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(54) RETROFIT KIT ASSEMBLY

(57) The invention relates to a Retrofit kit assembly (1) for converting a gaseous hydrocarbon 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 more than 30 mol%, hydrogen wherein the retrofit kit (1) further comprises a burner (6) configured for combustion of more than 20 mol%, in particular more than 30 mol%, of hydrogen and a data carrier (21) comprising information which, when the data carrier is read out cause a computer or a control unit to carry out a method (100) for controlling the operation of the combustion appliance (2), in particular a gas boiler, wherein the burner (6) is configured to be operated between a minimum load and a maximum load, wherein the method comprises the steps:

• during a start-up phase: supplying combustible gas, in particular premixed gas, having a first lambda-value to the burner surface, wherein the first lambda-value is at least 1,5, in particular 1,7 in particular at least 1.8, and igniting the supplied gas having the first lambda-value using an ignition source,

• during an operation phase after the gas has been ignited: supplying gas having a second lambda-value to the burner surface, wherein the first lambda-value is larger than the second lambda-value.

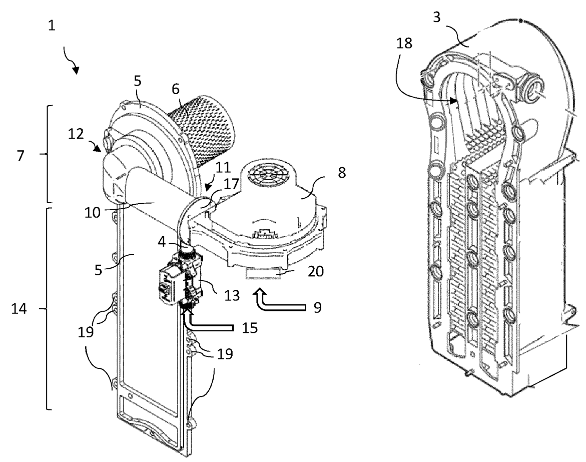

Fig. 2

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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 CO_2 emissions from this sector. Heating of spaces and heating of water are the two major causes of energy consumption and CO_2 emission from the building sector. Inefficient boilers and carbon-intensive power can further worsen this problem.

[0003] Nowadays, the majority of boilers are gas boilers and are designed for natural gas, using 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 CO_2-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 it is necessary to exchange the complete boiler in order to combust higher concentrations of hydrogen, in particular higher than 20 mol%, or pure hydrogen. The exchange is expensive and time consuming. In addition, exchanging the entire boiler, which still has a lifespan for use, is as such not environmentally friendly and the CO_2-footprint is unnecessarily further increased by making a new boiler.

[0004] 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.

[0005] 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.

[0006] Therefore, this and other prior art documents fail to address the problem of converting a hydrocarbon gas combustion appliance 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.

[0007] One further specific risk in converting a natural gas boiler to a hydrogen boiler is that the control of the mixture velocity is more important when the boiler uses hydrogen as fuel gas rather than other fuel gasses such as methane. In fact, flashback can occur more easily in hydrogen boilers since the laminar flame speed of hydrogen air mixture is around eight seven times higher than the flame speed for methane air mixture (with reference to the stoichiometric condition). It is therefore desirable to mistake-proof the retrofitting of a natural gas boiler in such a way that also the hydrogen combustion risk is reduced in such a way, that human error in parameter setting or forgetting to change said parameter setting is reduced.

[0008] The object of the invention is therefore to provide a retrofit kit assembly that is easy to implement and that is effective and safe 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, in particular the simple, safe and effective reduction of the risk of flashbacks.

[0009] The object is solved by a retrofit kit assembly for converting a gaseous hydrocarbon 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 more than 30 mol%, hydrogen wherein the retrofit kit further comprises a burner configured for combustion of more than 20 mol%, in particular more than 30 mol%, of hydrogen and a data carrier comprising information which, when the data carrier is read out cause a computer or a control unit to carry out a method for controlling the operation of the combustion appliance, in particular a gas boiler, wherein the burner is adapted to operate between a minimum load and a maximum load, and wherein the ratio of the maximum load over the min-

imum load is at least 4,
wherein the method comprises:

- supplying a combustible gas and air mixture, in particular a premix of combustible gas and air, to the burner at a combustible air to gas ratio,
- wherein the air to combustible gas ratio of the gas and air mixture, in particular the premix, which is supplied to the burner when the burner is operated at minimum load is set by a mechanism to be in relative terms at least 20% higher than the air to combustible gas ratio of the gas and air mixture, in particular the premix, which is supplied to the burner when the burner is operated at maximum load.

[0010] The method reduces the risk of flashback in hydrogen combustion.

[0011] A suitable data carrier can for example be a QR code, an RFID carrier, or a label comprising a weblink. The data carrier can be arranged on a surface of the retrofit kit assembly, including for example a housing, a frame or a packaging of the retrofit kit. This allows for a particularly simple, cheap, and effective poka-yoke solution.

[0012] In a further embodiment, the lambda-value can be controlled during the start-up phase by controlling the quantity of air supplied by an air channel and/or the quantity combustible gas supplied by a combustible gas channel. Alternatively or additionally, the first lambda-value can be larger than 2, e.g. between 2-6, preferably larger than 3, e.g. between 3-5, more preferably larger than 4, e.g. between 4 -5. Alternatively or additionally, the second lambda-value can be between 1-2, preferably between 1 - 1.5, more preferably between 1 - 1.3. Alternatively or additionally, the first lambda-value can be at least 1.5 times as large as the second lambda-value, preferably at least 2 times as large, e.g. at least 3 times as large. Alternatively or additionally, the start-up phase lasts at least 1 second, preferably at least 2 seconds, and even more preferably at least 3 seconds, e.g. between 3-6 seconds.

[0013] Gas boilers using natural gas are criticized due to their carbon dioxide emissions. The use of more than 30% hydrogen mixtures of natural gas up to 100 % hydrogen has the advantage to reduce CO_2 footprint in heating solutions. However, also the conversion needs to be sustainable. This is achieved by using the retrofit kit assembly and not exchange the entire boiler which still has a lifespan on its own.

[0014] 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.

[0015] 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.

[0016] 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.

[0017] It is therefore in addition 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.

[0018] To meet this goal the retrofit kit assembly can comprise a frame structure fixable to a housing of the combustion appliance for, in particular fully, closing a burner chamber of the combustion appliance. Additionally or alternatively, the retrofit kit assembly can comprise a burner for hydrogen combustion fixed to the frame structure.

[0019] Therefore and additionally, thanks to the retrofit kit assembly, it is also 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 amount 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, misidentification, 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.

[0020] 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 hydrocarbon 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. 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. In particular, more components can be mounted during production, further reducing the time needed for conversion and further reducing the risk of human error in assembly.

[0021] 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. Additionally, the pre-assembled parts can already be tested in the factory and checked on leakage.

[0022] Fuel gas can comprise more than 20 mol% hydrogen, in particular more than 30 mol%. 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).

[0023] 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. In the application a hydrocarbon combustion appliance is an appliance in which natural gas is combusted.

[0024] According to an embodiment the retrofit kit assembly can comprise a manifold structure having an inlet portion and an outlet portion, the manifold structure being, in particular integrally, connected to the frame structure at the outlet portion. The manifold structure can comprise a first connection for receiving at least fuel gas and a second connection for receiving at least air, the first connection and the second connection being both located at the inlet portion of the manifold structure, wherein the first connection is located downstream the second connection. Thus, it is prevented that fuel gas is sucked by a fan used for proving the air.

[0025] In particular, 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.

[0026] 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.

[0027] 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. it decreases set-up time even further with associated reduction in set-up errors and thus even further improved quality and safety.

[0028] 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.

[0029] 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.

[0030] 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 needs to be configured such that the temperature stays 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.

[0031] 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.

[0032] 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.

[0033] 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 behavior is prioritized instead of an anchor-feature. Accordingly, using such burner deck, a better fluid dynamic and thermal behavior is obtained when and where the gas expands due to the combustion.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] 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.

[0038] 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%.

[0039] 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 NOx is generated when hydrogen is combusted.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] 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.

[0044] In an alternative embodiment, the frame structure does not have a second portion that extends from the first portion. In said embodiment the first portion, in particular a circular shaped first portion, is used to cover the combustion chamber.

[0045] 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.

[0046] 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 retro fit 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.

[0047] 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.

[0048] Furthermore, preinstalling a fan has the advantage that a right type is chosen, which has a low static build up.

[0049] 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.

[0050] 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.

[0051] 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.

[0052] 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.

[0053] The control unit can be a processor or comprise at least one processor. Additionally, the control unit can comprise printed circuit board.

[0054] 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 reduced amount 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 an 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.

[0055] 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.

[0056] The retrofit kit assembly can comprise at least one, in particular more than one, sensor. The sensor can be used for hydrogen detection. In particular, the sensor can be a thermal conductivity sensor, e.g. a temperature sensor and/or a thermocouple, and/or a catalytic sensor and/or an electrochemical sensor. At least one of said 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.

[0057] 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 (lambda) 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 an ionization electrode commonly used in natural gas combustion appliances.

[0058] 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.

[0059] 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.

[0060] 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 can be used to reduce the noise and/or the impact of flashback and/or can be an inlet silencer.

[0061] 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 configured to be greater than the flame speed. In another example, the burner can be suitable for the combustion of both natural gas and hydrogen.

[0062] 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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 prevents 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. The risk can be further reduced by providing a connector of the cable or cable harness that is in a poka-yoke design.

[0068] 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.

[0069] 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.

[0070] In a further aspect of the invention, the use of a retrofit kit assembly is provided, comprising a data carrier comprising information for executing a method comprising during a start-up phase: supplying combustible gas, in particular premixed gas, having a first lambda-value to the burner surface, wherein the first lambda-value is at least 1,5, in particular 1,7 in particular at least 1.8, and igniting the supplied gas having the first lambda-value using an ignition source, during an operation phase after the gas has been ignited: supplying gas having a second lambda-value to the burner surface, wherein the first lambda-value is larger than the second lambda-value.

[0071] 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.

[0072] 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.

[0073] 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.

[0074] 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.

[0075] 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 compliance 2. For example, the combustion compliance 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.

[0076] 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.

[0077] 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.

[0078] 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.

[0079] 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.

[0080] 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. Figure 3B further comprises a data carrier 21 which is arranged on the side of the frame structure 5 which faces away from a combustion chamber of the combustion appliance 2.

Reference Signs

[0081]

1. Retrofit kit assembly
2. Combustion appliance
3. Internal housing
4. First connection
5. Frame structure
6. Burner
7. First portion
8. Fan element
9. Air conduit
10. Manifold structure

11. Inlet portion
12. Outlet portion
13. Gas valve
14. Second portion
15. Gas conduit
16. Retrofit kit
17. Second connection
18. Opening
19. Through holes
20. Suppressor structure
21. Data carrier

Claims

1. Retrofit kit assembly (1) for converting a gaseous hydrocarbon 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 more than 30 mol%, hydrogen wherein the retrofit kit (1) further comprises a burner (6) configured for combustion of more than 20 mol%, in particular more than 30 mol%, of hydrogen and a data carrier (21) comprising information which, when the data carrier is read out cause a computer or a control unit to carry out a method (100) for controlling the operation of the combustion appliance (2), in particular a gas boiler, wherein the burner (6) is configured to be operated between a minimum load and a maximum load, wherein the method comprises the steps:

• during a start-up phase: supplying combustible gas, in particular premixed gas, having a first lambda-value to the burner surface, wherein the first lambda-value is at least 1,5, in particular 1,7 in particular at least 1.8, and igniting the supplied gas having the first lambda-value using an ignition source,
• during an operation phase after the gas has been ignited: supplying gas having a second lambda-value to the burner surface, wherein the first lambda-value is larger than the second lambda-value.

2. Retrofit kit assembly (1) according to claim 1, **characterized in that**

a. 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/or
b. a burner (6) for hydrogen combustion fixed to the frame structure (5).
c. the retrofit kit assembly (1) comprises a manifold structure (10) having an inlet portion (11) and an outlet portion (12), the manifold structure (10) being, in particular integrally, connected to the frame structure (5) at the outlet portion (12).

3. Retrofit kit assembly (1) according to claim 2, **characterized in that** the manifold structure (10) comprises a first connection (4) for receiving at least fuel gas and a second connection (17) for receiving at least air, the first connection (4) and the second connection (17) being both located at the inlet portion (11) of the manifold structure (10), wherein the first connection (4) is located downstream the second connection (17).

4. Retrofit kit assembly (1) according to any one of the claims 1 to 3, **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.

5. Retrofit kit assembly (1) according to any one of the claims 1 to 4, **characterized in that**

a. the frame structure (5) is configured to cover 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).

6. Retrofit kit assembly (1) according to any one of claims 1 to 5, **characterized in that** the first connection (4) is integrally connected to the manifold structure (10) and/or protrudes from the manifold structure (10).

7. Retrofit kit assembly (1) according to any one of claims 1 to 6, **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).

8. Retrofit kit assembly (1) according to any one of claims 1 to 7, **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 down-

stream 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.

9. Retrofit kit assembly (1) according to claim 7 or 8, **characterized in that** the gas valve (13) is, in particular directly, connected to the, in particular Venturi shaped, mixer.

10. Retrofit kit assembly (1) according to any one of claims 7 to 9, **characterized in that** the gas valve (13) is controlled electronically or pneumatically.

11. Retrofit kit assembly (1) according to any one of claims 1 to 10, **characterized in that**

a. the kit assembly (1) further comprises at least one flame detector sensor and/or **in that**
b. 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.

12. Retrofit kit assembly (1) according to claim 11, **characterized in that**

a. the outlet portion (12) comprises at least one receive portion for receiving a flame detector sensor and/or a sensor and/or **in that**
b. the manifold comprises a receive portion for receiving the sensor and/or **in that**
c. the first connection (4) of the manifold comprises a first receive portion for receiving the sensor and/or **in that**
d. the second connection of the manifold comprises a second receive portion for receiving the sensor.

13. Retrofit kit assembly according to one of claims 1 to 12, **characterized in that**

a. 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); and/or
b. the assembly (1) further comprises a suppressor structure (20) provided at the inlet portion (11), in particular fluidically connecting the inlet portion (11) with the mixer.

14. Retrofit kit assembly (1) according to one of claims 1 to 13, **characterized in that**

a. 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**
b. 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).

15. Retrofit kit assembly (1) according to one of claims 1 to 14, **characterized in that** the data carrier (21), is QR code, RFID carrier, or a label comprising a weblink.

16. Retrofit kit assembly (1), according one of claims 1 to 15, wherein

a.) the lambda-value is controlled during the start up phase by controlling the quantity of air supplied by an air channel and/or the quantity combustible gas supplied by a combustible gas channel, and/or
b.) the first lambda-value is larger than 2, e.g. between 2-6, preferably larger than 3, e.g. between 3-5, more preferably larger than 4, e.g. between 4 - 5; and/or
c.) the second lambda-value is between 1-2, preferably between 1 - 1.5, more preferably between 1 - 1.3, and/or
d.) wherein the first lambda-value is at least 1.5 times as large as the second lambda-value, preferably at least 2 times as large, e.g. at least 3 times as large, and/or
e.) wherein the start-up phase lasts at least 1 second, preferably at least 2 seconds, and even more preferably at least 3 seconds, e.g. between 3-6 seconds.

17. Combustion appliance (2), in particular a gas boiler, and more particularly a condensing gas boiler, comprising

a. the kit assembly (1) according to any one of claims 1 to 16 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
b. 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 16.

18. Use of a retrofit kit assembly (1) (1) according to any one of claims 1 to 16 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%, in particular more than 30 mol%, hydrogen.

19. Use of a retrofit kit assembly (1) comprising a data carrier (21) comprising information for executing a method (100) comprising

- during a start-up phase: supplying combustible gas, in particular premixed gas, having a first lambda-value to the burner surface, wherein the first lambda-value is at least 1,5, in particular 1,7 in particular at least 1.8, and igniting the supplied gas having the first lambda-value using an ignition source,
- during an operation phase after the gas has been ignited: supplying gas having a second lambda-value to the burner surface, wherein the first lambda-value is larger than the second lambda-value.

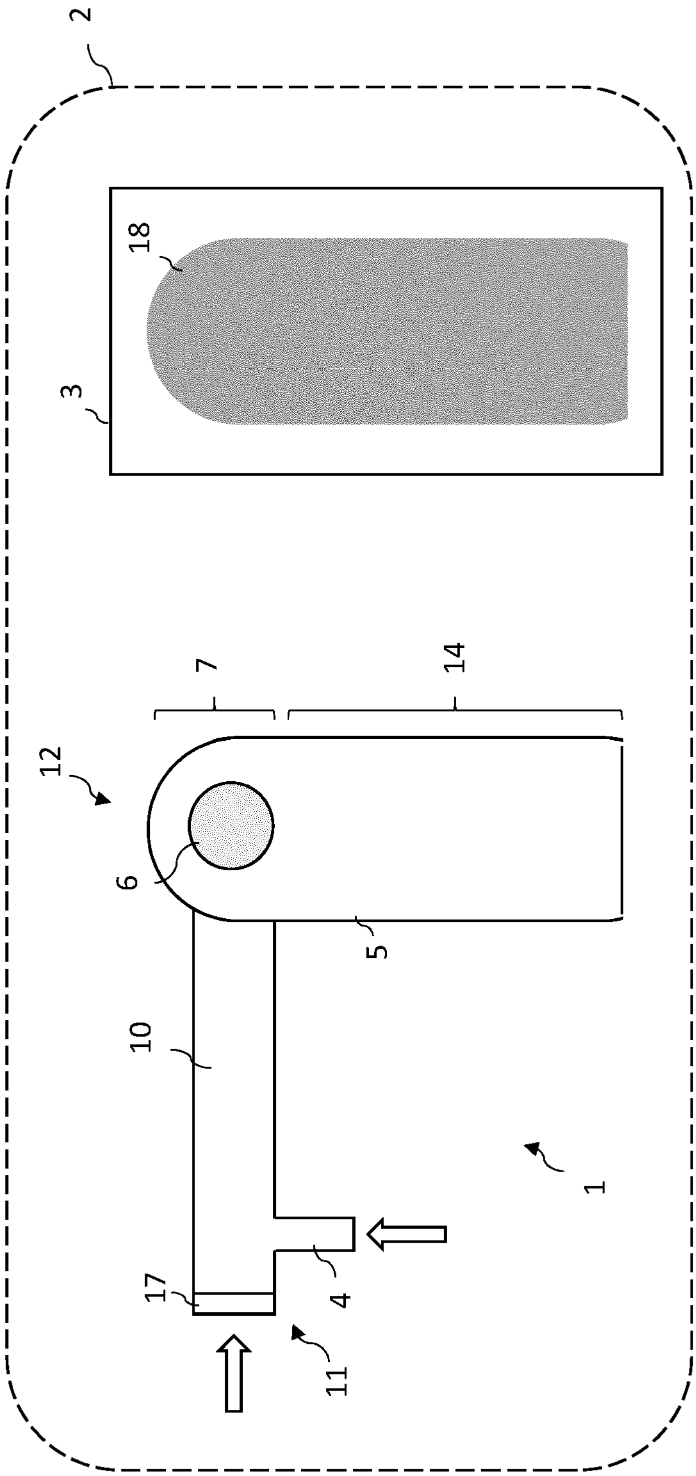

Fig. 1

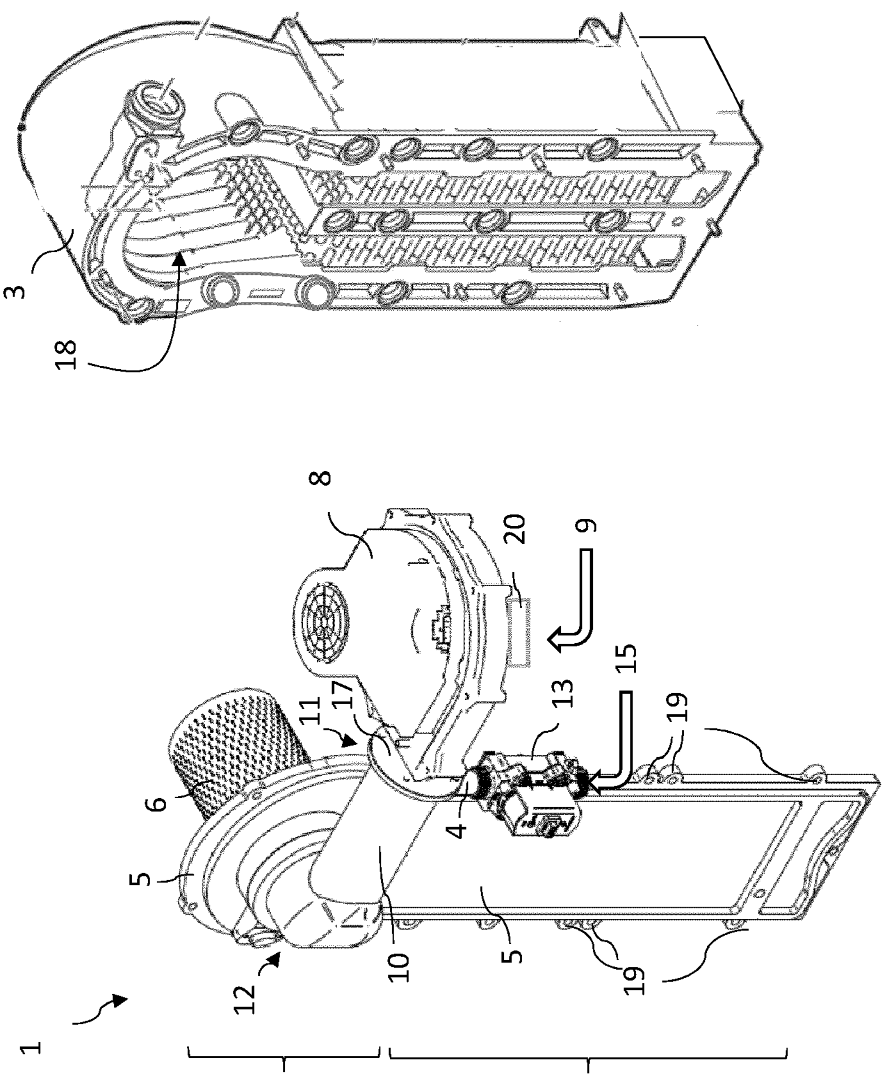

Fig. 2

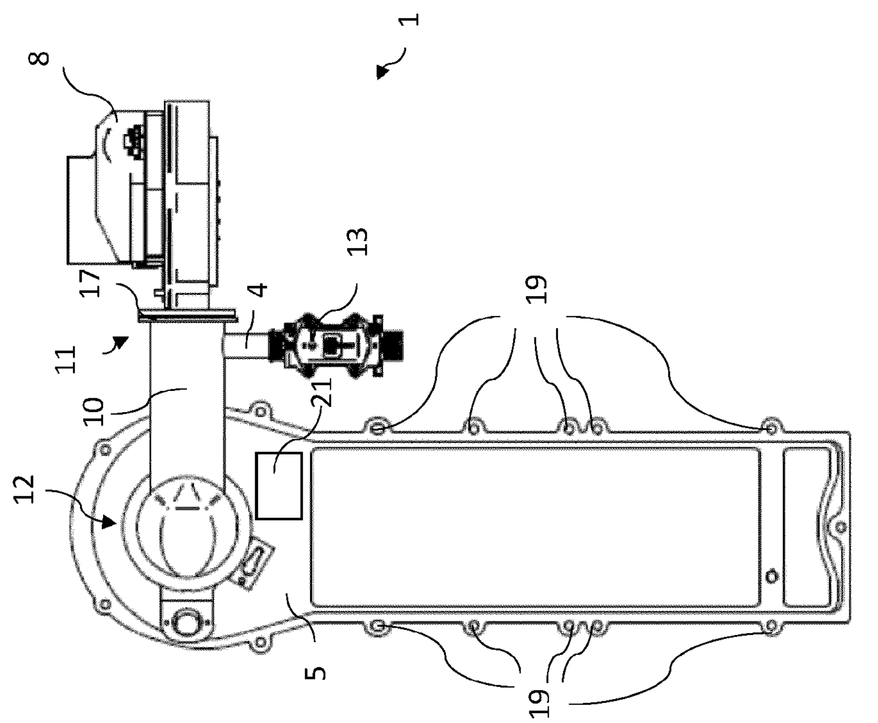

Fig. 3B

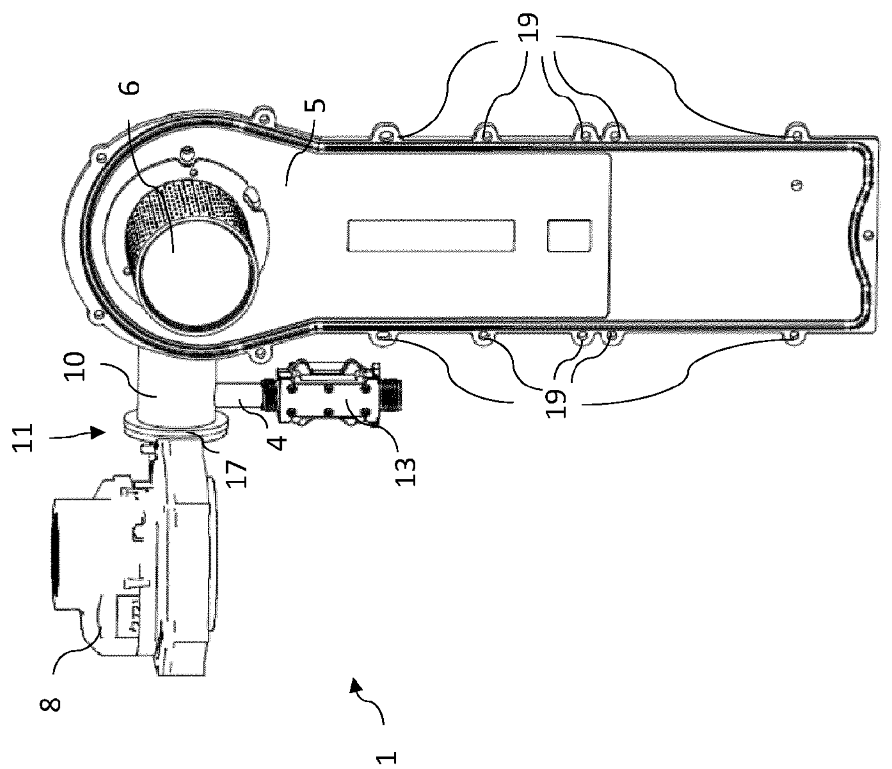

Fig. 3A

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EUROPEAN SEARCH REPORT

Application Number
EP 22 18 8115

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2021/078949 A1 (BEKAERT COMBUSTION TECH BV [NL]) 29 April 2021 (2021-04-29) * page 1, line 5 - line 8; claims 1-13; figure 1 * * page 1, line 26 - line 33 * * page 2, line 27 - page 3, line 19 * * page 4, line 27 - page 5, line 2 * * page 6, line 16 - page 7, line 12 * * page 11, line 20 - page 12, line 24 * * page 13, line 13 - page 14, line 25 * * page 15, line 29 - page 16, line 7 * * page 17, line 30 - page 20, line 22 * * page 21, line 5 - line 34 * -----	1-19	INV. F23D14/02 F23D99/00 F23N5/00
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A	* paragraphs [0001], [0002], [0004]; figure 1 * * paragraphs [0006], [0007] * * paragraph [0042]; claim 15 * * paragraph [0047] * -----	1,18,19	
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A	* paragraphs [0001], [0016] - [0018], [0022], [0035] * -----	1,18,19	

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	19 December 2022	Hauck, Gunther

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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