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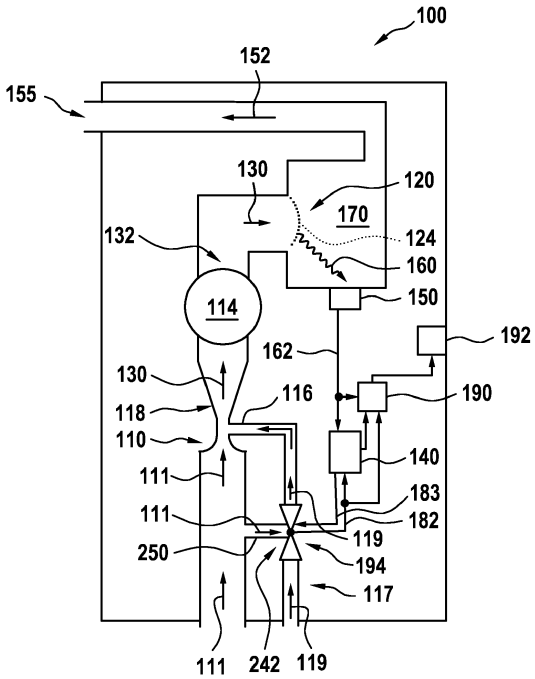
(54) A DEVICE FOR DETERMINING AN EARLIEST FLAME APPEARANCE TIME IN AN AIR-GAS MIXTURE BURNING APPLIANCE

(57) In an air-gas mixture burning appliance (100) that comprises a burning unit (120), a flame detector (150) an air-gas mixing unit (110), a gas valve (194), and a controller (140), the controller (!40) being adapted for determining an earliest flame appearance time for an ignition phase of the burning unit (120) by selecting from at least two different durations of time, wherein the controller (140) determines the earliest flame appearance time as an anticipated minimum duration of time that elapses between an opening of the gas valve (194) and the flame detector (150) sensing the presence of a flame (122) in the burning unit (120).

Fig. 2



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Description

Background of the Invention

[0001] The present invention relates to an air-gas mixture burning appliance. The air-gas mixture burning appliance comprises a controller, a burning unit for burning a combustible air-gas mixture, a flame detector for sensing a presence of a flame in the burning unit, an air-gas mixing unit that is arranged upstream of the burning unit and is adapted for mixing of air and gas to form the combustible air-gas mixture, and a gas valve that is arranged upstream of the air-gas mixing unit and is adapted for regulating a flow of the gas to the air-gas mixing unit. Furthermore, the present invention relates to a method of operating an air-gas mixture burning appliance that comprises a controller, a burning unit for burning a combustible air-gas mixture, a flame detector for sensing a presence of a flame in the burning unit, an air-gas mixing unit that is arranged upstream of the burning unit and is adapted for mixing of air and gas to form the combustible air-gas mixture, and a gas valve that is arranged upstream of the air-gas mixing unit and is adapted for regulating a flow of the gas to the air-gas mixing unit.

[0002] From the state of the art, an air-gas mixture burning appliance having a burning unit, a flame detector, an air-gas mixing unit, and a gas valve is known. More specifically, known air-gas mixture burning appliances usually mix air and gas directly before the burning unit. During the ignition phase, the combustible air-gas mixture enters the burning unit where it is ignited. However, internal leakage, which is sometimes also referred to as "let-by", of a closed gas valve can lead to a hazardous accumulation of gas within the air-gas mixture burning appliance.

[0003] While gas valves typically have redundancy through the use of two independent actuators acting in series in the gas train, safety engineering standards require a third layer of protection. Moreover, conventional air-gas mixture burning appliances are usually equipped with a small number of sensors that can be used for safety functions. In the gas combustion system, the only signals available to the safety controls are usually the fan speed and the flame signal which indicates the strength of any flame in the burning unit. Addition sensors in the burning unit may be costly in terms of complexity and materials.

[0004] In the remainder of this description, the term "gas" refers to any fuel in gaseous form that, when mixed with air, forms a combustible air-gas mixture. Examples for such a gas include hydrogen, propane, butane, methane, liquefied petroleum gas, etc. Moreover, the term "air" refers to any suitable oxidizer that may be mixed with a fuel gas to form a combustible air-gas mixture.

Summary of the Invention

[0005] The present invention relates to an air-gas mixture burning appliance, comprising a burning unit for burning a combustible air-gas mixture, a flame detector for sensing a presence of a flame in the burning unit, an air-gas mixing unit that is arranged upstream of the burning unit and is adapted for mixing of air and gas to form the combustible air-gas mixture, a gas valve that is arranged upstream of the air-gas mixing unit and is adapted for regulating a flow of the gas to the air-gas mixing unit, and a controller that is adapted for determining an earliest flame appearance time for an ignition phase of the burning unit by selecting from at least two different durations of time, wherein the controller determines the earliest flame appearance time as an anticipated minimum duration of time that elapses between an opening of the gas valve and the flame detector sensing the presence of a flame in the burning unit.

[0006] Accordingly, the inventive air-gas mixture burning appliance may be able to predict the time that elapses before a flame is established in the burning unit.

[0007] Optionally, the air-gas mixture burning appliance further comprises a secured gas pathway that is arranged between the gas valve and the air-gas mixing unit and is adapted for providing the gas from the gas valve to the air-gas mixing unit, and wherein the controller determines the earliest flame appearance time based on an inferred concentration of the gas in the secured gas pathway.

[0008] Thus, the controller can select the earliest flame appearance time based on whether the secured gas pathway is already filled with a gas or whether the secured gas pathway is filled with air at the beginning of the ignition phase.

[0009] Preferably, the air-gas mixture burning appliance further comprises a gas valve leak detector that is adapted for detecting a leak of the gas valve during the ignition phase of the burning unit based on measuring a measured duration of time between the opening of the gas valve and the flame detector sensing the presence of a flame in the burning unit, and checking that the measured duration of time is shorter than the determined earliest flame appearance time.

[0010] Accordingly, the air-gas mixture burning appliance may be able to detect a leaky gas valve without using an additional sensing device.

[0011] According to one aspect, the air-gas mixture burning appliance further comprises a gas valve leak handling device that, in response to the gas valve leak detector detecting a current leak of the gas valve, is adapted for signalling the current leak of the gas valve and for putting the air-gas mixture burning appliance in at least one of a safe state, a non-operational state, or a restricted performance state.

[0012] Thus, the air-gas mixture burning appliance can react to a leaky gas valve and ensure a safe operation.

[0013] Optionally, the gas valve is shut off periodically for a predetermined period of time to provide the gas valve leak detector an opportunity for detecting a leak of the gas valve.

[0014] Accordingly, a leaky gas valve may be detected

early.

[0015] Optionally, the controller determines the earliest flame appearance time based at least on the type of the gas.

[0016] Thus, the inventive air-gas mixture burning appliance may be operated with different gas types.

[0017] Preferably, the controller determines the earliest flame appearance time based at least on an elapsed time since the flame detector previously sensed a flame in the burning unit.

[0018] Accordingly, the inventive air-gas mixture burning appliance may reliably predict the concentration of the gas in the secured gas pathway at the beginning of the ignition phase.

[0019] According to one aspect, the controller determines the earliest flame appearance time by selecting from a continuous range of values, wherein all values in the continuous range of values are greater than a predetermined minimum earliest flame appearance time.

[0020] Thus, the controller may fine-tune the earliest flame appearance time and react to the combination of multiple parameters that may have an influence on the earliest flame appearance time.

[0021] Accordingly, the invention allows for the detection of leaks from the gas valve into the secured gas way without the need for a gas sensor.

[0022] Furthermore, a method of operating an air-gas mixture burning appliance that comprises a burning unit for burning a combustible air-gas mixture, a flame detector for sensing a presence of a flame in the burning unit, an air-gas mixing unit that is arranged upstream of the burning unit and is adapted for mixing of air and gas to form the combustible air-gas mixture, and a gas valve that is arranged upstream of the air-gas mixing unit and is adapted for regulating a flow of the gas to the air-gas mixing unit, comprises a determining step, comprising determining with a controller, an earliest flame appearance time for an ignition phase of the burning unit by determining an anticipated minimum duration of time that elapses between an opening of the gas valve and the flame detector sensing the presence of a flame in the burning unit.

[0023] Accordingly, the inventive air-gas mixture burning appliance may be able to predict the minimum time that elapses before a flame is established in the burning unit.

[0024] According to one aspect, the air-gas mixture burning appliance further comprises a secured gas pathway that is arranged between the gas valve and the air-gas mixing unit, and the determining step further comprises determining, with the controller, the earliest flame appearance time based on an inferred concentration of the gas in the secured gas pathway.

[0025] Thus, the controller can select the earliest flame appearance time based on whether the secured gas pathway is already filled with a gas or whether the secured gas pathway is filled with air at the beginning of the ignition phase.

[0026] Optionally, the method may further include a detecting step, comprising detecting, with a gas valve leak detector, a leak of the gas valve during the ignition phase of the burning unit by measuring a measured duration of time between the opening of the gas valve and the flame detector sensing the presence of a flame in the burning unit, and checking that this measured duration of time is shorter than the determined earliest flame appearance time.

[0027] Accordingly, the air-gas mixture burning appliance may be able to detect a leaky gas valve without using an additional sensing device.

[0028] Preferably, the method may further include a handling step, comprising responding to the leak of the gas valve with a gas valve leak handling device by signalling the leak of the gas valve and accordingly putting the air-gas mixture burning appliance in one or more of a safe state, a non-operational state, or a restricted performance state.

[0029] Thus, the air-gas mixture burning appliance can react to a leaky gas valve and ensure a safe operation.

[0030] According to one aspect, the determining step may further comprise determining the earliest flame appearance time based on at least the type of gas.

[0031] Accordingly, the inventive air-gas mixture burning appliance may be operated with different gas types.

[0032] Optionally, the determining step may further comprise determining the earliest flame appearance time based at least on an elapsed time since the flame detector previously sensed a flame in the burning unit.

[0033] Thus, the inventive air-gas mixture burning appliance may reliably predict the concentration of the gas in the secured gas pathway at the beginning of the ignition phase.

[0034] Preferably, the determining step may further comprise determining the earliest flame appearance time by selecting from a continuous range of values, wherein all values in the continuous range of values are greater than a predetermined minimum earliest flame appearance time.

[0035] Accordingly, the controller may fine-tune the earliest flame appearance time and react to the combination of multiple parameters that may have an influence on the earliest flame appearance time.

Brief Description of the Drawings

[0036] Exemplary embodiments of the present invention are described in detail hereinafter with reference to the attached drawings. In these attached drawings, identical or identically functioning components and elements are labelled with identical reference signs and they are generally only described once in the following description.

Fig. 1 shows a schematic view of an air-gas mixture burning appliance according to the present invention, during the ignition phase,

Fig. 2 shows a schematic view of an air-gas mixture burning appliance having a fan downstream of an air-gas mixer and an air flow channel to a reference pressure port of a gas valve, and

Fig. 3 shows a flowchart illustrating a method of operating an air-gas mixture burning appliance.

Detailed Description

[0037] Fig. 1 shows an exemplary air-gas mixture burning appliance 100 with a burning unit 120 for burning a combustible air-gas mixture 130, an air-gas mixing unit 110, a gas valve 194, a flame detector 150, and a controller 140. By way of example, the air-gas mixture burning appliance 100 may be used in a boiler or, more generally, in a building heating system.

[0038] The air-gas mixing unit 110 is arranged upstream of the burning unit 120 and is adapted for mixing of air 111 and gas 119 to form the combustible air-gas mixture 130. Preferentially, the combustible air-gas mixture 130 is a homogenous mixture of the air 111 and the gas 119.

[0039] By way of example, the air-gas mixing unit 110 includes an air supply unit and a gas supply unit. Illustratively, the air supply unit includes a fan 114 that may be operated with an adaptable fan speed and/or within predetermined ranges of fan speeds to draw and/or push air 111 into the air-gas mixing unit 110.

[0040] The gas supply unit may include the gas valve 194. The gas valve 194 is arranged upstream of the air-gas mixing unit 110 and is adapted for regulating a flow of the gas 119 to the air-gas mixing unit 110. A secured gas pathway 116 is arranged between the gas valve 194 and the air-gas mixing unit 110 and is adapted for providing the gas 119 from the gas valve 194 to the air-gas mixing unit 110.

[0041] The air supply unit and the gas supply unit may be interconnected via a mixer 118 which forms a corresponding discrete point of mixing. Preferably, the combustible air-gas mixture 130 is formed at the discrete point of mixing and guided via the mixer 118 and the combustible air-gas pathway 132 to the burning unit 120.

[0042] Illustratively, the burning unit 120 is provided with a burner surface 124 that is arranged downstream of the air-gas mixing unit 110 such that the combustible air-gas mixture 130 flows towards the burner surface 124. The combustible air-gas mixture 130 is burned by the burning unit 120 and, more specifically, at the burner surface 124.

[0043] By way of example, during an ignition phase of the air-gas mixture burning applance 100, the combustible air-gas mixture 130 from the air-gas mixing unit 110 may be ignited in the burning unit 120 at the burner surface 124. The resulting flame 122 is illustratively stabilised against the burner surface 124.

[0044] According to one aspect, the flame detector 150 is provided for sensing presence of a flame 122 in the burning unit 120. Thus, the flame detector 150 is suitable for determining whether a flame 122 is present at the burner surface 124 in the burning unit 120. However, it should be noted that suitable flame detection techniques that may be used with the flame detector 150 are well-known to the person skilled in the art and are, therefore, not described in more detail, for brevity and conciseness. For instance, the flame detector 150 may use any suitable sensing element for sensing presence of the flame 122 in the burning unit 120.

[0045] Illustratively, the flame detector 150 may be connected to the controller 140. If desired, the flame detector 150 may generate and/or provide a flame detection signal 162 to the controller 140 based on whether the flame detector 150 senses the presence of a flame 122 in the burning unit 120 or fails to sense the presence of a flame 122 in the burning unit 120.

[0046] Alternatively, the controller 140 may determine whether a flame 122 is present in the burning unit 120 by comparing the detected flame signal 160 with a predetermined flame detection threshold.

[0047] As shown in Fig. 1, the controller 140 may be connected to the gas valve 194. Illustratively, the controller 140 may receive a control signal 182 from the gas valve 194. By way of example, the control signal 182 may be indicative of the status of the gas valve 194. For example, the controller signal 182 may indicate whether the gas valve 194 is open or closed.

[0048] Illustratively, the controller 140 may send an actuator signal 183 to the gas valve 194. If desired, the actuator signal 183 may direct the gas valve 194 to open and/or to close. For example, at the beginning of an ignition phase, the controller 140 may direct the gas valve 194 to open.

[0049] During the ignition phase, the controller 140 tracks the duration of time between the opening of the gas valve 194 and the detection of a flame signal 160 at the burning unit 120. To avoid a delayed ignition, which refers to igniting a hazardous accumulation of the combustible air-gas mixture 130 and which usually leads to an explosion that may damage internal components of the air-gas mixture burning appliance 100 and endanger the surrounding environment, the maximum allowed opening time of the gas valve 194 without a flame 122 being detected is limited to a short period of time, which is sometimes also referred to as the ignition safety time.

[0050] In contrast thereto, the gas valve 194 needs to be open for a minimum opening time. The minimum opening time is defined as the time that is required for the gas 119 to flow from the gas valve 194 through the secured gas pathway 116 to the air-gas mixing unit 110 and from there, as a combustible air-gas mixture 130 to the burner surface 124, where a sufficient quantity of the combustible air-gas mixture 130 is required to accumulate such that a reliable ignition of the flame 122 is ensured.

[0051] However, the time between the opening of the gas valve 194 and the accumulation of a quantity of the combustible air-gas mixture 130 in the burning unit 120

that is sufficient for a sustained ignition may depend on the concentration of the gas 119 in the secured gas pathway 116 at the opening of the gas valve 194.

[0052] As an example, If the air-gas mixture burning appliance 100 were to stop burning gas 119, but after a short period of time be re-lit, then the secured gas pathway 116 would still be filled with gas 119, and the combustible air-gas pathway 132 would still be filled with the combustible air-gas mixture 130, and, as a result, a flame 122 could be established comparatively quickly at the burner surface 124.

[0053] As another example, in between periods of operation, the concentration of the gas 119 in the secured gas pathway 116 and in the combustible air-gas pathway 132 decays over time. Thus, if the air-gas mixture burning appliance 100 is re-lit after a sufficient period of time, the secured gas pathway 116 and the combustible air-gas pathway 132 is nominally filled with air and contains a negligible concentration of the gas 119 at the start of the ignition sequence. In this case, the nominally air that is present in the secured gas pathway 116 and in the combustible air-gas pathway 132 must be displaced by gas 119 that is streaming through the opened gas valve 194.

[0054] This process of re-priming the secured gas pathway 116 and the combustible air-gas pathway 132 takes some time, which may depend, for example, on the flow rate of nominally air and the volume of the consecutive pathways 116, 132.

[0055] Consequently, a flame 122 appears at the burner surface 124 only after this priming process has sufficiently progressed, which takes more time in comparison to the ignition attempt made shortly after an end of a previous burn that was described in the previous example.

[0056] Thus, the controller 140 is adapted for determining an earliest flame appearance time for an ignition phase of the burning unit 120 by selecting from at least two different durations of time. Thereby, the controller 140 determines the earliest flame appearance time as an anticipated minimum duration of time that elapses between an opening of the gas valve 194 and the flame detector 150 sensing a flame 122 in the burning unit 120.

[0057] Since the decay of the concentration of the gas 119 in the secured gas pathway 116 over time is driven by a diffusion process that is relatively repeatable and predictable, the controller 140 may determine the earliest flame appearance time based on an inferred concentration of the gas 119 in the secured gas pathway 116.

[0058] Moreover, the decay of the concentration of the gas 119 and/or the time to re-prime the secured gas pathway 116 and the combustible air-gas pathway 132 may depend on the type of gas 119. For example, the difference in density of hydrogen or any other fuel gas that is less dense than air may result in an exacerbated delay in the appearance of a flame 122 at the burner surface 124. Therefore, the controller 140 may determine the earliest flame appearance time based at least on the type of the gas 119.

[0059] Illustratively, the controller 140 may determine the earliest flame appearance time based at least on an elapsed time since the flame detector 150 previously sensed a flame 122 in the burning unit 120.

[0060] By way of example, the controller 140 may determine the shortest duration of time after the opening of the gas valve 194 that a flame 122 appears in the burning unit 120 after the gas valve 194 has been opened. This shortest duration of time is sometimes also referred to as a predetermined minimum earliest flame appearance time.

[0061] Illustratively, the controller 140 may determine the earliest flame appearance time by selecting from a continuous range of values, wherein all values in the continuous range of values are greater than a predetermined minimum earliest flame appearance time.

[0062] As an example, consider the scenario in which the gas valve 194 has an internal leak. In this scenario, the concentration of the gas 119 in the secured gas pathway 116 is not decaying as predicted after the gas valve 194 is closed and the air-gas mixture burning appliance 100 is turned off. Instead, the concentration of the gas 119 remains high in the secured gas pathway 116.

[0063] The diffusion of the gas 119 is a relatively slow process. Thus, a small leak of the gas valve 194 results in a high concentration of the gas 119 being sustained in the secured gas pathway 116. Therefore, during an ignition attempt that occurs a comparatively long time after the end of the most recent detection of a flame 122 in the burning unit 120, a new flame 122 will appear sooner than anticipated, and before the earliest anticipated time appearance time.

[0064] Illustratively, the air-gas mixture burning appliance 100 may include a gas valve leak detector 190 that is adapted for detecting a leak of the gas valve 194 during the ignition phase of the burning unit 120 based on measuring a measured duration of time between the opening of the gas valve 194 and the flame detector 150 sensing the presence of a flame 122 in the burning unit, and checking that the measured duration of time is shorter than the determined earliest flame appearance time.

[0065] If desired, the gas valve leak detector 190 may be adjusted such that the minimum detectable size of a leak of the gas valve 194 is lower than the minimum hazardous size of a leak. However, as internal leaks of the gas valve 194 are usually progressive in their development over a period of months, the leak of the gas valve 194 could be detected before a hazardous situation occurs.

[0066] By way of example, the air-gas mixture burning appliance 100 may include a gas valve leak handling device 192. In response to the gas valve leak detector 190 detecting a current leak of the gas valve 194, the gas valve leak handling device 192 may be adapted for signalling the current leak of the gas valve 194 and for putting the air-gas mixture burning appliance 100 in at least one of a safe state, a non-operational state, or a restricted performance state. Thereby, the gas valve leak

handling device 192 may ensure that the current leak of the gas valve 194 is noticed and rectified.

[0067] If desired, the controller 140 may be adapted for signalling the current leak of the gas valve 194 and for putting the air-gas mixture burning appliance 100 in at least one of a safe state, a non-operational state, or a restricted performance state.

[0068] Preferably, the gas valve 194 is shut off periodically for a predetermined period of time to provide the gas valve leak detector 190 an opportunity for detecting a leak of the gas valve 194. For example, the controller 140 may direct the gas valve 194 to shut off using actuator signal 183 and enforce a minimum period of standby. The minimum period of standby may be selected based on the type of gas, the dimensions of the secured gas pathway 116, the dimensions of the combustible air-gas pathway 132, etc. As an example, the minimum period of standby may be selected to last for approximately 20 to 30 minutes.

[0069] Advantageously, the gas valve 194 may be shut off during times of the day with typical low demand for the air-gas mixture burning appliance 100 to produce heat. For example, the controller may shut off the gas valve 194 for a short period of time during the night.

[0070] Fig. 2 shows a schematic view of an air-gas mixture burning appliance 100 having a fan 114 downstream of an air-gas mixer 118 and an air flow channel 250 to a reference pressure port 242 of a gas valve 194. As shown in Fig. 2, the air-gas mixture burning appliance 100 may include an air inlet for providing air 111, a gas inlet 117 for providing gas 119, and a flue outlet 155 for the evacuation of exhaust gas 152. Illustratively, the air-gas mixture burning appliance 100 may further include an air-gas mixing unit 110, a burning unit 120, and a heat exchanger 170.

[0071] The air-gas mixing unit 110 is preferably adapted for mixing of air 111 and gas 119 to form a combustible air-gas mixture 130. Preferably, the combustible air-gas mixture 130 is a homogenous mixture of the air 111 and the gas 119.

[0072] Illustratively, the burning unit 120 is provided with a burner surface 124 that is arranged downstream of the air-gas mixing unit 110 such that the combustible air-gas mixture 130 flows towards the burner surface 124. If desired, the fan 114 may drive the combustible air-gas mixture 130 through the combustible air-gas pathway 132 towards the burner surface 124.

[0073] The combustible air-gas mixture 130 is burned by the burning unit 120 and, more specifically, at the burner surface 124. The heat exchanger 170 may transfer the heat that is generated at the burner surface 124 to another medium. For example, the heat exchanger 170 may transfer the heat that is generated at the burner surface 124 to water in a water circuit. The flue outlet 155 may evacuate the exhaust gas 152 from the air-gas mixture burning appliance 100.

[0074] The gas valve 194 may include a reference pressure port 242. Preferably, the air flow channel 250 is adapted for providing the flow of the air 111 to the reference pressure port 242, and the gas valve 194 is adapted for regulating the flow of the gas 119 based on the pressure of the flow of the air 111 at the reference pressure port 242.

[0075] The controller 140 is adapted for determining an earliest flame appearance time for an ignition phase of the burning unit 120 by selecting from at least two different durations of time. Thereby, the controller 140 determines the earliest flame appearance time as an anticipated minimum duration of time that elapses between an opening of the gas valve 194 and the flame detector 150 sensing the presence of a flame 122 in the burning unit 120.

[0076] Illustratively, the controller 140 may send an actuator signal 183 to the gas valve 194. If desired, the actuator signal 183 may direct the gas valve 194 to open and/or to close. As an example, at the beginning of an ignition phase, the controller 140 may direct the gas valve 194 to open. As another example, the controller 140 may direct the gas valve 194 to close periodically using actuator signal 183 to provide the gas valve leak detector 190 an opportunity for detecting a leak of the gas valve 194. Thus, actuator signal 183 may override the reference pressure port 242 of the gas valve 194.

[0077] Fig. 3 shows a flowchart illustrating a method 300 of operating an air-gas mixture burning appliance. The air-gas mixture burning appliance comprises a burning unit for burning a combustible air-gas mixture, a flame detector for sensing a presence of a flame in the burning unit, an air-gas mixing unit that is arranged upstream of the burning unit and is adapted for mixing of air and gas to form the combustible air-gas mixture, and a gas valve that is arranged upstream of the air-gas mixing unit and is adapted for regulating a flow of the gas to the air-gas mixing unit.

[0078] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 comprises a burning unit 120 for burning a combustible air-gas mixture 130, a flame detector 150 for sensing a presence of a flame 122 in the burning unit 120, an air-gas mixing unit 110 that is arranged upstream of the burning unit 120 and is adapted for mixing of air 111 and gas 119 to form the combustible air-gas mixture 130, and a gas valve 194 that is arranged upstream of the air-gas mixing unit 110 and is adapted for regulating a flow of the gas 119 to the air-gas mixing unit 110.

[0079] During a determining step 310, the air-gas mixture burning appliance determines, with a controller, an earliest flame appearance time for an ignition phase of the burning unit by determining an anticipated minimum duration of time that elapses between an opening of the gas valve and the flame detector sensing the presence of a flame in the burning unit.

[0080] For example, air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may use controller 140 to determine an earliest flame appearance time for an ignition phase of the burning unit 120 by determining an anticipated min-

imum duration of time that elapses between an opening of the gas valve 194 and the flame detector 150 sensing the presence of a flame 122 in the burning unit 120.

[0081] If desired, the air-gas mixture burning appliance may further comprise a secured gas pathway that is arranged between the gas valve and the air-gas mixing unit.

[0082] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may comprise a secured gas pathway 116 that is arranged between the gas valve 194 and the air-gas mixing unit 110.

[0083] In such an air-gas mixture burning appliance, the determining step 310 may further comprise the operation of determining, with the controller, the earliest flame appearance time based on an inferred concentration of the gas in the secured gas pathway.

[0084] For example, the controller 140 of the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may determine the earliest flame appearance time based on an inferred concentration of the gas 119 in the secured gas pathway 116.

[0085] During a detecting step 320, the air-gas mixture burning appliance detects, with a gas valve leak detector, a leak of the gas valve during the ignition phase of the burning unit by measuring a measured duration of time between the opening of the gas valve and the flame detector sensing the presence of a flame in the burning unit, and checking that this measured duration of time is shorter than the determined earliest flame appearance time.

[0086] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may detect, with gas valve leak detector 190, a leak of the gas valve 194 during the ignition phase of the burning unit 120 by measuring a measured duration of time between the opening of the gas valve 194 and the flame detector 150 sensing the presence of a flame 122 in the burning unit 120, and checking that this measured duration of time is shorter than the determined earliest flame appearance time.

[0087] Preferably, the method may further include a handling step, comprising responding to the leak of the gas valve with a gas valve leak handling device by signalling the leak of the gas valve and accordingly putting the air-gas mixture burning appliance in one or more of a safe state, a non-operational state, or a restricted performance state.

[0088] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may use gas valve leak handling device 192 to signal the leak of the gas valve 194 and accordingly putting the air-gas mixture burning appliance 100 in one or more of a safe state, a non-operational state, or a restricted performance state.

[0089] According to one aspect, the determining step may further comprise determining the earliest flame appearance time based on at least the type of gas.

[0090] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may determine the earliest flame appearance time based on at least the type of gas.

[0091] Optionally, the determining step may further comprise determining the earliest flame appearance time based at least on an elapsed time since the flame detector previously sensed a flame in the burning unit.

[0092] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may determine the earliest flame appearance time based at least on an elapsed time since the flame detector 150 previously sensed a flame 122 in the burning unit 120.

[0093] Preferably, the determining step may further comprise determining the earliest flame appearance time by selecting from a continuous range of values, wherein all values in the continuous range of values are greater than a predetermined minimum earliest flame appearance time.

[0094] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may determine the earliest flame appearance time by selecting from a continuous range of values, wherein all values in the continuous range of values are greater than a predetermined minimum earliest flame appearance time.

[0095] Optionally, the method may further comprise a leak test window step. During the leak test window step, the air-gas mixture burning appliance may periodically shut off the gas valve for a predetermined period of time to provide the gas valve leak detector an opportunity for detecting a leak of the gas valve.

[0096] For example, the air-gas mixture burning appliance 100 of Fig. 1 or Fig. 2 may periodically shut off the gas valve 194 for a predetermined period of time to provide the gas valve leak detector 190 an opportunity for detecting a leak of the gas valve 194.

Claims

1. An air-gas mixture burning appliance (100), comprising:

   a burning unit (120) for burning a combustible air-gas mixture (130);
   a flame detector (150) for sensing a presence of a flame (122) in the burning unit (120);
   an air-gas mixing unit (110) that is arranged upstream of the burning unit (120) and is adapted for mixing of air (111) and gas (119) to form the combustible air-gas mixture (130);
   a gas valve (194) that is arranged upstream of the air-gas mixing unit (110) and is adapted for regulating a flow of the gas (119) to the air-gas mixing unit (110);
   a controller (140) that is adapted for determining an earliest flame appearance time for an ignition phase of the burning unit (120) by selecting from at least two different durations of time, wherein the controller (140) determines the earliest flame appearance time as an anticipated minimum duration of time that elapses between an opening of the gas valve (194) and the flame detector (150) sensing the presence of a flame

(122) in the burning unit (120).

2. The air-gas mixture burning appliance of claim 1, further comprising:
a secured gas pathway (116) that is arranged between the gas valve (194) and the air-gas mixing unit (110) and is adapted for providing the gas (119) from the gas valve (194) to the air-gas mixing unit (110), and wherein the controller (140) determines the earliest flame appearance time based on an inferred concentration of the gas (119) in the secured gas pathway (116).

3. The air-gas mixture burning appliance of any one of claims 1 or 2, further comprising:
a gas valve leak detector (190) that is adapted for detecting a leak of the gas valve (194) during the ignition phase of the burning unit (120) based on measuring a measured duration of time between the opening of the gas valve (194) and the flame detector (150) sensing the presence of a flame (122) in the burning unit, and checking that the measured duration of time is shorter than the determined earliest flame appearance time.

4. The air-gas mixture burning appliance of claim 3, further comprising:
a gas valve leak handling device (192) that, in response to the gas valve leak detector (190) detecting a current leak of the gas valve (194), is adapted for signalling the current leak of the gas valve (194) and for putting the air-gas mixture burning appliance (100) in at least one of a safe state, a non-operational state, or a restricted performance state.

5. The air-gas mixture burning appliance of any one of claims 3 or 4, wherein the gas valve (194) is shut off periodically for a predetermined period of time to provide the gas valve leak detector (190) an opportunity for detecting a leak of the gas valve (194).

6. The air-gas mixture burning appliance of any one of the preceding claims, wherein the controller (140) determines the earliest flame appearance time based at least on the type of the gas (119).

7. The air-gas mixture burning appliance of any one of the preceding claims, wherein the controller (140) determines the earliest flame appearance time based at least on an elapsed time since the flame detector (150) previously sensed a flame (122) in the burning unit (120).

8. The air-gas mixture burning appliance of any one of the preceding claims, wherein the controller (140) determines the earliest flame appearance time by selecting from a continuous range of values, wherein all values in the continuous range of values are greater than a predetermined minimum earliest flame appearance time.

9. A method (300) of operating an air-gas mixture burning appliance (100) that comprises a burning unit (120) for burning a combustible air-gas mixture (130), a flame detector (150) for sensing a presence of a flame (122) in the burning unit (120), an air-gas mixing unit (110) that is arranged upstream of the burning unit (120) and is adapted for mixing of air (111) and gas (119) to form the combustible air-gas mixture (130), and a gas valve (194) that is arranged upstream of the air-gas mixing unit (110) and is adapted for regulating a flow of the gas (119) to the air-gas mixing unit (110), the method comprising:
a determining step (310), comprising determining with a controller (140), an earliest flame appearance time for an ignition phase of the burning unit (120) by determining an anticipated minimum duration of time that elapses between an opening of the gas valve (194) and the flame detector (150) sensing the presence of a flame (122) in the burning unit (120).

10. The method of claim 9, wherein the air-gas mixture burning appliance (100) further comprises a secured gas pathway (116) that is arranged between the gas valve (194) and the air-gas mixing unit (110), and wherein the determining step (310) further comprises:
determining, with the controller (140), the earliest flame appearance time based on an inferred concentration of the gas (119) in the secured gas pathway (116).

Fig. 1

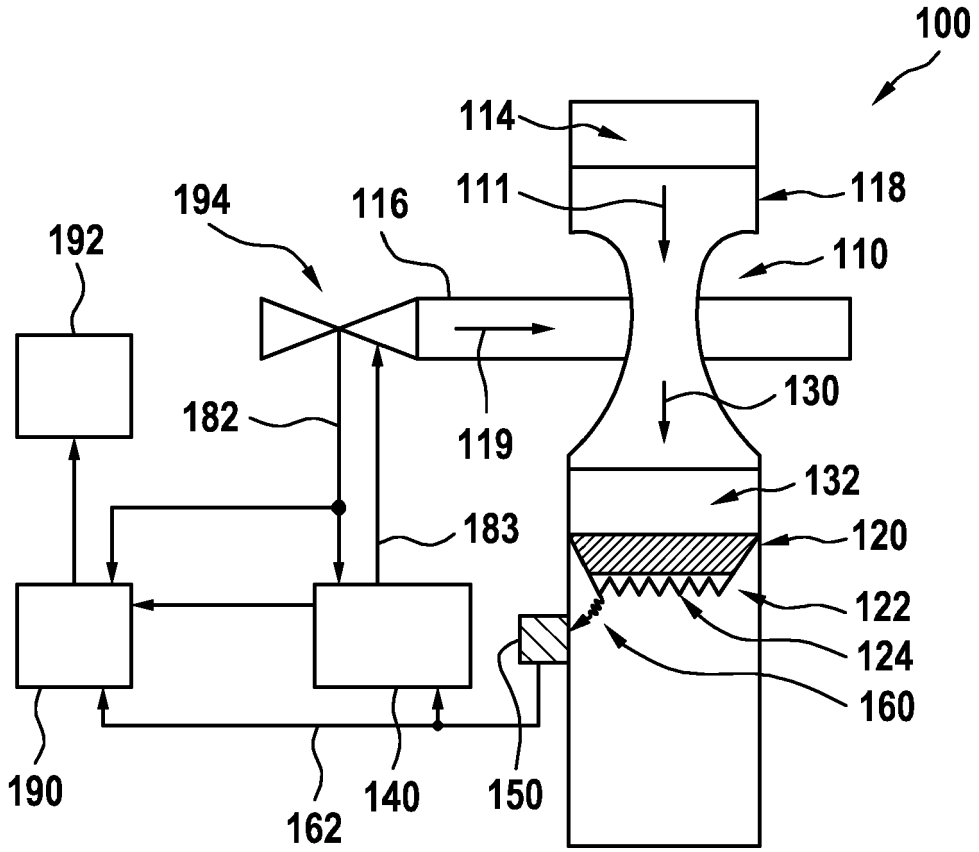
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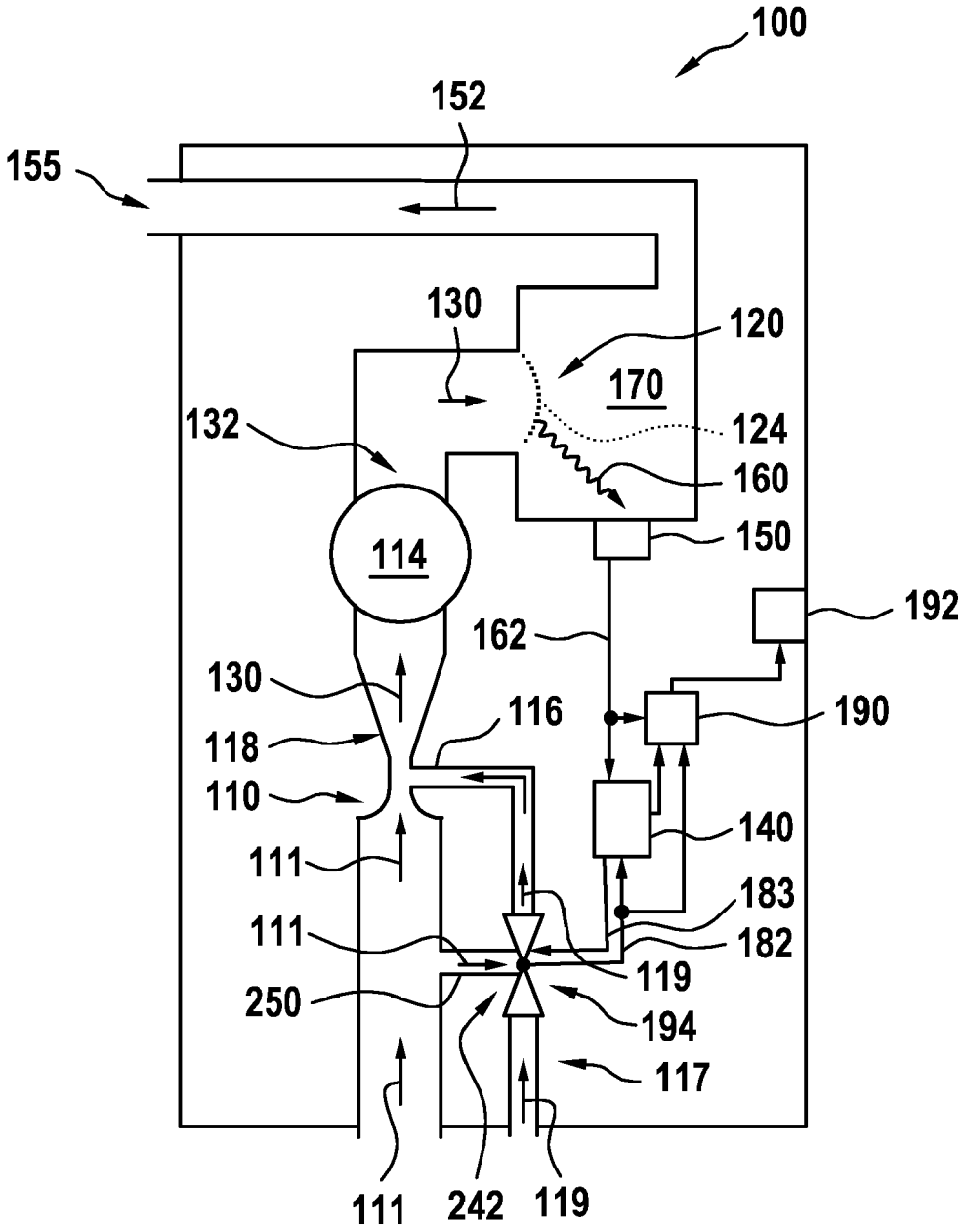
Fig. 2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242
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Fig. 3