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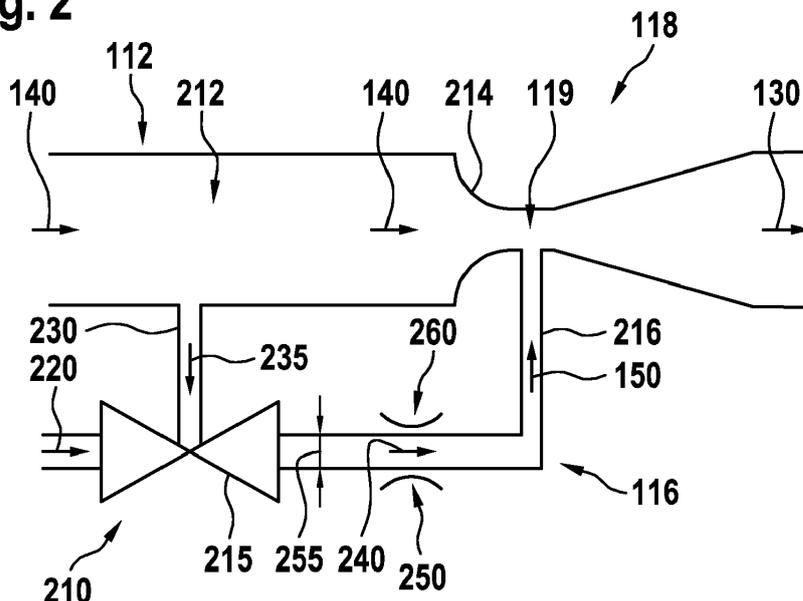
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(54) **AN AIR-GAS MIXING UNIT FOR AN AIR-GAS MIXTURE BURNING APPLIANCE**

(57) In an air-gas mixing unit for an air-gas mixture burning appliance, comprising: at least one air-gas mixer (118), an air supply (112) with an airway (212), and a gas supply (116) with a gas channel (216) that is connected to a gas governor (210), wherein the gas governor comprises: a gas valve (215) that is adapted to control gas pressure in the gas channel (216) dependant on an air pressure signal (235) that is indicative of a static air pres-

sure in the air way, and a gas restrictor (250) that restricts flow of gas from the gas valve to a point of mixing (119); the gas restrictor is interchangeable between at least one first gas restrictor that is embodied to form a gas flow with a first Reynolds number and at least one second gas restrictor that is embodied to form a gas flow with a second Reynolds number.

Fig. 2



Description

Background of the Invention

[0001] The present invention relates to an air-gas mixing unit for an air-gas mixture burning appliance, comprising at least one air-gas mixer that forms a point of mixing for mixing of air and gas to form a combustible air-gas mixture, an air supply with an air way that is connected to the point of mixing for supply of air to the point of mixing, and a gas supply with a gas channel that is connected to the point of mixing and a gas governor that is adapted to control supply of gas to the point of mixing via the gas channel, wherein the gas governor comprises a gas valve that is adapted to control gas pressure in the gas channel dependant on an air pressure signal that is indicative of a static air pressure in the air way, and a gas restrictor that restricts flow of gas from the gas valve to the point of mixing. The present invention relates further to an air-gas mixture burning appliance that comprises such an air-gas mixing unit.

[0002] From the state of the art an air-gas mixture burning appliance with an air-gas mixing unit is known, wherein e.g. a hydrocarbon gas such as methane or propane may be used as gas and mixed with air to form a combustible air-gas mixture. The air-gas mixing unit may comprise a Venturi-type mixing nozzle that forms the combustible air-gas mixture with a desired concentration or ratio from separate gas and air streams. The air stream is generally forced into motion by a fan, which may be located upstream or downstream of the Venturi-type mixing nozzle. The Venturi-type mixing nozzle usually comprises an airway with a converging channel in order to accelerate the air stream for creating a decreased air pressure. This decreased air pressure, which may also be referred to as suction pressure, causes a suction effect on the gas stream in an associated gas channel, which causes the gas stream to flow into the Venturi-type mixing nozzle, where the gas stream mixes with the air stream. In the associated gas channel, an upstream side of the gas stream is controlled by a gas valve, which regulates a respective gas pressure relative to an air pressure measured at an air pressure measuring point located usually in the airway, thus, controlling a respective flow rate of the gas stream. In order to further control the respective flow rate of the gas stream, a gas restrictor is placed in between the gas valve and the Venturi-type mixing nozzle. The gas restrictor has usually a cross sectional area which is smaller than elsewhere in the gas channel between the gas valve and the Venturi-type mixing nozzle of the air-gas mixing unit.

[0003] The air-gas mixing unit and, more generally, the air-gas mixture burning appliance can be embodied to operate on multiple different gases, such as a hydrocarbon gas and hydrogen gas. However, when switching between different gases, usually some part of the air-gas mixture burning appliance, i.e. the air-gas mixing unit, needs to be exchanged. For instance, the gas restrictor

and/or the gas valve must be exchanged, and/or a respective gas offset pressure setting must be adjusted at an associated gas valve regulator.

5 Summary of the Invention

[0004] The present invention relates to an air-gas mixing unit for an air-gas mixture burning appliance, comprising at least one air-gas mixer that forms a point of mixing for mixing of air and gas to form a combustible air-gas mixture, an air supply with an air way that is connected to the point of mixing for supply of air to the point of mixing, and a gas supply with a gas channel that is connected to the point of mixing and a gas governor that is adapted to control supply of gas to the point of mixing via the gas channel. The gas governor comprises a gas valve that is adapted to control gas pressure in the gas channel dependant on an air pressure signal that is indicative of a static air pressure in the air way, and a gas restrictor that restricts flow of gas from the gas valve to the point of mixing. The gas restrictor is interchangeable between at least one first gas restrictor that is embodied to form a gas flow with a first Reynolds number and at least one second gas restrictor that is embodied to form a gas flow with a second Reynolds number, the first Reynolds number being at least three times greater than the second Reynolds number.

[0005] Advantageously, the inventive air-gas mixing unit enables provision of an interchangeable set of gas restrictors which can be used to make an associated air-gas mixture burning appliance gas-convertible, wherein the particular Reynolds number associated with each one of the gas restrictors, evaluated using respective properties of the gas that is to be used therewith, differs by a factor of at least three. In other words, one gas restrictor will e.g. create a more turbulent gas flow having a Reynolds number at least 3 times greater than the Reynolds number of the gas flow of another, more laminar gas restrictor. In other words, independent of naturally arising differences in the properties of different gases, such as density, viscosity, and heating value, the gas restrictors are specifically embodied to form gas flows with Reynolds numbers which intentionally differ by a ratio of at least three, i.e. three to one.

[0006] More particularly, by providing the at least one first gas restrictor that is embodied to form a gas flow with a first Reynolds number and the at least one second gas restrictor that is embodied to form a gas flow with a second Reynolds number as interchangeable gas restrictors for a single air-gas mixing unit for an air-gas mixture burning appliance, the latter may easily, quickly and reliably be converted from use with a first type of gas, such as a hydrocarbon gas, to a second type of gas, such as hydrogen gas. Advantageously, by merely exchanging the at least one first gas restrictor with the at least one second gas restrictor, safety of the air-gas mixture burning appliance may be increased and respective costs for conversion may be decreased.

[0007] More specifically, in currently available hydrocarbon gas-convertible air-gas mixture burning appliances, which may e.g. be converted between methane and propane, an underlying operating curve of air-gas ratio (λ) versus heat input does not change significantly, showing a similar range in air-gas ratio across the heat input modulation range for both gases. However, as a respective flame speed of hydrogen gas is significantly higher than that of methane and propane, and that of hydrocarbon gases in general, an associated burner temperature in the air-gas mixture burning appliance may increase significantly when using hydrogen gas, compared to methane or propane. Especially at low heat input, the associated burner temperature with hydrogen gas can increase dramatically because of a prevailing low mixture flow rate at low heat input. This increased burner temperature also increases risk of a flame flashback, which is a safety concern.

[0008] If, however, the air-gas ratio can be increased at low heat input when using hydrogen gas, the burner temperature will reduce and, therefore, the risk of flame flashback will decrease. At the same time, the air-gas ratio at high heat input should not be increased in order to avoid a reduction in thermal efficiency and maximum heat input.

[0009] In the currently available hydrocarbon gas-convertible air-gas mixture burning appliances, the air-gas ratio is increased at low heat input by means of adjusting the gas offset pressure setting at the gas valve regulator. Nevertheless, this action is susceptible to user error. In contrast thereto, exchanging the at least one first gas restrictor that is embodied to form a gas flow with a first Reynolds number with the at least one second gas restrictor that is embodied to form a gas flow with a second Reynolds number, enables to increase the air-gas ratio at low heat input without adjusting the gas offset pressure setting and without affecting the air-gas ratio at high heat input.

[0010] According to one aspect, the gas restrictor is interchangeable to permit adaptation of the gas governor to operate with a hydrocarbon gas, in particular methane, by means of the at least one first gas restrictor or with hydrogen gas by means of the at least one second gas restrictor.

[0011] Thus, the inventive air-gas mixing unit enables provision of a gas-convertible hydrocarbon gas-hydrogen gas air-gas mixture burning appliance which retains a common and proven range of air-gas ratio across a respective heat input range of a conventional air-gas mixture burning appliance when using hydrocarbon gas, while simultaneously enabling a different range of air-gas ratio across the heat input range when using hydrogen gas. Accordingly, improved reliability and performance are enabled because of a resulting reduced burner temperature and, hence, a reduced flame flashback risk.

[0012] According to one aspect, the at least one first gas restrictor forms a first reduced cross-sectional flow opening that is embodied with a first isoperimetric ratio,

and wherein the at least one second gas restrictor forms a second reduced cross-sectional flow opening that is embodied with a second isoperimetric ratio, the first isoperimetric ratio being at least two times smaller than the second isoperimetric ratio.

[0013] More generally, in order to make a given gas restrictor more inertia-driven for creation of a comparatively turbulent gas flow, i.e. to embody the given gas restrictor such that it forms a gas flow with a comparatively high Reynolds number, the isoperimetric ratio of a respective smallest cross-sectional flow opening in the gas restrictor is preferably comparatively low. Conversely, in order to make the given gas restrictor more friction-driven for creation of a comparatively laminar gas flow, i. e. to embody the given gas restrictor such that it forms a gas flow with a comparatively low Reynolds number, the isoperimetric ratio of the respective smallest cross-sectional flow opening in the gas restrictor is preferably comparatively high.

[0014] The second reduced cross-sectional flow opening may be formed by a plurality of reduced cross-sectional flow openings.

[0015] Thus, the second reduced cross-sectional flow opening may easily and reliably be adapted to form a gas flow with a reduced Reynolds number.

[0016] The second reduced cross-sectional flow opening may be embodied with a length that is at least two times greater than the second isoperimetric ratio.

[0017] Thus, the second reduced cross-sectional flow opening may advantageously be provided to form an increased frictional resistance. As a result, the overall pressure drop behavior of the at least one second gas restrictor becomes even more friction-driven.

[0018] According to one aspect, the at least one first gas restrictor is configured to vary an air-gas ratio of an air-gas mixture burning appliance by less than 1.3 over a heat input range of the air-gas mixture burning appliance, wherein the at least one second gas restrictor is configured to vary an air-gas ratio of an air-gas mixture burning appliance by more than 1.3 over a heat input range of the air-gas mixture burning appliance.

[0019] Thus, the inventive air-gas mixing unit enables operation of an associated air-gas mixture burning appliance on a gas, such as e.g. hydrogen gas, with a comparatively high air-gas ratio (λ) at low heat input for a reduced burner temperature, while keeping a lower air-gas ratio (λ) at high heat input for satisfactory thermal efficiency and satisfactory maximum heat input capability. At the same time, the inventive air-gas mixing unit enables operation of the associated air-gas mixture burning appliance on a gas, such as a hydrocarbon gas, e.g. methane or propane, with a relatively constant air-gas ratio (λ) across the heat input range for satisfactory thermal efficiency, combustion stability, and emissions of pollutants. In other words, the variation in air-gas ratio across the heat input range can be tailored to the needs of each type of gas used, without negatively affecting the performance on other types of gases.

[0020] Preferably, the gas restrictor is interchangeable independent of the gas valve.

[0021] Thus, the air-gas mixing unit and, more generally, an associated air-gas mixture burning appliance may easily and rapidly be adapted for use with different types of gas.

[0022] The gas valve may comprise a gas valve regulator with a gas offset pressure setting that is identical for the at least one first gas restrictor and the at least one second gas restrictor.

[0023] Thus, any adjustment of the gas offset pressure setting by a user, which is usually comparatively error-prone, may advantageously be avoided.

[0024] According to one aspect, the at least one first gas restrictor is configured for exclusive use with a first type of gas in an air-gas mixture burning appliance, wherein the at least one second gas restrictor is configured for exclusive use with a second type of gas in an air-gas mixture burning appliance.

[0025] Accordingly, the at least one first gas restrictor may e.g. be adapted to the characteristics of a hydrocarbon gas, such as methane or propane, while the at least one second gas restrictor may e.g. be adapted to the characteristics of hydrogen gas.

[0026] Furthermore, the present invention relates to an air-gas mixture burning appliance with an air-gas mixing unit, wherein the air-gas mixing unit comprises at least one air-gas mixer that forms a point of mixing for mixing of air and gas to form a combustible air-gas mixture, an air supply with an air way that is connected to the point of mixing for supply of air to the point of mixing, and a gas supply with a gas channel that is connected to the point of mixing and a gas governor that is adapted to control supply of gas to the point of mixing via the gas channel. The gas governor comprises a gas valve that is adapted to control gas pressure in the gas channel dependant on an air pressure signal that is indicative of a static air pressure in the air way, and a gas restrictor that restricts flow of gas from the gas valve to the point of mixing. The gas restrictor is interchangeable between at least one first gas restrictor that is embodied to form a gas flow with a first Reynolds number and at least one second gas restrictor that is embodied to form a gas flow with a second Reynolds number, the first Reynolds number being at least three times greater than the second Reynolds number.

[0027] By providing the at least one first gas restrictor that is embodied to form a gas flow with a first Reynolds number and the at least one second gas restrictor that is embodied to form a gas flow with a second Reynolds number as interchangeable gas restrictors for the air-gas mixing unit of the air-gas mixture burning appliance, the latter may easily, quickly and reliably be converted from use with a first type of gas, such as a hydrocarbon gas, to a second type of gas, such as hydrogen gas. Advantageously, by merely exchanging the at least one first gas restrictor with the at least one second gas restrictor, safety of the air-gas mixture burning appliance may be

increased and respective costs for conversion may be decreased.

Brief Description of the Drawings

[0028] 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 with an air-gas mixing unit according to the present invention,

Fig. 2 shows a schematic cross-sectional view of the air-gas mixing unit of Fig. 1 with a gas restrictor according to a preferred embodiment,

Fig. 3 shows a diagram with illustrative air-gas ratios of a conventional gas-convertible air-gas mixture burning appliance,

Fig. 4 shows a diagram with illustrative air-gas ratios of the air-gas mixture burning appliance of Fig. 1, and

Fig. 5 to Fig. 7 show schematic views of illustrative gas restrictors for the air-gas mixing unit of Fig. 2.

Detailed Description

[0029] Fig. 1 shows an illustrative air-gas mixture burning appliance 100 with an air-gas mixing unit 110, an air supply 112, a gas supply 116, and a burning unit 120. 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.

[0030] Preferably, the air-gas mixture burning appliance 100 is convertible for use with different types of gases and, thus, forms a gas-convertible air-gas mixture burning appliance. More specifically, the air-gas mixture burning appliance 100 may initially be adapted for use with a first type of gas, such as e.g. hydrogen gas, so that the air-gas mixture burning appliance 100 forms an air-hydrogen gas mixture burning appliance. Furthermore, the air-gas mixture burning appliance 100 may be converted to be used with a second type of gas, such as e.g. a hydrocarbon gas, for instance methane or propane, so that the air-gas mixture burning appliance 100 then forms an air-hydrocarbon gas mixture burning appliance.

[0031] The air-gas mixing unit 110 is preferably adapt-

ed for mixing of air and gas to form a combustible air-gas mixture 130. Preferentially, the combustible air-gas mixture 130 is a homogenous mixture of the air and the gas.

[0032] The air is preferably drawn into the air-gas mixing unit 110 via the air supply 112, which is illustratively connected to the air-gas mixing unit 110, and the gas is preferably supplied to the air-gas mixing unit 110 via the gas supply 116. Illustratively, the air supply 112 includes a fan 114 that may be operated with an adaptable fan speed and/or within predetermined ranges of fan speeds to draw air into the air-gas mixing unit 110.

[0033] According to one aspect, the air supply 112 and the gas supply 116 are interconnected via a plurality of air-gas mixers 118 of the air-gas mixing unit 110. Each one of the plurality of air-gas mixers 118 forms preferably an associated discrete point of mixing 119. Preferably, the combustible air-gas mixture 130 is formed at all such discrete points of mixing 119 from a respective air flow 140 supplied via the air supply 112 and a respective gas flow 150 supplied via the gas supply 116. The combustible air-gas mixture 130 is then guided via the plurality of air-gas mixers 118 to the burning unit 120.

[0034] 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 that is formed at the points of mixing 119 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.

[0035] By way of example, the burner surface 124 is illustrated with a comparatively small flame 122 which occurs e.g. at a low firing rate of the air-gas mixing unit 110, i.e. at a comparatively low rate at which feed of the combustible air-gas mixture 130 from the air-gas mixing unit 110 to the burning unit 120 occurs, in terms of volume, heat units, or weight per unit time. Such a low firing rate may e.g. be applied to the air-gas mixing unit 110 during an ignition phase of the air-gas mixture burning appliance 100.

[0036] Fig. 2 shows one of the plurality of air-gas mixers 118 of the air-gas mixing unit 110 of Fig. 1. However, for simplicity and clarity of the drawing only a single air-gas mixer of the plurality of air-gas mixers 118 is shown, which is preferably representative of all air-gas mixers of the plurality of air-gas mixers 118 of Fig. 1, which are preferentially embodied identically, at least within predetermined manufacturing tolerances and with respect to an underlying functioning. This single air-gas mixer is described in detail hereinafter and illustratively referred to as "the air-gas mixer 118". Thus, a detailed description of each one of the plurality of air-gas mixers 118 of Fig. 1 may be omitted for brevity and conciseness.

[0037] As described above at Fig. 1, the air-gas mixer 118 is provided for mixing of air supplied by means of the air flow 140 flowing through an air way 212 of the air supply 112 with gas supplied by means of the gas flow 150 via the gas supply 116 at the point of mixing 119 in order to form the combustible air-gas mixture 130. More

specifically, the air-gas mixer 118 is preferably connected to the gas supply 116 such that the gas flow 150 may be guided from the gas supply 116 to the point of mixing 119. Illustratively, the gas supply 116 comprises a gas channel 216 that is connected to the point of mixing 119 for guiding the gas flow 150 to the point of mixing 119.

[0038] Preferably, the air-gas mixer 118 is embodied as a Venturi-type mixing nozzle that comprises a converging channel 214 which is connected to the air way 212. The converging channel 214 is provided to accelerate the air flow 140 in order to create a decreased air pressure, which is sometimes also referred to as "suction (air) pressure", which causes a suction effect on the gas flow 150, which causes the gas flow 150 to flow into the Venturi-type mixing nozzle and mix with the air stream 140 at the point of mixing 119.

[0039] Preferably, the gas supply 116 further comprises a gas governor 210 that is adapted to control supply of gas to the point of mixing 119 via the gas channel 216. The gas governor 210 illustratively comprises a gas valve 215 and a gas restrictor 250. The gas restrictor 250 preferably restricts flow of gas from the gas valve 215 to the point of mixing 119 via the gas channel 216. The gas valve 215 is adapted to control gas pressure in the gas channel 216.

[0040] More specifically, the gas valve 215 is connected to the airway 212 by means of a reference pressure port 230 that is adapted to determine an air pressure signal 235 from the air flow 140 in the air way 212, which is indicative of a static air pressure in the airway 212. Thus, the gas valve 215 may control gas pressure of an incoming gas flow 220 dependant on the air pressure signal 235 in order to create an air pressure-controlled gas flow 240 that flows to the gas restrictor 250.

[0041] The gas restrictor 250 is embodied to form a gas flow with a predetermined Reynolds number. By way of example, the gas restrictor 250 restricts the air pressure-controlled gas flow 240 and, thus, forms the gas flow 150 which is supplied via the gas channel 216 to the point of mixing 119.

[0042] More specifically, the gas restrictor 250 preferably forms a reduced cross-sectional flow opening 260 that is embodied with an associated isoperimetric ratio. Illustratively, the reduced cross-sectional flow opening 260 is embodied with a reduced isoperimetric ratio and comprises by way of example a reduced hydraulic diameter 255.

[0043] At this point, it should be noted that functioning of a gas governor and, more particularly, a gas valve and/or a gas restrictor to perform an air-gas ratio control as such is well-known to the person skilled in the art. Thus, a more detailed description of the functioning of the gas governor 210 and, more particularly, of the gas valve 215 and/or the gas restrictor 250 may be omitted for brevity and conciseness.

[0044] According to a preferred embodiment, the gas restrictor 250 of the gas governor 210 is interchangeable between at least one first gas restrictor (e.g. gas restrictor

500 in Fig. 5) that is embodied to form a gas flow with a first Reynolds number and at least one second gas restrictor (e.g. gas restrictor 600 in Fig. 6) that is embodied to form a gas flow with a second Reynolds number, the first Reynolds number being at least three times greater than the second Reynolds number. Preferably, the gas restrictor 250 is interchangeable independent of the gas valve 215. The gas valve 215 may comprise a gas valve regulator with a gas offset pressure setting that is identical for the at least one first gas restrictor (e.g. gas restrictor 500 in Fig. 5) and the at least one second gas restrictor (e.g. gas restrictor 600 in Fig. 6).

[0045] For instance, the at least one first gas restrictor (e.g. gas restrictor 500 in Fig. 5) may be configured for exclusive use with a first type of gas in the air-gas mixture burning appliance 100 of Fig. 1, and the at least one second gas restrictor (e.g. gas restrictor 600 in Fig. 6) may be configured for exclusive use with a second type of gas in the air-gas mixture burning appliance 100 of Fig. 1. By way of example, the gas governor 210 may be adapted to operate with a hydrocarbon gas, such as methane or propane, by means of the at least one first gas restrictor (e.g. gas restrictor 500 in Fig. 5) or with hydrogen gas by means of the at least one second gas restrictor (e.g. gas restrictor 600 in Fig. 6).

[0046] More specifically, provision of the at least one first gas restrictor (e.g. gas restrictor 500 in Fig. 5) and the at least one second gas restrictor (e.g. gas restrictor 600 in Fig. 6) enables use of interchangeable gas restrictors with different pressure drop behaviors in order to change an underlying range of air-gas ratio across an underlying heat input range for the different gases that are useable with a given gas-convertible air-gas mixture burning appliance, such as the air-gas mixture burning appliance 100 of Fig. 1. These different pressure drop behaviors of the interchangeable gas restrictors may be obtained by ensuring that respective geometric designs of the interchangeable gas restrictors create gas flows with different Reynolds number.

[0047] Preferably, isoperimetric ratios associated with the interchangeable gas restrictors are adapted such that the interchangeable gas restrictors create gas flows with different Reynolds number, as explained in more detail below with reference to Fig. 4. By way of example, the at least one first gas restrictor (e.g. gas restrictor 500 in Fig. 5) may form a first reduced cross-sectional flow opening (e.g. 560 in Fig. 5) that is embodied with a first isoperimetric ratio, and the at least one second gas restrictor (e.g. gas restrictor 600 in Fig. 6) may form a second reduced cross-sectional flow opening (e.g. 660 in Fig. 6) that is embodied with a second isoperimetric ratio, the first isoperimetric ratio being at least two times smaller than the second isoperimetric ratio.

[0048] Fig. 3 shows by way of example a diagram 300 with illustrative air-gas ratios obtainable in a conventional gas-convertible air-gas mixture burning appliance. The diagram 300 represents illustrative variations in air-gas ratios (λ) 320 across an associated heat input

range 310 of the conventional gas-convertible air-gas mixture burning appliance.

[0049] More specifically, for common hydrocarbon gases, such as methane or propane, a respectively desired air-gas ratio has a limited variability across the heat input range, as illustrated with two graphs 330, 340, one representing the air-gas ratios of methane, and the other one representing the air-gas ratios of propane, by way of example. As illustrated with the two graphs 330, 340, the air-gas ratios between an air-gas ratio at minimum heat input and an air-gas ratio at maximum heat input usually differs by less than a factor of 1.3. Such a characteristic can be produced with a gas restrictor which has a predominantly inertia-driven pressure drop behavior. Such a behavior is associated with a quadratic increase in pressure drop (Δp) as a function of the heat input (Q), according to the Bernoulli equation ($\Delta p \propto Q^2$). This condition is paired with a comparatively high Reynolds number, which means a comparatively turbulent flow regime.

[0050] Fig. 4 shows by way of example a diagram 400 with illustrative air-gas ratios obtainable in the air-gas mixture burning appliance 100 of Fig. 1 with the air-gas mixing unit 110 that comprises the air-gas mixer 118 of Fig. 2. The diagram 400 represents illustrative variations in air-gas ratios (λ) 420 across an associated heat input range 410 of the air-gas mixture burning appliance 100 of Fig. 1 with the air-gas mixing unit 110 that comprises the air-gas mixer 118 of Fig. 2.

[0051] More specifically, for hydrogen gas a respectively desired air-gas ratio has a large variability across the heat input range, as illustrated with a graph 440, which is illustratively shown together with a graph 430 that represents the air-gas ratios of methane, by way of example, similar to the graph 330 of Fig. 3. For instance, the graph 430 is associated with a gas restrictor that is configured to vary the air-gas ratio by less than 1.3 over the heat input range, while the graph 440 is associated with a gas restrictor that is configured to vary the air-gas ratio by more than 1.3 over the heat input range.

[0052] At this point, it should be noted that the air-gas ratios between an air-gas ratio at minimum heat input and an air-gas ratio at maximum heat input for hydrogen gas are advantageously different by a factor of more than 1.3. By using such a large variability in the air-gas ratios across the heat input range, as represented by the graph 440, the air-gas ratio at high heat input can be maintained at a level favorable for thermal efficiency and maximum heat input capability (slightly leaner than stoichiometric), while the air-gas ratio at low heat input can be increased significantly (much leaner than stoichiometric) in order to decrease an associated burner temperature in the air-gas mixture burning appliance 100 of Fig. 1 with the air-gas mixing unit 110 that comprises the air-gas mixer 118 of Fig. 2, thereby reducing the risk of flame flashback and increasing the safety of the the air-gas mixture burning appliance 100. Such a characteristic may be obtained with a gas restrictor which has a predominantly friction-

driven pressure drop behavior. Such a predominantly friction-driven pressure drop behavior is associated with a linear increase in pressure drop (Δp) as a function of the heat input (Q), according to the Darcy-Weisbach equation ($\Delta p \propto Q$). This condition is paired with a comparatively low Reynolds number, which means a comparatively laminar flow regime.

[0053] In order to change the pressure drop behavior of a gas restrictor, its geometric shape can be changed in order to control an associated Reynolds number. More specifically, the shape of the gas restrictor can be characterized by the predicted Reynolds number of the gas flow through it. The Reynolds number (Re [-]) is defined as a function of the gas density (ρ [mass/length³]), the flow velocity (U [length/time]), the hydraulic diameter of the cross-sectional flow opening (D_h [length]), and the dynamic viscosity of the gas (μ [mass/(length*time)]):

$$Re = \frac{\rho U D_h}{\mu}$$

[0054] In this definition, the flow velocity (U [length/time]) shall be taken as the area-averaged flow velocity in the smallest cross-sectional flow opening in the gas restrictor, evaluated at the maximum heat input rate of the air-gas mixture burning appliance 100 of Fig. 1 with the air-gas mixing unit 110 that comprises the air-gas mixer 118 of Fig. 2. Furthermore, the hydraulic diameter (D_h [length]) of the cross-sectional flow opening shall be evaluated at the location of the smallest cross-sectional flow opening in the gas restrictor. If the gas restrictor at the smallest cross-sectional flow opening contains parallel flow channels, the characteristic flow velocity and hydraulic diameter shall be taken as the average of all the parallel flow channels. Finally, the Reynolds number (Re [-]) shall be evaluated using the properties of the gas for which the gas restrictor is intended to be used. In other words, a gas restrictor which is e.g. embodied for hydrogen gas shall be characterized by the Reynolds number using the properties of hydrogen gas. Similarly, another gas restrictor embodied for another gas, e.g. a hydrocarbon gas such as methane or propane, shall be characterized by the Reynolds number using the properties of the respective hydrocarbon gas.

[0055] From the aforementioned definition of the Reynolds number, it can be derived that there are two key geometric parameters to control the pressure drop behavior of a gas restrictor. An inertia-driven pressure drop behavior can be controlled most directly using the cross-sectional area of the cross-sectional flow opening in the gas restrictor (A [length²]). The friction-driven pressure drop behavior can be controlled most directly using the perimeter of the cross-sectional flow opening in the gas restrictor (P [length]). By combining these two parameters, it is possible to compare multiple gas restrictors with a single geometric parameter, i.e. the isoperimetric ratio.

[0056] The isoperimetric ratio is defined as the square

of the perimeter divided by the cross-sectional area:

$$\left(\frac{P^2}{A}\right) [-]$$

[0057] The isoperimetric ratio is generally smallest for a circular channel and is larger for any other shape. Similar to the definition of the Reynolds number, the isoperimetric ratio shall be evaluated at the location of the smallest cross-sectional flow opening in the gas restrictor. Furthermore, if the gas restrictor at the smallest cross-sectional flow opening contains parallel flow channels, the isoperimetric ratio shall be taken as the average of all the parallel flow channels. As a result, the isoperimetric ratio is N times as large for a gas restrictor with N identical flow channels as for a gas restrictor with a single flow channel. In order to make a gas restrictor more friction-driven, that is, to reduce its Reynolds number and make it more laminar, the isoperimetric ratio of the smallest cross-sectional flow opening in the gas restrictor may be increased.

[0058] Fig. 5 shows a gas restrictor 500 which is illustratively arranged in the gas channel 216 having the hydraulic diameter 255 in order to restrict the air pressure-controlled gas flow 240 and, thus, form the gas flow 150 of Fig. 2. The gas restrictor 500 is preferably comparatively inertia-driven, i.e. the gas restrictor 500 is embodied to form a comparatively turbulent gas flow with a comparatively high Reynolds number. By way of example, the gas restrictor 500 is configured to operate with a hydrocarbon gas, such as methane or propane.

[0059] The gas restrictor 500 illustratively forms a reduced cross-sectional flow opening 560 that is embodied with an isoperimetric ratio, which is schematically indicated by means of an arrow 555. Illustratively, the reduced cross-sectional flow opening 560 is reduced with respect to the cross-sectional flow opening of the gas channel 216, which is for simplicity merely illustrated by means of the hydraulic diameter 255, and forms a smallest cross-sectional flow opening 590 of the gas restrictor 500. This smallest cross-sectional flow opening 590 has a perimeter 570 and a cross-sectional area which is represented by a radius 580.

[0060] Fig. 6 shows a gas restrictor 600 which is illustratively arranged in the gas channel 216 having the hydraulic diameter 255 in order to restrict the air pressure-controlled gas flow 240 and, thus, form the gas flow 150 of Fig. 2. The gas restrictor 600 is preferably comparatively friction-driven, i.e. the gas restrictor 600 is embodied to form a comparatively laminar gas flow with a comparatively low Reynolds number. By way of example, the gas restrictor 500 is configured to operate with hydrogen gas.

[0061] The gas restrictor 600 illustratively forms a reduced cross-sectional flow opening 660 that is embodied with an isoperimetric ratio, which is schematically indicated by means of an arrow 655. Preferably, the isoper-

imetric ratio 655 is more than two times higher than the isoperimetric ratio 555 of Fig. 5.

[0062] Illustratively, the reduced cross-sectional flow opening 660 is reduced with respect to the cross-sectional flow opening of the gas channel 216, which is for simplicity merely illustrated by means of the hydraulic diameter 255, and formed by a plurality of reduced cross-sectional flow openings 692, 693, 694, 696, 698 of the gas restrictor 600. Each one of the plurality of reduced cross-sectional flow openings 692, 693, 694, 696, 698 has a perimeter 670 and a cross-sectional area which is represented by a radius 680.

[0063] Fig. 7 shows a gas restrictor 700 which is illustratively arranged in the gas channel 216 having the hydraulic diameter 255 in order to restrict the air pressure-controlled gas flow 240 and, thus, form the gas flow 150 of Fig. 2. The gas restrictor 700 is preferably comparatively friction-driven, i.e. the gas restrictor 700 is embodied to form a comparatively laminar gas flow with a comparatively low Reynolds number. By way of example, the gas restrictor 700 is configured to operate with hydrogen gas.

[0064] The gas restrictor 700 illustratively forms a reduced cross-sectional flow opening 760 which is, by way of example, embodied similar to the reduced cross-sectional flow opening 660 of Fig. 6 with the isoperimetric ratio 655 defined by means of the plurality of reduced cross-sectional flow openings 692, 693, 694, 696, 698. However, in order to make the gas restrictor 700 even more friction-driven than the gas restrictor 600 of Fig. 6, each one of the plurality of reduced cross-sectional flow openings 692, 693, 694, 696, 698 extends over an increased length 780 in streamwise direction. Preferably, the length 780 is at least two times greater than the isoperimetric ratio 655.

[0065] It should be noted that the gas restrictor 700 and the gas restrictor 600 of Fig. 6 are both preferably configured to operate with hydrogen gas in the air-gas mixture burning appliance 100 of Fig. 1 with the air-gas mixing unit 110 that comprises the air-gas mixer 118 of Fig. 2, while the gas restrictor 500 of Fig. 5 is preferably configured to operate with hydrocarbon gas, such as methane or propane, in the air-gas mixture burning appliance 100 of Fig. 1 with the air-gas mixing unit 110 that comprises the air-gas mixer 118 of Fig. 2. Thus, the gas restrictors 500, 600, 700 may be used interchangeably in the air-gas mixture burning appliance 100 of Fig. 1 with the air-gas mixing unit 110 that comprises the air-gas mixer 118 of Fig. 2, so that the air-gas mixture burning appliance 100 of Fig. 1 forms a gas-convertible air-gas mixture burning appliance, which may also be considered as a hydrogen gas-ready air-gas mixture burning appliance.

[0066] It should finally be noted, that the above description refers to a "comparatively high Reynolds number" and a "comparatively low Reynolds number". In the context of the present invention, these expressions are not intended to relate to particular absolute values,

which must e.g. be above or below a predetermined threshold. Instead, these expressions refer to relative values which are related to a comparison between these expressions. This applies likewise to any other expressions, where no particular values are indicated.

Claims

1. An air-gas mixing unit (110) for an air-gas mixture burning appliance (100), comprising:

at least one air-gas mixer (118) that forms a point of mixing (119) for mixing of air and gas to form a combustible air-gas mixture (130),
an air supply (112) with an air way (212) that is connected to the point of mixing (119) for supply of air to the point of mixing (119), and
a gas supply (116) with a gas channel (216) that is connected to the point of mixing (119) and a gas governor (210) that is adapted to control supply of gas to the point of mixing (119) via the gas channel (216), wherein the gas governor (210) comprises:

a gas valve (215) that is adapted to control gas pressure in the gas channel (216) dependant on an air pressure signal (235) that is indicative of a static air pressure in the air way (212), and

a gas restrictor (250) that restricts flow of gas from the gas valve (215) to the point of mixing (119);

wherein the gas restrictor (250) is interchangeable between at least one first gas restrictor (500) that is embodied to form a gas flow with a first Reynolds number and at least one second gas restrictor (600) that is embodied to form a gas flow with a second Reynolds number, the first Reynolds number being at least three times greater than the second Reynolds number.

2. The air-gas mixing unit of claim 1, wherein the gas restrictor (250) is interchangeable to permit adaptation of the gas governor (210) to operate with a hydrocarbon gas, in particular methane, by means of the at least one first gas restrictor (500) or with hydrogen gas by means of the at least one second gas restrictor (600).

3. The air-gas mixing unit of claim 1 or 2, wherein the at least one first gas restrictor (500) forms a first reduced cross-sectional flow opening (560) that is embodied with a first isoperimetric ratio, and wherein the at least one second gas restrictor (600) forms a second reduced cross-sectional flow opening (660) that is embodied with a second isoperimetric ratio,

the first isoperimetric ratio being at least two times smaller than the second isoperimetric ratio.

4. The air-gas mixing unit of claim 3, wherein the second reduced cross-sectional flow opening (660) is formed by a plurality of reduced cross-sectional flow openings (692, 693, 694, 696, 698). 5
5. The air-gas mixing unit of claim 3 or 4, wherein the second reduced cross-sectional flow opening (760) is embodied with a length (780) that is at least two times greater than the second isoperimetric ratio. 10
6. The air-gas mixing unit of any one of the preceding claims, wherein the at least one first gas restrictor (500) is configured to vary an air-gas ratio of an air-gas mixture burning appliance (100) by less than 1.3 over a heat input range of the air-gas mixture burning appliance (100), and wherein the at least one second gas restrictor (600) is configured to vary an air-gas ratio of an air-gas mixture burning appliance (100) by more than 1.3 over a heat input range of the air-gas mixture burning appliance (100). 15 20
7. The air-gas mixing unit of any one of the preceding claims, wherein the gas restrictor (250) is interchangeable independent of the gas valve (215). 25
8. The air-gas mixing unit of claim 7, wherein the gas valve (215) comprises a gas valve regulator with a gas offset pressure setting that is identical for the at least one first gas restrictor (500) and the at least one second gas restrictor (600). 30
9. The air-gas mixing unit of any one of the preceding claims, wherein the at least one first gas restrictor (500) is configured for exclusive use with a first type of gas in an air-gas mixture burning appliance (100), and wherein the at least one second gas restrictor (600) is configured for exclusive use with a second type of gas in an air-gas mixture burning appliance (100). 35 40
10. An air-gas mixture burning appliance (100) with an air-gas mixing unit (110), wherein the air-gas mixing unit (110) comprises: 45

at least one air-gas mixer (118) that forms a point of mixing (119) for mixing of air and gas to form a combustible air-gas mixture (130), 50
 an air supply (112) with an air way (212) that is connected to the point of mixing (119) for supply of air to the point of mixing (119), and
 a gas supply (116) with a gas channel (216) that is connected to the point of mixing (119) and a gas governor (210) that is adapted to control supply of gas to the point of mixing (119) via the gas channel (216), wherein the gas governor 55

(210) comprises:

a gas valve (215) that is adapted to control gas pressure in the gas channel (216) dependant on an air pressure signal (235) that is indicative of a static air pressure in the air way (212), and
 a gas restrictor (250) that restricts flow of gas from the gas valve (215) to the point of mixing (119);

wherein the gas restrictor (250) is interchangeable between at least one first gas restrictor (500) that is embodied to form a gas flow with a first Reynolds number and at least one second gas restrictor (600) that is embodied to form a gas flow with a second Reynolds number, the first Reynolds number being at least three times greater than the second Reynolds number.

Fig. 1

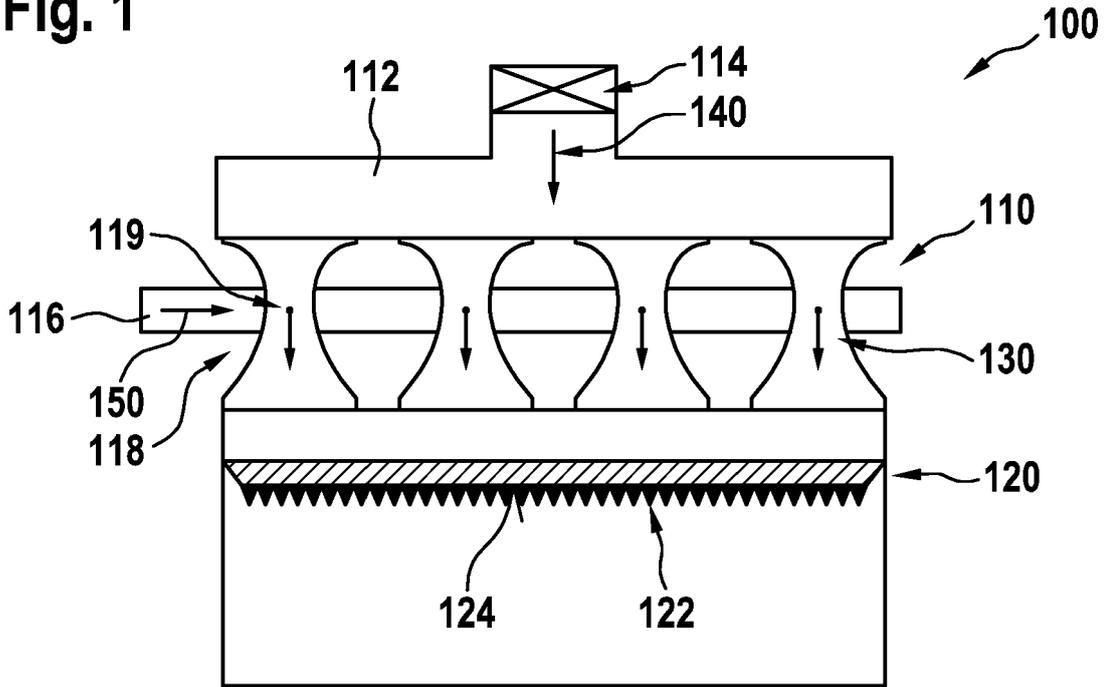


Fig. 2

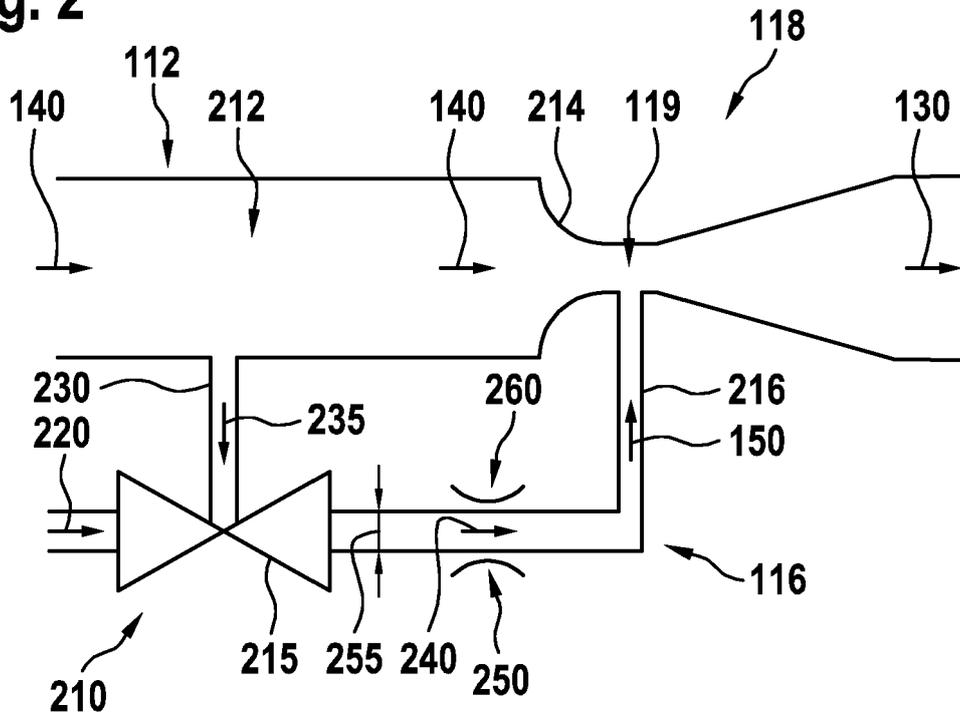


Fig. 3

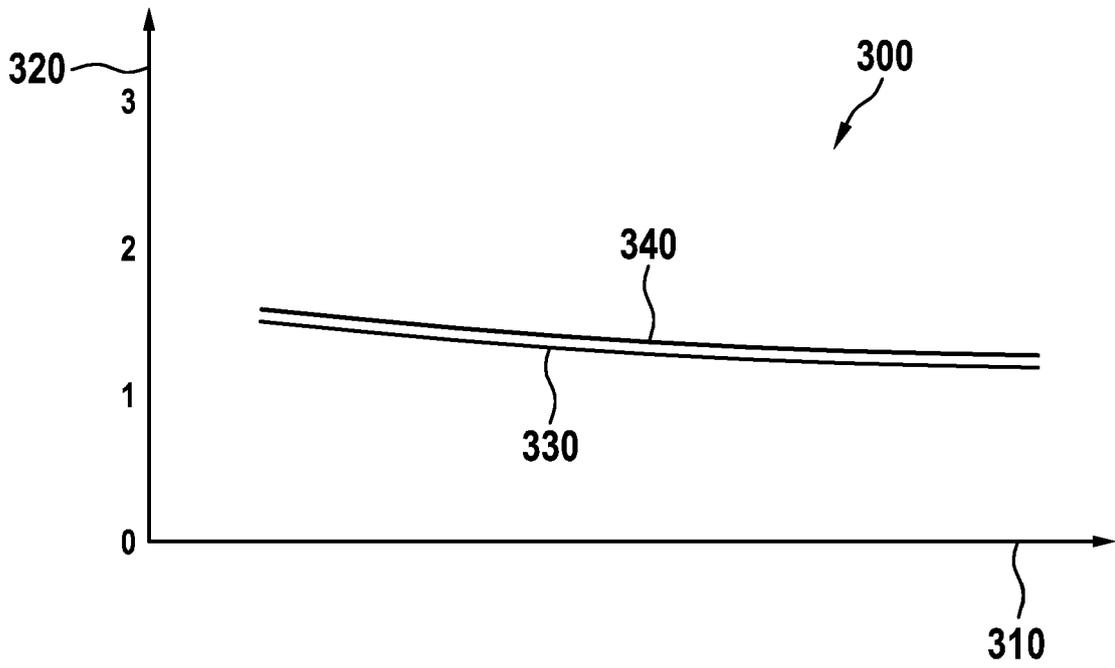


Fig. 4

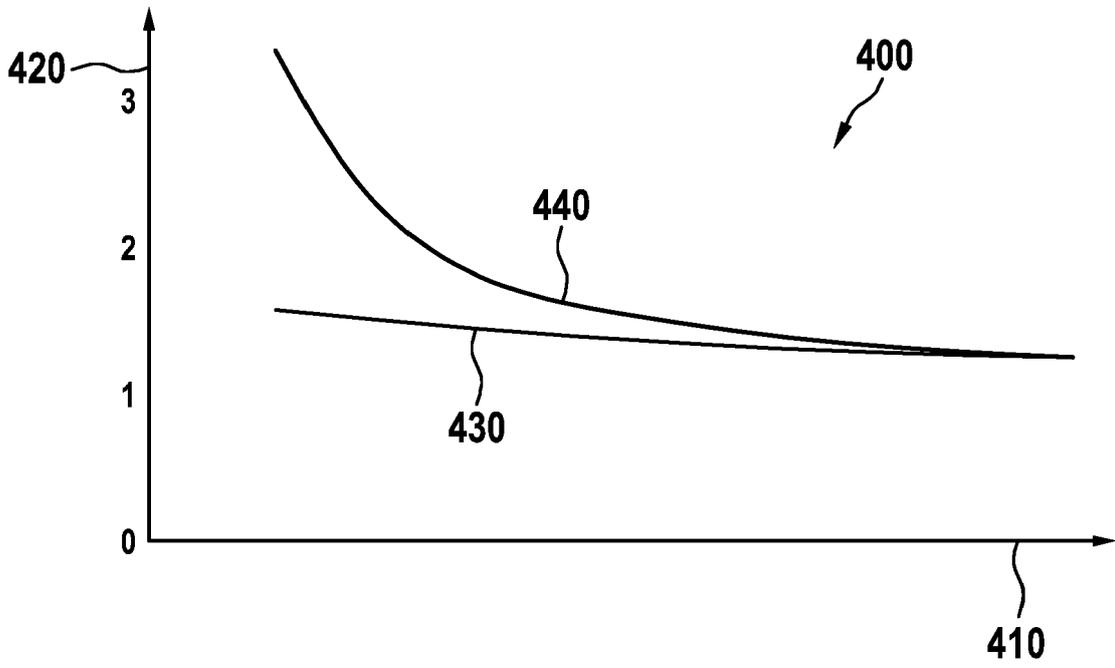


Fig. 5

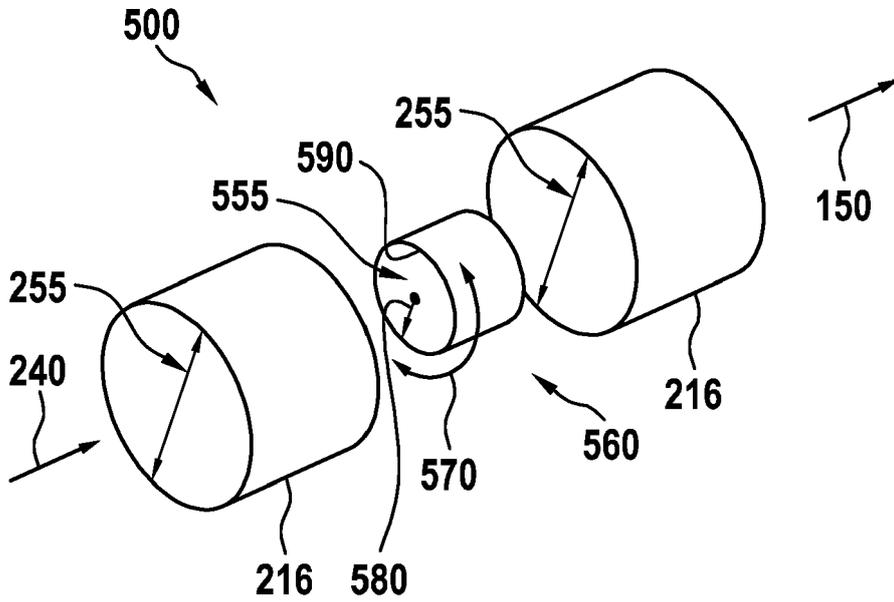


Fig. 6

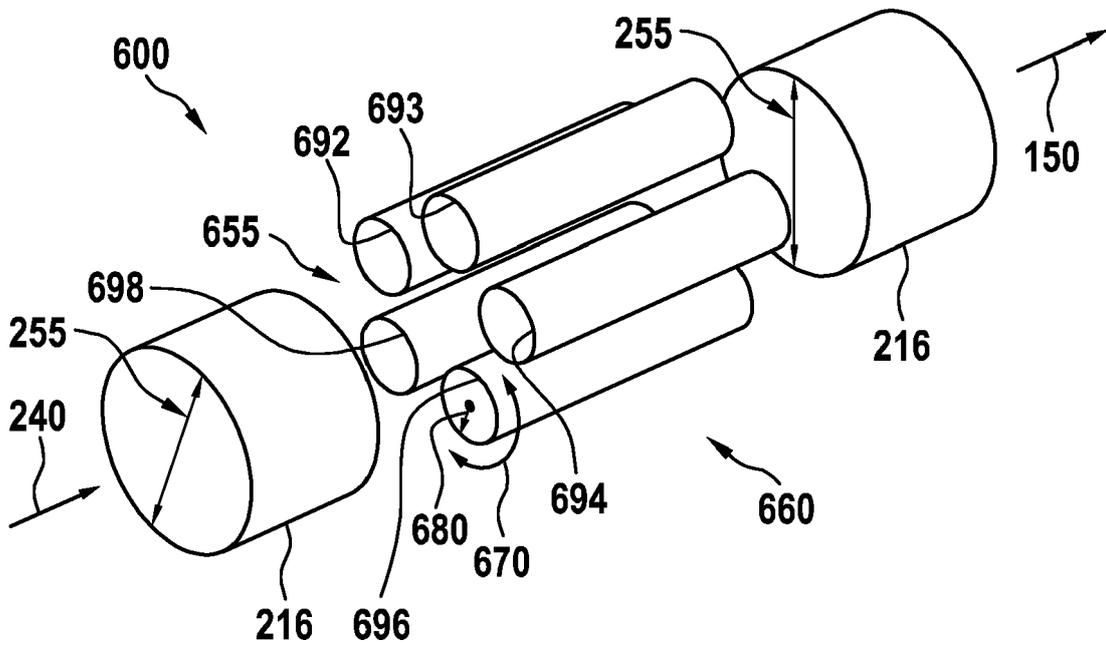
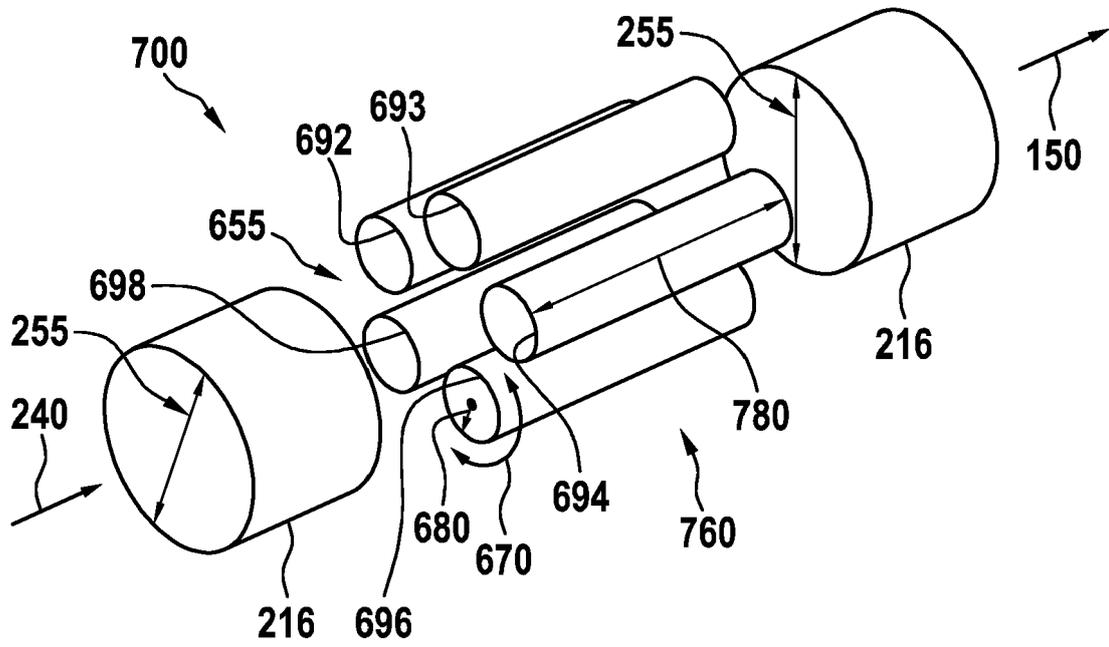


Fig. 7





EUROPEAN SEARCH REPORT

Application Number

EP 22 20 2352

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DOCUMENTS CONSIDERED TO BE RELEVANT

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X A	DE 197 49 510 A1 (BUDERUS HEIZTECHNIK GMBH [DE]) 12 May 1999 (1999-05-12) * column 3, line 22 - column 5, line 51; figures 1a, 2-12, 12a *	1, 2, 7, 9, 10 3-5, 8	
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A	Honeywell - Krom_schröder: "Industrial & Commercial Thermal" In: "Industrial & Commercial Thermal", 31 December 2016 (2016-12-31), Honeywell - Krom_Schröder, XP093041927, pages 1-16,	1-10	
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The present search report has been drawn up for all claims

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Place of search Munich	Date of completion of the search 26 April 2023	Examiner Theis, Gilbert
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26-04-2023

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