blower mixing.

[0046] It is noted that the gas valve is hydrogen ready. Due to the small size of hydrogen molecules, conventional gas valves are prone to leak. Therefore, the gas valve used in the present retrofit kit assembly is more leak tight compared to the commonly used burners for

natural gas. For example, to reach the same load with hydrogen compared to natural gas, the volume flow of gas is about three times bigger. Similarly, the fan element is hydrogen ready, meaning that no electro-static discharge is present. In case of hydrogen comprising fuel gas combustion electrostatic discharge can lead to unwanted ignition of the fuel gas.

[0047] To improve the safety even further, the manifold structure can comprise a, in particular Venturi shaped, mixer placed downstream the second connection, i.e. downstream the fan element. In this way, the volume of explosive hydrogen-air mixture is reduced. Since the air and gas flows in hydrogen combustion appliances might differ from the natural gas combustion, the, in particular Venturi shaped, mixer is configured to handle these flows without too much pressure drop. In this case the mixer is the means for providing the air/gas mixture.

[0048] In a particular example, to further improve safety, the gas valve is, in particular directly connected, to the, in particular Venturi shaped, mixer. That means, no further components are arranged in the gas flow path between the gas valve and the mixer. In this embodiment, even fewer parts need to be assembled during conversion making mounting even simpler and further reducing mounting errors.

[0049] For a natural gas combustion appliance, a certain working principle can be chosen, i.e. a pneumatic system or an electronic controlled system. For the conversion towards hydrogen gas the same working principle can be maintained or the working principle can be switched from pneumatic towards electronic or the other way around from electronic towards pneumatic. For this reason, the gas valve can be controlled electronically or pneumatically. Additionally, the fan and the gas valve can be controlled by the same electrical control unit or by separate control units.

[0050] Most of the current natural gas combustion appliances, in particular boilers, make use of an ionization probe to detect the flame. For hydrogen gas combustion appliances, it is not possible to use this ionization sensor to detect the flame due to the absence of carbon containing components in the gas mixture. Therefore, in one example, the assembly further comprises a flame detector sensor, in particular a UV sensor and/or a thermal sensor, wherein the flame detector is located at the outlet portion of the manifold. The ionization probe is the conventional flame detector for hydrocarbon combusting heating appliances, however, ionization probes do not detect hydrogen flames correctly or at all, in particular at high hydrogen concentrations. In particular when pure hydrogen is used, the flame can no longer be detected using a ionization probe. Therefore, a retrofit kit assembly comprising a UV sensor contains a further behavior-shaping constraint which facilitates that the correct safety critical sensor is included in the conversion without requiring additional checks and tests during conversion.

[0051] Alternatively or additionally, the assembly can comprise at least one of an optical sensor, a temperature

sensor, a thermocouple or a catalytic sensor to function as flame detector. To improve the safety of the combustion appliance for which the present retrofit kit assembly is configured, the assembly can further comprise a thermocouple placed in the burner.

[0052] The retrofit kit assembly can comprise at least one, in particular more than one, sensor. The sensor can be a hydrogen detector. Alternatively, the sensor can be an oxygen sensor and/or flow sensor and/or a temperature sensor and/or a thermocouple and/or a catalytic sensor. The sensor or sensors can be used to detect the presence of hydrogen, in particular, the leakage of hydrogen which increases the safety in a simple and reliable way.

[0053] Alternatively or additionally, it is possible to control the combustion based on the sensor signals. For example, for an electronic controlled system, it is important to monitor the air to fuel ratio (λ) and to control the combustion appliance based on that ratio. For this purpose, flow sensors, thermal conductivity sensors, O_2 sensor, UV sensor or temperature sensor/thermocouple, or catalytic sensor can be used instead of or additionally to a ionization electrode commonly used in natural gas combustion appliances.

[0054] The outlet portion can comprise at least one receive portion for receiving a flame detector sensor and/or a sensor as discussed above. The manifold can also comprise a receive portion for receiving the sensor. In particular, the manifold can comprise a first receive portion for receiving a sensor. The sensor can be gas flow sensor for sensing a gas flow. The manifold can also comprise a second receive portion for receiving a sensor. The sensor can be an air flow sensor for sensing an air flow.

[0055] Also, the combustion appliance can comprise control components, in particular connecting cables, for the connection of the at least one of the above-mentioned additional components (i.e. flow sensors, thermal conductivity sensors, oxygen sensor, UV sensor or temperature sensor/thermocouple, or catalytic sensor) to the combustion appliance.

[0056] In one example, the frame structure is provided with a plurality of through holes arranged along the perimeter of the frame structure for receiving connecting means, in particular screws, to fix said frame structure to the internal housing of the combustion appliance, i.e. to the housing of the heat exchanger. In addition or alternatively, to cope with possible noise issue, the assembly can further comprise a suppressor structure provided at the inlet portion of the manifold. The suppressor structure is used to reduce the noise.

[0057] For hydrogen gas combustion appliance, a different burner is usually provided compared to the burners of natural gas combustion appliances. Since the flame speed of hydrogen is higher than for natural gas, the burner is more prone to flashbacks. Therefore, according to one example, the burner is suitable for hydrogen combustion. In this way, the outflow velocity can be config-

ured to be greater than the flame speed. In another example, the burner can be suitable for the combustion of both natural gas and hydrogen.

[0058] At the end a retrofit kit assembly is provided by means of which a natural gas combustion appliance can be retrofitted to a hydrogen gas combustion appliance. The retrofit kit assembly is configured in the aforementioned manner in order to reduce leakage and/or explosion risks.

[0059] According to one aspect of the invention, a combustion appliance and more particularly for a condensing gas boiler, is provided, the combustion appliance comprising an inventive retrofit kit assembly that is fixed to the housing. According to another aspect of the invention, a combustion appliance comprises a housing that has an interface configured to be connected with the retrofit kit assembly. The interface can be a mechanical interface so that the retrofit kit assembly can be mechanically connected to the housing of the combustion appliance. The connection can be a form-fitting or force fitting connection. In particular, the connection can be releasable. That means the connection can be released without destroying the retrofit kit assembly and/or the housing.

[0060] 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 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.

[0061] To improve the safety and to monitor important parameters during the functioning of the appliance, the at least one flame detector sensor and/or least one sensor be positioned such on the retrofit kit assembly that they sense physical values from the burner chamber. The burner chamber is at least partly delimited by the housing of the combustion appliance.

[0062] The retrofit kit assembly can comprise means for fixing the kit assembly to the housing, in particular the interface of the housing, of the combustion appliance. Accordingly, an operator would have all the required elements for converting a natural gas combustion appliance into a hydrogen combustion appliance.

[0063] The retrofit kit assembly can comprise a cable, in particular being part of a cable harness, that is electrically connected with at least one component of the kit assembly. Alternatively the kit assembly comprises a cable, in particular being part of a cable harness, that is electrically connected with at least one component of the kit assembly and is connectable with an electrical component of the combustion appliance. This has the further advantage that it prevents in a safe and easy manner that the wrong cable is connected to the wrong port on the PCB, resulting for example in a short cut. It also pre-

vents that a sensor is connected to the wrong port resulting in faulty data and thus can lead to either a non-functioning boiler or poses a safety risk.

[0064] In a further aspect of the invention, a combustion appliance, in particular a gas boiler, and more particularly a condensing gas boiler, is provided, wherein the kit assembly according to the invention and a housing is provided, wherein the combustion appliance comprises a combustion chamber wherein the kit assembly is fixed to the housing. Additionally or alternatively, a combustion appliance is provided with a housing comprising an interface configured to be connected with the retrofit kit assembly according to the invention.

[0065] In a further aspect of the invention, the use of the inventive retrofit kit assembly for converting a hydrocarbon gas combustion appliance into a combustion appliance for the combustion of pure hydrogen is provided. By using the present retrofit kit assembly, the combustion appliance conversion can be easy to realize and can be carried out in a very short time (for example less than one hour). Also, the conversion can be safe and effective for the operation of a hydrogen combustion appliance.

[0066] In another aspect of the invention, a method for retrofitting a combustion appliance, in particular a gas boiler, and more particularly for a condensing gas boiler, is provided. The combustion appliance has a burner for combusting a gas mixture including gaseous hydrocarbons, in particular natural gas or propane, and the method comprises:

removing a front cover from an internal housing of the combustion appliance and removing the burner, installing an inventive retrofit kit assembly in the combustion appliance by fixing the frame structure to the internal housing of the combustion appliance. The poka-yoke behavior-shaping constraints by way of contact, meaning the use of shape, size, or other physical attributes for detection, ensures that the right conditions exist before a process step is executed, and thus preventing defects from occurring in the first place. The value of using the poka-yoke is that they help people and processes work right the first time, which prevents in a simple and reliable way an improper part setup.

[0067] Optionally, the method can further comprise the step of updating the setting parameters of the combustion appliance for the combustion of pure hydrogen. By updating of setting parameters an improper operation can be prevented..

[0068] In one example, updating the setting parameters occurs automatically by detecting the presence of hydrogen being above a predetermined value, in particular 20 mol% or pure hydrogen, in the gas mixture. This can be carried out by measuring the amount of hydrogen in the gas mixture using for example a hydrogen detector conveniently placed in the combustion appliance. In another example, updating the setting parameters can occur

automatically by connecting an additional sensor to the appliance. In a further example, updating the setting parameters can occur by detecting the absence of a ionization signal and by detecting a flame detection signal generated by a flame detector, in particular a UV sensor and/or a thermal sensor, and/or a ionization probe.

[0069] 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 retrofit kit assembly according to an embodiment of the invention.

Figure 2 shows a perspective representation of the retrofit kit assembly according to another embodiment of the invention.

Figures 3A-B show a front view and a rear view of the retrofit kit assembly of Figure 2.

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

[0070] With reference to Figure 1, a retrofit kit assembly 1 is shown. The assembly 1 comprises at least a frame structure 5, a manifold structure 10 and a burner 6 for the combustion of hydrogen. The manifold structure 10 serves to distribute the gas mixture and comprises an inlet portion 11 and an outlet portion 12. As can be shown in figure 2, the manifold structure 10 is integrally connected to the frame structure 5 at the outlet portion 12. The frame structure 5 has the shape of a plate and extends orthogonally from the manifold structure 10. In particular, the frame structure 5 comprises a first portion 7 and a second portion 14, wherein the frame structure 5 is connected to the manifold structure 10 at the first portion 7. It is noted that the second portion 14 extends longitudinally from the first portion 7. The retrofit kit 1 further comprises a control unit 23 configured to control a burner 6 configured for hydrogen combustion wherein the control unit 23 is connected to the frame structure 5. In particular, the control unit 23 is attached to the manifold structure 10.

[0071] The burner 6 is fixed to the frame structure 5 at the first portion 7. The burner 6 can be fixed to the frame structure 5 through suitable connecting means, such as screws or can be integrally connected to the frame structure 5 by welding. It is clear that at the connection region between the burner 6 and the frame structure 5, the first portion 7 of the frame structure 5 comprises at least an opening (not shown in the figure) for allowing the gas mixture coming from the manifold structure 10 to flow into the burner 6 for the combustion.

[0072] The inlet portion 11 of the manifold structure 10 is provided with a first connection 4 for receiving at least

a first fluid, i.e. fuel gas (vertical arrow in the figure), and with a second connection 17 for receiving at least a second fluid, i.e. air (horizontal arrow in the figure). It is noted that the first connection 4 is located downstream the second connection 17 with respect to the air flow. Also, the first connection 4 is integrally connected to the manifold structure 10 and protrudes (extends longitudinally) from the manifold structure 10.

[0073] As mentioned above, the burner 6 is suitable for combustion of hydrogen. In this way, the retrofit kit assembly 1 can be used to convert a gas boiler such as a natural gas boiler into a hydrogen boiler. In fact, the retrofit kit assembly 1 can be coupled to a housing 3 of a combustion appliance 2. For example, the combustion appliance 2 can be a gas boiler, in particular a natural gas boiler, and the housing 3 can be the housing of a heat exchanger of the gas boiler. Specifically, the frame structure 5 of the retrofit kit assembly 1 can be fixed to a burner chamber 18 delimited by the housing 3. In particular, the burner chamber 18 is arranged within the housing and comprises an opening that is covered by the retrofit kit assembly 1, in particular by the frame structure 5.

[0074] The retrofit kit assembly 1 consists of different components, which are connected to each other and in some cases are integrated in one single block element (i.e. the manifold structure 10, the frame structure 5 and the first connection 4). In this case, it is easy to replace the elements of the gas boiler to be converted with the present retrofit kit assembly 1. Specifically, the burner (i.e. from a burner suitable only for natural gas combustion to a burner suitable for pure hydrogen) as well as the arrangement of the connections for the inlet of gas and air (for hydrogen boilers, it is preferred a post blower mixing) are changed in order to carry out the conversion. The operator can simply remove the components to be replaced, i.e. the burner and the manifold, and fix the retrofit kit assembly 1 to the combustion appliance 2 (gas boiler), thereby modifying the general operation of the appliance.

[0075] Figure 2 illustrates a perspective view of the retrofit kit assembly 1 according to an example. The retrofit kit assembly 1 of figure 2 further comprises a gas valve 13 and a fan element 8. The gas valve 13 is fixed to the first connection 4 and is connected to a gas conduit 15 whereas the fan element 8 is fixed to the second connection 17 and is fluidically connected to ambient air. This particular arrangement of the first and second connections, i.e. of the gas valve 13 and the fan element 8, allows a post blower mixing of the fuel gas before entering into the burner 6 through the manifold structure 10. In order to reduce the noise, a suppressor structure 20 can optionally be provided at the inlet portion 11, for example at the fan element 8. More details of this advantageously arrangement can be gathered from figures 3A and 3B that illustrate a front view and a rear view of the retrofit kit assembly of figure 2. In this embodiment the control unit 23 is attached to the frame structure 5, in particular

to the second portion 14 of the frame structure 5. In both embodiments the control unit 23 is firmly connected to the frame structure 5 so that the control unit 23 moves together with the frame structure 5 when the retrofit kit assembly is moved.

[0076] From the figures it is also clear the characteristics of the frame structure 5. The frame structure 5 is shaped like a plate or wall and can have a double function. In fact, the frame structure 10 can be used as a support element for the burner 6, the manifold structure 10 (and the components connected to the manifold structure 10) and can be used, at the same time, as a front cover for the housing 3 of the combustion appliance 2.

[0077] As shown in figure 2, the housing 3 is the housing of a heat exchanger of a gas boiler. The frame structure 5 is shaped to fit the edges of the housing 3 and to completely cover the burner chamber 18. When the retrofit kit assembly 10 is fixed to the housing 3, the burner 6 is inserted in the burner chamber 18, thereby replacing a burner previously present in the combustion appliance, i.e. in the housing of the heat exchanger. On the other hand, after fixing the retrofit kit assembly 10 to the housing 3, the manifold structure 10 and the components connected to the manifold structure 10 (i.e. the gas valve 13 and the fan element 8) are located outside the housing 3, thereby allowing possible connections for example with the gas conduit 15 and ambient air.

[0078] The fixing occurs through suitable connecting means, such as pins or screws. For this purpose, the frame structure 5 is provided with a plurality of through holes 19 arranged along the peripheral border of the frame structure 5, as clearly shown in figures 3A and 3B. Likewise, the housing 3 is provided with the plurality of through holes 19.

[0079] 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.

[0080] At step S101, the method 100 comprises the step of removing a front cover from the housing 3 of the combustion appliance 2 and removing the burner. For example, at the step S101 the front cover of a heat exchanger is removed. At step S102, the method 100 comprises installing a retrofit kit assembly 1 as described in figures 1 to 3B in the combustion appliance 2. In particular, the step S102 occurs by fixing the frame structure 5 of the retrofit kit assembly 1 to the housing 3 of the combustion appliance 2, for example to the housing of the heat exchanger. At step S103, the method 100 comprises updating the setting parameters of the combustion appliance 2 for the combustion of pure hydrogen.

Reference Signs

[0081]

1. Retrofit kit assembly

- 2. Combustion appliance
- 3. Internal housing
- 4. First connection
- 5. Frame structure
- 6. Burner 5
- 7. First portion
- 8. Fan element
- 9. Air conduit
- 10. Manifold structure 10
- 11. Inlet portion
- 12. Outlet portion
- 13. Gas valve
- 14. Second portion
- 15. Gas conduit 15
- 16. Retrofit kit
- 17. Second connection
- 18. Opening
- 19. Through holes
- 20. Suppressor structure
- 23. Control unit 20

Claims

1. Retrofit kit assembly (1) for converting a hydrocarbon gas combustion appliance (2), in particular a gas boiler, and more particularly for a condensing gas boiler, to a combustion appliance for combustion of fuel gas comprising more than 20 mol%, in particular 30 mol%, hydrogen, the kit assembly (1) comprising:
 - a frame structure (5) fixable to a housing (3) of the combustion appliance (2) for, in particular fully, closing a burner chamber (18) of the combustion appliance (2); and
 - a control unit (23) configured to control a burner (6) configured for hydrogen combustion wherein the control unit (23) is, in particular firmly, connected to the frame structure (5).
2. Retrofit kit assembly (1) according to claim 1, **characterized in that** a manifold structure (10) is integrally connected to the frame structure (5) at an outlet portion (12) of the manifold structure (10) and/or protrudes from the frame structure (5).
3. Retrofit kit assembly (1) according to claim 2, **characterized in that** the retrofit kit (1) comprises a burner (6) configured for hydrogen combustion fixed to the frame structure (5) and/or the manifold structure (10).
4. Retrofit kit assembly (1) according to any one of the claims 1 to 3, **characterized in that** the manifold structure (10) comprises means for providing an air/gas mixture and the manifold structure (10) further comprising an inlet portion (11) and an outlet portion (12), wherein the inlet portion (11) is configured to receive the air/gas mixture and wherein the inlet portion (11) comprises a first connection (4) for receiving at least fuel gas, and a second connection (12) for receiving air and located downstream from the first connection (4) and wherein the outlet portion (12) is arranged such that the air/gas mixture exits the manifold structure (10) through the outlet portion (12) and wherein the outlet portion (12) is connected to the frame structure (5).
5. Retrofit kit assembly (1) according to any one of the claims 1 to 4, **characterized in that** the burner (6) is connectable or connected to the manifold structure (10) at the outlet portion (12) for receiving a gas mixture to be combusted.
6. Retrofit kit assembly (1) according to any one of the claims 1 to 5, **characterized in that**
 - a. the frame structure (5) covers the burner chamber (18) in a sealing manner and/or **in that**
 - b. the frame structure (5) comprises a first portion (7) and a second portion (14), wherein the burner (6) is fixed to said first portion (7) and the second portion (13) extending longitudinally from the first portion (7), wherein the first portion (7) of the frame structure (5) is interposed between the burner (6) and the outlet portion (12) of the manifold structure (10).
7. Retrofit kit assembly (1) according to any one of claims 1 to 6, **characterized in that** the manifold structure (10) comprises a suppressor structure (20).
8. Retrofit kit assembly (1) according to any one of claims 1 to 7, **characterized in that** the assembly (1) further comprises at least one of:
 - a. a gas valve (13) fixed to the first connection (4) of the manifold structure (10) and connectable to a gas conduit (15) that is fluidically connected with a fuel gas source; and
 - b. a fan element (8) fixed to the second connection (17) of the manifold structure (10).
9. Retrofit kit assembly (1) according to any one of claims 1 to 8, **characterized in that**
 - a. the manifold structure (10) comprises a, in particular Venturi shaped, mixer placed downstream the second connection (17) or
 - b. the manifold structure (10) comprises a, in particular Venturi shaped, mixer placed downstream the second connection (17) so that air and fuel gas are mixed downstream a fan element (8), in particular and before the mixture flows into the burner.

10. Retrofit kit assembly (1) according to claim 8 or 9, **characterized in that** the gas valve (13) is, in particular directly, connected to the, in particular Venturi shaped, mixer.
11. Retrofit kit assembly (1) according to any one of claims 8 to 10, **characterized in that** the gas valve (13) is controlled electronically or pneumatically.
12. Retrofit kit assembly (1) according to any one of claims 1 to 11, **characterized in that**
- the kit assembly (1) further comprises at least one flame detector sensor, in particular; and/or **in that**
 - the kit assembly (1) further comprises at least one sensor, in particular a hydrogen detector and/or an oxygen sensor and/or a flow sensor and/or a temperature sensor and/or a thermocouple and/or a catalytic sensor.
13. Retrofit kit assembly (1) according to claim 12, **characterized in that**
- the outlet portion (12) comprises at least one receive portion for receiving a flame detector sensor and/or a sensor and/or **in that**
 - the manifold comprises a receive portion for receiving the sensor and/or **in that**
 - the first connection (4) of the manifold comprises a first receive portion for receiving the sensor and/or **in that**
 - the second connection of the manifold comprises a second receive portion for receiving the sensor.
14. Retrofit kit assembly according to one of claims 1 to 13, **characterized in that** the frame structure (5) is provided with a plurality of through holes (19) arranged along the perimeter of the frame structure (5) for receiving connecting means, in particular screws, to fix said frame structure (5) to the housing (3) of the combustion appliance (2).
15. Retrofit kit assembly (1) according to one of claims 1 to 14, **characterized in that**
- the kit assembly (1) comprises a cable, in particular being part of a cable harness, that is electrically connected with at least one component of the kit assembly (1) or **in that**
 - the kit assembly (1) comprises a cable, in particular being part of a cable harness, that is electrically connected with at least one component of the kit assembly (1) and is connectable with an electrical component of the combustion appliance (2).
16. Combustion appliance (2), in particular a gas boiler, and more particularly a condensing gas boiler, comprising
- the kit assembly (1) according to any one of claims 1 to 15 and a housing (3) with a combustion chamber (18) of the combustion appliance (2) wherein the kit assembly (1) is fixed to the housing (3) and/or
 - a housing (3) comprising an interface configured to be connected with the retrofit kit assembly (1) according to any one of the claims 1 to 15.
17. Use of a retrofit kit assembly (1) (1) according to any one of claims 1 to 15 for converting a hydrocarbon gas combustion appliance into a combustion appliance for the combustion of fuel gas comprising at least or more than 20 mol% hydrogen.
18. Method (100) for retrofitting a combustion appliance (2), in particular a gas boiler, and more particularly for a condensing gas boiler, having a burner for combusting a gas mixture including hydrocarbon gases, the method comprising:
- removing (S101) a front cover from an internal housing (3) of the combustion appliance (2) and removing the burner,
installing (S102) a retrofit kit assembly (1) according to any one of claims 1 to 15 in the combustion appliance (2) by fixing the frame structure (5) to the housing (3) of the combustion appliance (2).
19. Method (100) according to claim 18, **characterized in that**
- updating (S103) the setting parameters of the combustion appliance (2) for the combustion of fuel gas comprising more than 20 mol % hydrogen, and/or
 - updating (S103) the setting parameters occurs, in particular automatically, by detecting the presence of fuel comprising more than 20 mol% hydrogen in the gas mixture, and/or
 - updating (S103) the setting parameters occurs automatically by connecting an additional sensor to the appliance (2), and/or
 - updating (S103) the setting parameters occurs by detecting the absence of a ionization signal and by detecting a flame detection signal generated by a flame detector, in particular a UV sensor and/or a thermal sensor.

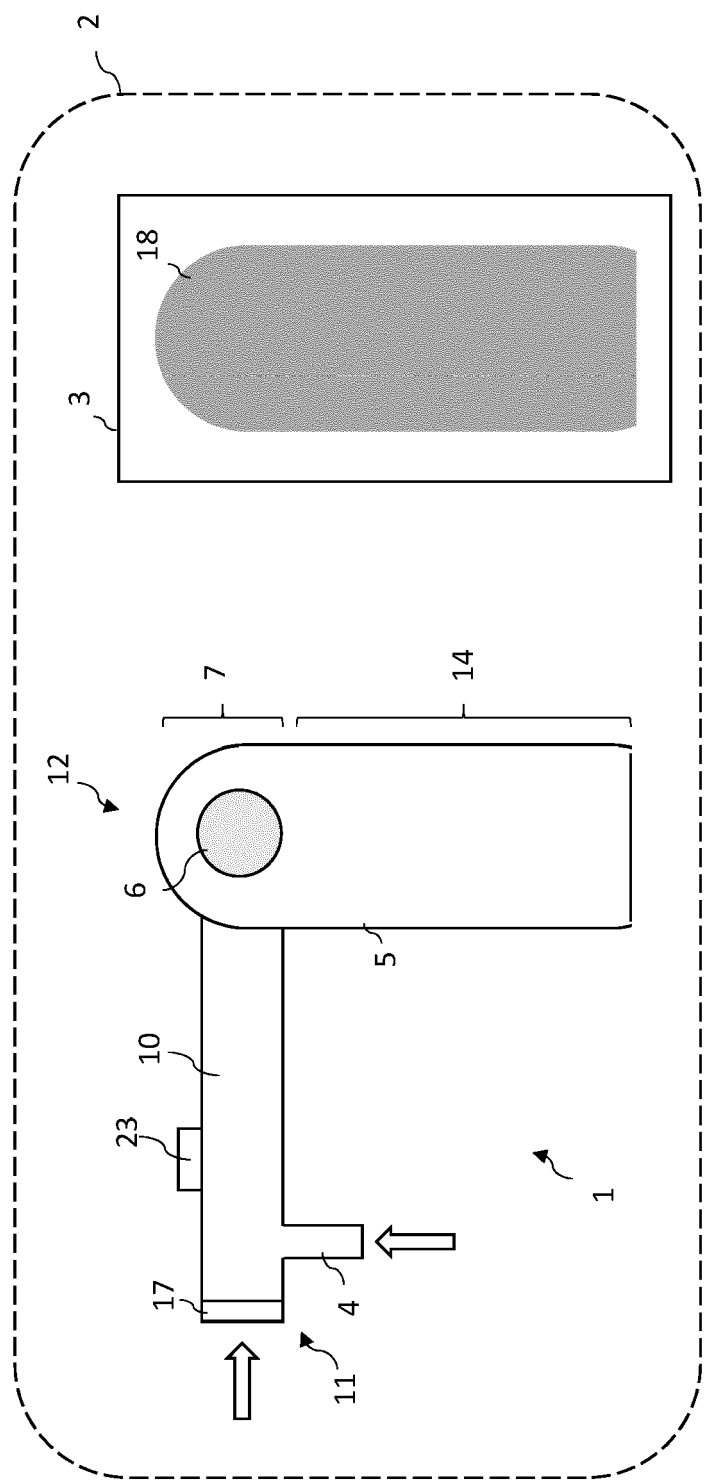


Fig. 1

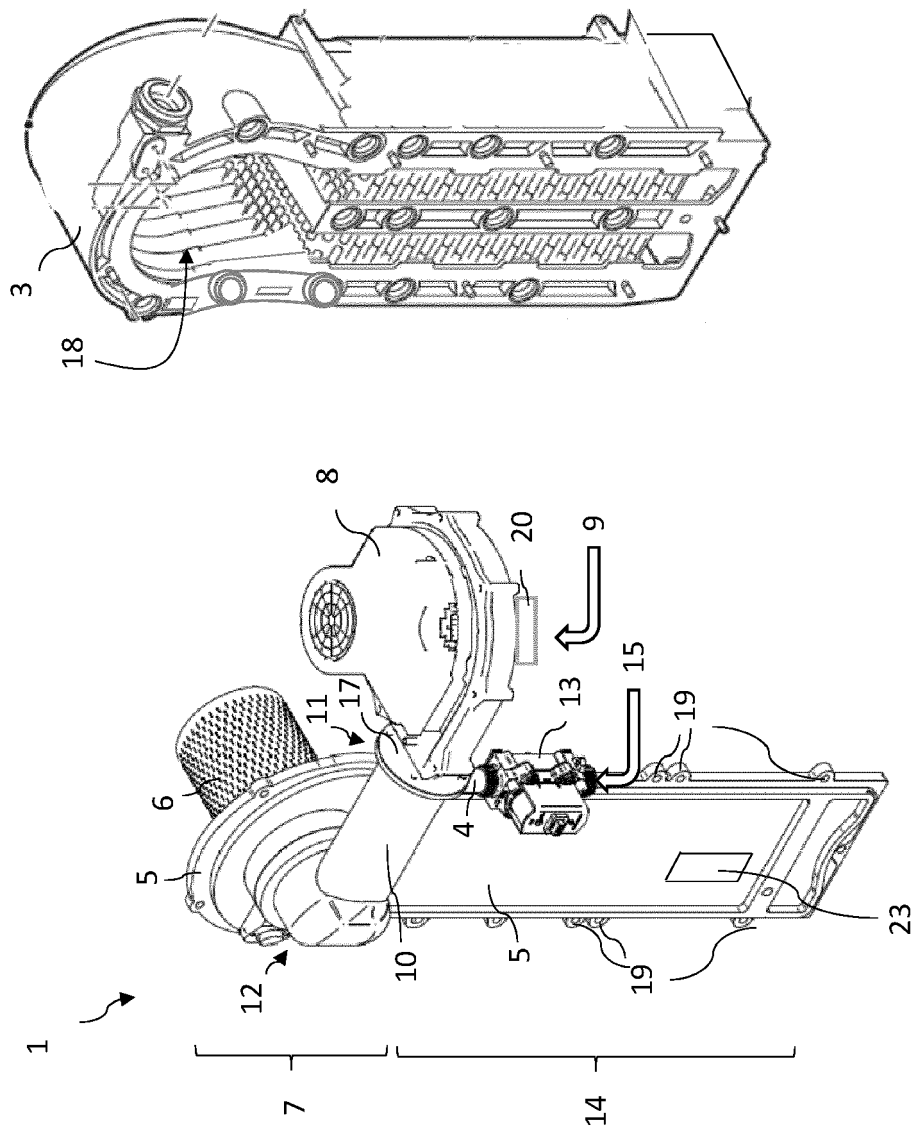


Fig. 2

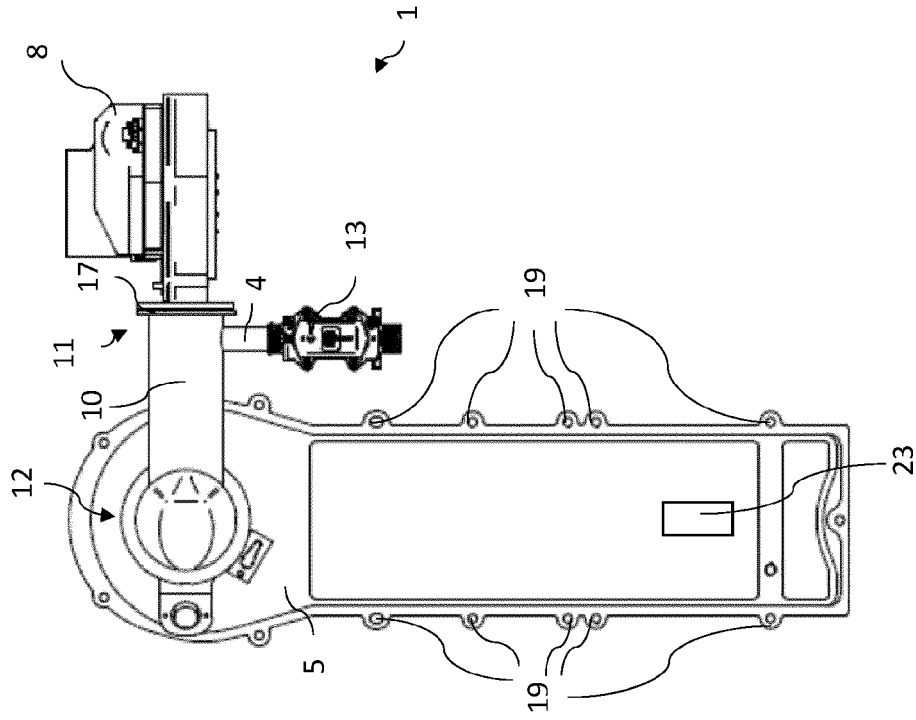


Fig. 3B

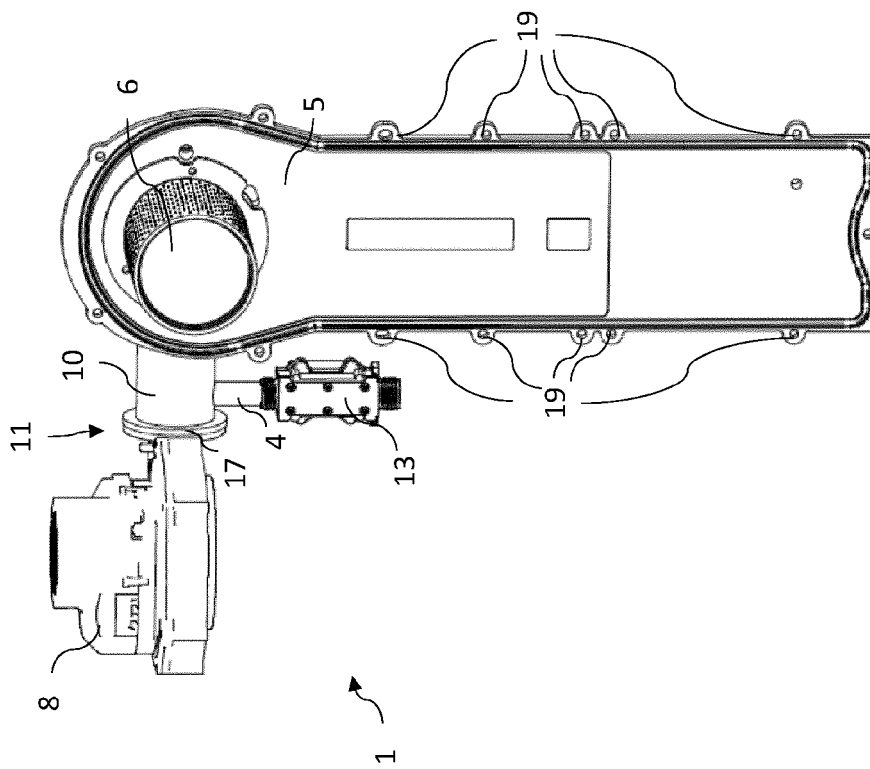


Fig. 3A

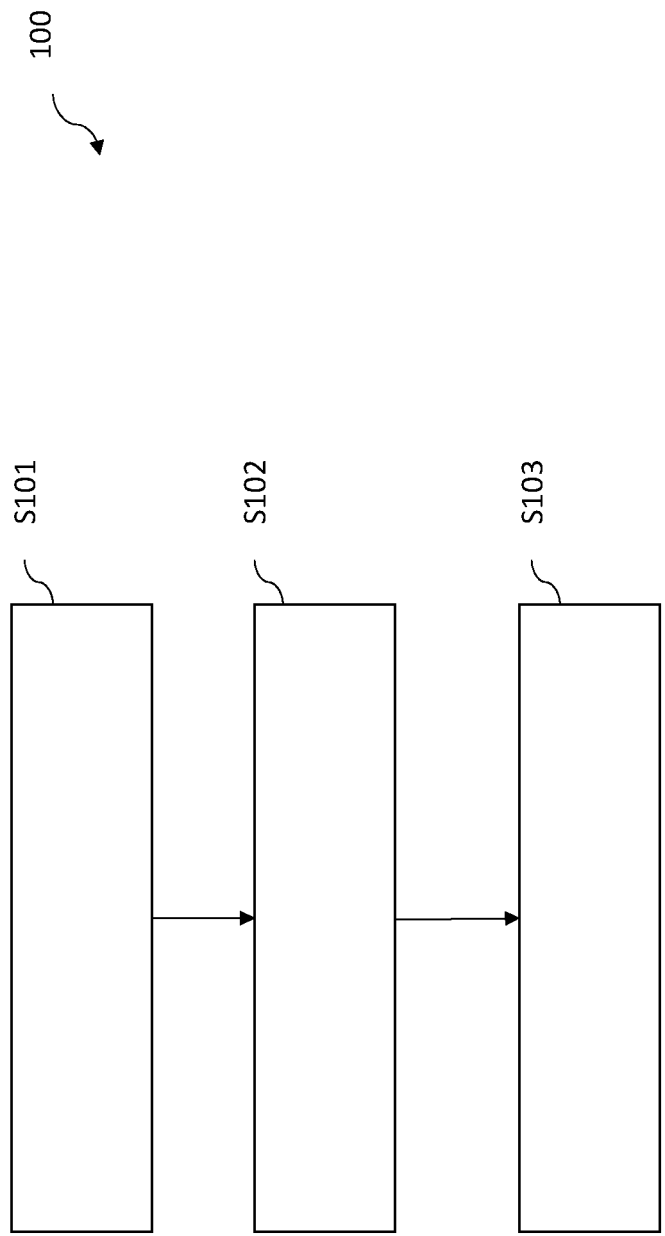


Fig. 4



EUROPEAN SEARCH REPORT

Application Number

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EPO FORM 1503 03:82 (P04C01)

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X	KR 2007 0097930 A (ACOD INC [KR]) 5 October 2007 (2007-10-05)	1-13, 15-19	INV. F23D14/02
Y	* paragraphs [0001] - [0021], [0034] - [0039] * * figure 1 *	14	F24H1/00
A	DE 10 2020 117692 A1 (VIESSMANN WERKE KG [DE]) 13 January 2022 (2022-01-13) * paragraphs [0003] - [0005], [0011] - [0016] * * figure 1 *	1-6, 16, 17	
Y	N/a: "Remeha Selecta System", /, 16 September 2003 (2003-09-16), pages 1-6, XP093001004, Retrieved from the Internet: URL:https://hinchliffeheating.co.uk/wp-content/uploads/Remeha-Selecta-Parts.pdf [retrieved on 2022-11-22]	14	
A	* the whole document *	1-6, 8-12, 15-18	TECHNICAL FIELDS SEARCHED (IPC) F23D F24H
A	US 2022/003406 A1 (RUIZ ROBERTO [US]) 6 January 2022 (2022-01-06) * paragraphs [0003], [0015], [0016], [0026], [0032], [0036], [0039], [0040] * * claim 1; figures 2, 7, 8 *	1-5, 8-10, 17	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 November 2022	Examiner Vogl, Paul
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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