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(54) COMBUSTION CHAMBER FOR A GAS TURBINE ENGINE AND GAS TURBINE

(57) The invention concerns a combustor (24) for a gas turbine assembly (20). The combustor comprises a plurality of fuel injection nozzles (24.7) and an annular combustion chamber (24.1). The annular combustion chamber comprises an inner space (24.5) that is enclosed by a combustion chamber wall (24.2) with an inner wall portion (24.2.1), a front wall portion (24.2.2) and an outer wall portion (24.2.3). The front wall portion (24.2.2) closes the combustion chamber (24.1) at a combustion chamber front end and the inner wall portion (24.2.1) and the outer wall portion (24.2.3) define an open annular nozzle (24.3) at the rear side of the combustion chamber (24.1). The fuel injection nozzles are circumferentially

arranged around the outer wall portion (24.2.3) and protrude into the inner space (24.5) enclosed by the combustion chamber wall (24.2).

According to the invention, the innerwall portion (24.2.1) and the outerwall portion (24.2.3) are shaped so as to provide that the inner cross-sectional diameter of the annular inner space of the combustion chamber (24.1) initially decreases (narrows) towards the open end of the combustion chamber nozzle (24.3) and ultimately widens again, thus causing a Venturi effect where radial distance between the inner wall portion (24.2.1) and the outer wall portion (24.2.3) is smallest.

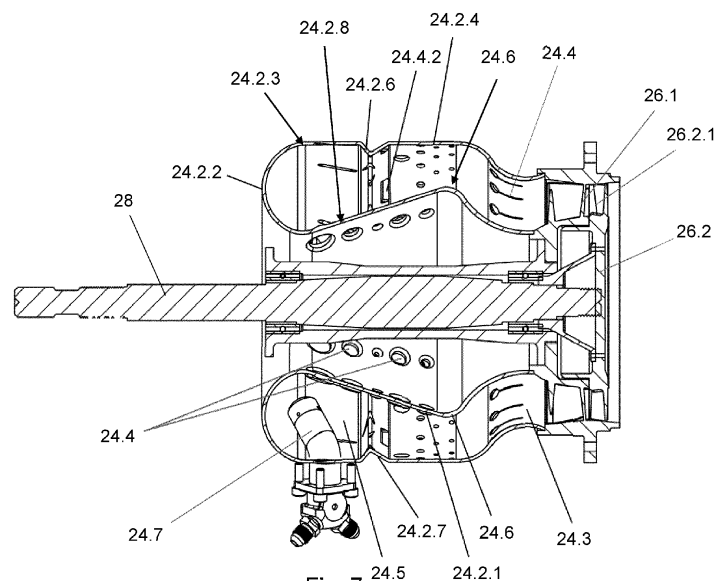


Fig. 7

Description

[0001] The invention relates to a gas turbine engine with a gas turbine. The invention relates in particular to a combustion chamber of a combustor of a gas turbine of a gas turbine engine, in particular a turboprop engine.

[0002] Gas turbine engines in particular turboprop engines are generally known. A turboprop engine comprises a gas turbine that drives a propeller via a reduction gear. The gas turbine engine comprises a compressor, a combustion chamber and a turbine. The compressor is fed with air from the environment, compresses the air and feeds the compressed air to the combustion chamber. In the combustion chamber, the compressed air is mixed with fuel and the mixture is ignited and combusts. The hot combustion gases then drive a gas turbine that in turn drives the compressor and the propeller.

[0003] A turboprop engine is typically used as an aero engine that creates thrust by means of the propeller. The thrust of the hot combustion gases at the exhaust of the turbine does not significantly contribute to the engine's overall thrust.

[0004] In general, gas turbine engines can comprise an axial compressor or a centrifugal (i.e. radial) compressor. The gas turbine of the gas turbine engine in most cases is an axial turbine with one or more turbine stages. Turboprop gas turbine engines can have separate turbines for driving the propeller and for driving the compressor. Alternatively, the compressor can be fixed to the same shaft as the turbine for driving the propeller. Then, only one turbine is needed.

[0005] In a gas turbine engine, the compressor feeds high-pressure air to the combustion chamber. The combustion chamber is also known as combustor. In the combustor the compressed air is mixed with fuel and ignited. Thus, the compressed air is heated at constant pressure as the fuel/air mix burns. As it burns the fuel/air mix heats and rapidly expands. The burned mix, i.e. the combustion gases are exhausted from the combustor through the nozzle guide vanes to a turbine wheel.

[0006] The gas turbine can be an axial gas turbine comprising one or more turbine stages with nozzle guide vanes and turbine wheels (also known as turbine vanes). A nozzle guide vane is a stationary component located at the entry of a turbine stage in a gas turbine. The nozzle guide vane's function is to direct and guide the flow of high-velocity hot gases from the combustion chamber onto the turbine blades. The nozzle guide vane also helps to optimize the velocity and pressure of the gases entering the turbine stage, which can improve the efficiency and performance of the engine.

[0007] For larger airplanes, gas turbine engines and turboprop engines are the most secure and efficient aero engines. Gas turbine engines and turboprop engines having a size, weight and power suiting smaller airplanes, however, suffer from a very high consumption and thus are economically not feasible.

[0008] While turboprop engines typically are used for

larger airplanes, small airplanes typically are powered by piston engines, for instance air cooled boxer engines providing a power between 100 and 400 kW. While turboprop engines have proven to be very reliable, replacing less reliable piston engines with turboprop engines typically is not feasible, because the efficiency of turboprop engines suffers from downscaling. This results in higher fuel consumption.

[0009] It is therefore an object of the invention to provide a turboprop engine for small airplanes with improved efficiency.

[0010] According to a first aspect, a combustor for a gas turbine assembly is provided. The combustor comprises a plurality of fuel injection nozzles and an annular combustion chamber. The annular combustion chamber comprises an inner space that is enclosed by a combustion chamber wall with an inner wall portion, a front wall portion and an outer wall portion. The front wall portion closes the combustion chamber at a combustion chamber front end and the inner wall portion and the outer wall portion define an open annular nozzle at the rear side of the combustion chamber. The fuel injection nozzles are circumferentially arranged around the outer wall portion and protrude into the inner space enclosed by the combustion chamber wall.

[0011] According to the invention, the inner wall portion and the outer wall portion are shaped so as to provide that the inner cross-sectional diameter of the annular inner space of the combustion chamber initially decreases (narrows) towards the open end of the combustion chamber nozzle and ultimately widens again, thus causing a Venturi effect where a radial distance between the inner wall portion and the outer wall portion is smallest.

[0012] The Venturi effect created by the annular Venturi nozzles portion of the combustion chamber improves the mass flow exiting from the combustion chamber and is fed to the axial turbine of the gas turbine assembly.

[0013] According to a preferred embodiment of the combustion chamber, the distance of the inner wall portion from a longitudinal axis of the gas turbine assembly initially increases in the direction of a combustion gas flow and then decreases again thus defining an apex that together with the outer wall portion of the combustion chamber wall defines a Venturi nozzle for accelerating the hot combustion exhaust gases and causing a lowered static pressure in the inner space close to the combustion chamber annular nozzle.

[0014] Preferably, the combustion chamber is surrounded by an open space that during operation is filled with compressed air and wherein the outer wall portion narrows towards to an open end of the annular nozzle portion of the combustion chamber. Preferably, holes (orifices) are provided in the narrowing outer wall portion. The holes are placed where during operation a reduced static pressure exists in the inner space, thus allowing air entering from the surrounding open space into the inner space and increasing the mass flow of the hot combustion gases exiting the combustion chamber. This im-

proves the efficiency of the gas turbine assembly.

[0015] According to a preferred embodiment of the combustion chamber, the holes provided in the narrowing outer wall portion have a keyhole shape.

[0016] According to a further preferred embodiment of the combustion chamber, the outer wall portion comprises a generally cylindrical sub-portion in which an annular vortex generating protrusion is arranged, that protrudes inwardly into the inner space enclosed by the combustion chamber wall. The annular vortex generating protrusion improves mixing of fuel and compressed air and provides for an equal and complete combustion, thus improving the efficiency of the gas turbine assembly.

[0017] Preferably, the annular vortex generating protrusion comprises an upstream wall portion facing towards the fuel injection nozzles and a downstream wall portion facing away from the fuel injection nozzles. The vortex generating holes preferably are arranged in the downstream wall portion. This further improves the efficiency of the gas turbine assembly.

[0018] According to a further preferred embodiment of the combustion chamber, the inner wall portion comprises a frusto-conical shaped wall sub-portion with a diameter that increases towards the annular Venturi nozzles portion of the combustion chamber and provides that the annular free space between the inner wall portion and the outer wall portion becomes narrower, thus causing an acceleration of the hot combustion gases during operation and a decreasing static pressure in the annular free space between the inner wall portion and the outer wall portion.

[0019] Preferably, the frusto-conical shaped wall sub-portion of the inner wall portion is provided with holes allowing compressed air from the surrounding open space entering into the inner space, thus increasing the mass flow of the hot combustion gases exiting the combustion chamber. The increased mass flow further improves the efficiency of the gas turbine assembly.

[0020] According to a preferred embodiment of the combustor, the combustor comprises four fuel injection nozzles that are equally spaced from each other. This arrangement of fuel injection nozzles supports producing a homogeneous stream of hot combustion gases for driving the axial gas turbine of the gas turbine assembly.

[0021] The combustor preferably is part of a turboprop engine that comprises a gas turbine assembly with a compressor, the combustor and an axial gas turbine and wherein the gas turbine comprises a nozzle guide vane and a turbine wheel.

[0022] The nozzle guide vane preferably is arranged between the annular exhaust nozzle of the combustion chamber and the turbine wheel. The compressor and turbine wheel preferably are connected to a turbine shaft and the nozzle guide vane is arranged to guide hot combustion gases from the combustion chamber to turbine blades of the turbine wheel. The nozzle guide vane comprises guide blades radially extending between an inner ring of the nozzle guide vane and an outer ring of the

nozzle guide vane. The outer ring has an inner wall portion defining a feed gas passage for feeding the hot combustion gases to the guide blades of the nozzle guide vane. Preferably, an inner diameter of the feed gas passage is defined by the inner wall of the outer ring wherein the inner diameter of the inner wall portion of the outer ring at the entrance of the feed gas passage corresponds to an outer diameter of the annular exhaust nozzle of the combustion chamber of the combustor at the exit of the annular exhaust nozzle.

[0023] According to a second aspect that can be combined with the first aspect, a fuel injection nozzle for a combustion chamber of a gas turbine assembly is provided. The fuel injection nozzle comprises a central fuel duct having a distal end provided with a fuel nozzle. The central fuel duct is configured for feeding fuel from a proximal end of the fuel duct to the fuel nozzle at the distal end of the fuel duct. The fuel injection nozzle further comprises a fuel intake connector and a fuel return connector that both are connected to the proximal end of the fuel duct for feeding pressurized fuel into the fuel duct and allowing the fuel to circulate in an external fuel line. The fuel injection nozzle further comprises a coaxial air duct coaxially surrounding the fuel duct and being configured for providing that fuel exiting at the fuel nozzle at the distal end of the fuel duct is surrounded by an air stream that prevents the fuel from sticking to parts of the fuel injection nozzle. According to the invention, the fuel injection nozzle is provided with a Venturi nozzle formed at the distal end of the air duct surrounding the fuel nozzle of the fuel duct. The Venturi nozzle has an inner diameter that varies over the length of the Venturi nozzle, i.e. in the longitudinal direction of the fuel injection nozzle, and that is larger at the beginning of the Venturi nozzle and at the end of the Venturi nozzle than in the middle of the Venturi nozzle.

[0024] The inventor found that the Venturi nozzle at the end of the air duct and in front of the fuel nozzle at the end of the fuel duct improves vaporization fuel exiting the fuel duct even if the fuel is provided with lower than usual pressure. In prior art fuel injection nozzles, the vaporization of fuel is affected if the pressure of the fuel is too low. However, a higher fuel pressure leads to a larger amount of fuel being injected and thus leads a higher fuel consumption.

[0025] According to a preferred embodiment of the fuel injection nozzle, the fuel injection nozzle comprises a baffle body that is arranged directly in line with the fuel duct in front of the fuel nozzle of the fuel duct. During operation, fuel exiting from the fuel nozzle at the end of the fuel duct hits the baffle body and thus is vaporized even if the pressure in the fuel duct is not high enough to cause vaporizing of the fuel alone. Thus, the baffle body further improves fuel vaporization.

[0026] Preferably, the baffle body has a cone shape with a cone tip facing away from the fuel nozzle and a baffle face facing towards the fuel nozzle. The cone shape of the baffle body supports the Venturi effect of

the Venturi nozzle and helps controlling flow separation and forming of a wake downstream of the baffle body.

[0027] Preferably, the baffle body is held by a pin in the middle of the Venturi nozzle at the distal orifice of the air duct. The arrangement of the baffle body in the middle of the Venturi nozzle optimizes the Venturi effect and the acceleration of the injected fuel-air mixture.

[0028] Preferably, the fuel injection nozzle is further configured for adding hydrogen to the fuel-air mixture that is formed by the fuel injection nozzle. In particular, the fuel injection nozzle is configured for enriching the air in the coaxial air duct with 1% to 8% of hydrogen further, thus improving the mixture provided by the fuel injection nozzle.

[0029] The preferably reduced fuel pressure in the fuel duct results in less fuel being injected into the combustion chamber. While this generally improves the efficiency, it also leads to less power provided by the combusted mixture of fuel and air. Adding a small amount of hydrogen to the mixture does not increase the temperature of the combusted fuel mixture but makes the combustion 60% more clean than a prior art combustion.

[0030] The Venturi nozzle with the baffle body in front of the fuel nozzle of the fuel duct improves mixing of the fuel with air even at lower fuel pressures. Additionally adding some amount of hydrogen makes the combustion cleaner and thus reduces air pollution. In combination, a lower fuel consumption and less pollution is achieved by means of the novel fuel injection nozzle.

[0031] According to a third aspect, that can be combined with the first and/or the second aspect a gas turbine engine, in particular a turboprop engine, with an axial gas turbine is provided, wherein the gas turbine comprises a nozzle guide vane and a turbine wheel. The nozzle guide vane is arranged between an exhaust of a combustion chamber and the turbine wheel. The turbine wheel is connected to a turbine shaft. The nozzle guide vane is arranged to guide hot combustion gases from the combustion chamber to turbine blades of the turbine wheel. According to the invention, the nozzle guide vane comprises nozzle guide blades radially extending between an inner ring of the nozzle guide vane and an outer ring of the nozzle guide vane. The outer ring has an inner diameter that narrows in the direction of gas flow and thus provides a Venturi effect to accelerate the gas flow between the inner ring and the outer ring of the nozzle guide vane.

[0032] Thus, the nozzle guide vane provides a specific geometry of the walls provided by the inner ring and the outer ring and the guide blades extending there between in a radial direction to thus maximize the efficiency of the gas flow towards the turbine blades of the turbine wheel.

[0033] It is noted that the nozzle guide vane is a stator in the hot section of the gas turbine engine and is fundamental for directing the flow of hot combustion gases from the combustion chamber to the turbine wheel.

[0034] In general, the turboprop engine comprises a gas turbine assembly with a compressor, a combustor and an axial gas turbine. The gas turbine comprises the at

least one nozzle guide vane and the at least one turbine wheel. Preferably, the gas turbine comprises a single axial turbine stage with one nozzle guide vane and one turbine wheel.

[0035] The outer ring of the nozzle guide vane has an inner wall portion that defines a feed gas passage for feeding the hot combustion gases to the guide blades of the nozzle guide vane. A diameter of the feed gas passage as defined by the inner wall of the outer ring initially decreases in the direction of flow of the hot combustion gases causing the feeding gas passage to narrow in the direction of gas flow resulting in an acceleration of the gas flow through the feed gas passage due to a Venturi effect.

[0036] According to a preferred embodiment of the nozzle guide vane, the diameter of the inner wall portion of the outer ring increases where the guide blades contact the inner wall portion of the outer ring. Accordingly, the inner wall of the outer ring has the smallest inner diameter where hot combustion gases are hitting the guide blades during operation of the gas turbine.

[0037] According to a further preferred embodiment of the nozzle guide vane, an outer diameter of an outer wall portion of the inner ring decreases where the guide blades contact the outer wall portion of the inner ring. Thus, the distance between the outer wall of the inner ring and the inner wall of the outer ring increases in the direction of gas flow where the guide blades are arranged. This improves the efficiency of the gas turbine because it reduces losses caused by the nozzle guide vane.

[0038] Preferably, the outer ring, the guide blades and the inner ring are an integral part made of metal.

[0039] Preferably, the nozzle guide vane comprises between 16 to 24 guide blades, in particular 20 guide blades. The number of nozzle guide blades preferably is different from the number of turbine blades of the turbine wheel.

[0040] According to a preferred embodiment of the nozzle guide vane, the inner diameter of the inner wall portion of the outer ring at the entrance of the feed gas passage corresponds to an outer diameter of the annular exhaust nozzle of the combustion chamber of the combustor at the exit of the annular exhaust nozzle.

[0041] According to a further preferred embodiment of the nozzle guide vane, a longitudinal extension of the feed gas passage along a longitudinal axis of the gas turbine assembly is about 1.2 to 2.3 times of the extension of the guide blades of the nozzle guide vane along a longitudinal axis of the gas turbine assembly.

[0042] Preferably, the inner diameter of the inner wall portion of the outer ring at the entrance of the feed gas passage is between 140 mm and 170 mm, for instance 155mm.

[0043] Further preferred features and advantages will be apparent from the disclosure of exemplary embodiments. Additional aspects of the present invention will become more readily apparent from the detailed description, particularly when taken together with the drawings.

Figure 1: illustrates an embodiment of a turboprop engine comprising a gas turbine according to the invention;

Figure 2: is a perspective view of a combustion chamber;

Figure 3a: is a rear view of the combustion chamber of figure 2;

Figure 3b: is a side view of the combustion chamber of figure 2;

Figure 3c: is a front view of the combustion chamber of figure 2;

Figure 4: is a longitudinal cross-section through the combustion chamber of figures 2 and 3;

Figures 5a and 5b: are perspective views of a nozzle guide vane of the gas turbine of the turboprop engine according to the invention;

Figure 6a: is a front view of the nozzle guide vane according to the invention;

Figure 6b: is a rear view of the nozzle guide vane according to the invention;

Figure 6c: is a side view of the nozzle guide vane according to the invention;

Figure 6d: is a central cut away view of the nozzle guide vane according to the invention;

Figure 7: is a longitudinal cross-section through the turbine shaft, the gas turbine and the combustion chamber of figures 4 and 5;

Figure 8: is a longitudinal cross-section similar to figure 7 illustrating the narrowing of the exhaust gas stream at the exit of the combustion chamber and through the axial gas turbine;

Figure 9a and b: are perspective views of the combustion chamber together with the turbine shaft and the axial gas turbine;

Figure 10a: is a rear view of a fuel injection nozzle;

Figure 10b: is a side view of a fuel injection nozzle;

Figure 10c: is a bottom view of a fuel injection nozzle;

Figure 10d: is a top view of a fuel injection nozzle;

Figure 11a: is a front view of the fuel injection nozzle of figure 7;

Figure 11b: is a longitudinal cross-section through the fuel injection nozzle of figure 10 and

Figure 12: illustrates the individual parts the fuel injection nozzle of figures 10 and 11 is composed of.

As illustrated in figure 1, the main components of a turboprop engine 10 are a gas turbine assembly 20 that can drive a main shaft 30 of a propeller 12 via a reduction gear. The reduction gear comprises a helical reduction gearing 40, a centrifugal clutch 24 and a planetary reduction gear 32.

[0044] The gas turbine engine 20 comprises a compressor 22, for instance a centrifugal compressor. Compressed air provided by the centrifugal compressor 22 is fed into a combustor 24, for instance a combustor with an annular combustion chamber 24.1 with an outlet nozzle 24.3 for the hot exhaust that feeds the hot exhaust to a turbine, for instance an axial turbine 26. The axial turbine 26 drives the centrifugal compressor 22 and - via the planetary reduction gear - the propeller 12.

[0045] The turboprop engine 10 as shown in figure 1 comprises a gas turbine assembly 20 with a single turbine stage 26. The gas turbine assembly 20 comprises a stationary nozzle guide vane 26.1 and a turbine wheel 26.2 that is connected to a gas turbine shaft 28. The gas turbine shaft 28 is also connected to the centrifugal compressor 22. Accordingly, gas turbine 26 can drive compressor 22 of turboprop engine 10. Turbine shaft 28 is also connected to a reduction gear 32 that in turn is connected to a propeller 12 by means of gas turbine assembly 20.

[0046] During operation, the compressor 22 takes air from the environment, compresses the air and pushes the compressed air into the combustion chamber 24.1 wherein the compressed air is mixed with fuel and combusted by a spark. The combustion chamber nozzle 24.3 directs the resulting flow of hot combustion gases to the axial turbine 26. The axial turbine 26 comprises a single turbine stage with the nozzle guide vane 26.1 and the single turbine wheel 26.2. As mentioned above, the turbine wheel 26.2 drives the turbine shaft 28 that is connected to the centrifugal compressor 22 and the planetary reduction gear 32. The rotation speed of the turbine shaft 28 is reduced by the helical reduction gearing 40 and the planetary reduction gear 32 to a fraction in order to provide a rotation speed that is suitable for driving a standard propeller 12.

[0047] A number of improvements contribute to a more efficient turboprop engine providing a power between 100 kW and 400 kW.

The compressor 22

[0048] The compressor 22 is a centrifugal compressor comprising a centrifugal impeller 22.1, a diffuser 22.2 (not shown) and a collector (not shown). As the air passes through the impeller 22.1, the kinetic and potential energy increase. The diffuser 22.2 converts the air flow's kinetic energy (high velocity) into increased potential energy (static pressure) by gradually slowing (diffusing) the gas velocity. The collector gathers the flow from the diffuser 22.2 discharge annulus and delivers this flow downstream to an open space 23 surrounding the com-

bustor's combustion chamber.

The combustor 24

[0049] The combustor has an annular combustion chamber 24.1. The annular combustion chamber 24.1 is enclosed by a wall 24.2 with an inner wall portion 24.2.1, a front wall portion 24.2.2 and an outer wall portion 24.2.3. The front wall portion 24.2.2 closes the combustion chamber 24.1 at a combustion chamber front end. The inner wall portion 24.2.1 and the outer wall portion 24.2.3 define an open annular nozzle 24.3 at the rear side of the combustion chamber 24.1. Holes 24.4 in the wall 24.2 enclosing the combustion chamber 24.1 allow entering of compressed air from the open space 23 surrounding the combustion chamber into the inner space 24.5 of the combustion chamber. The combustion chamber 24.1 is the place where the mixing of the compressed high pressure air and fuel occurs and the mixture is combusted. Since the combustion generates a very high temperature, part of the compressed high pressure air entering the inner space 24.5 of the combustion chamber 24.1 is used to cool down the metal walls 24.2 of the combustion chamber. The purpose of the holes 24.4 is to keep flames of the burning fuel away from the metal walls 24.2 thus keeping the combustion chamber wall temperature under a limit temperature.

[0050] Another purpose of holes in walls of prior art combustion chambers walls is to generate a vortex to make the mixing of compressed air and fuel more efficient. That is why the combustor design is different for each gas turbine engine.

[0051] In the case of the instant turboprop engine 10, the combustion chamber 24.1 must handle a mixture of fuel and air that is fed into the combustion chamber 24.1 by one or more fuel injection nozzles 24.7. With annular combustion chambers, typically multiple fuel injection nozzles 24.7 are provided and arranged around the circumference of the combustion chamber 24.1. Prior art combustion chambers have special holes in the combustion chamber wall around the fuel injection nozzle to make a vortex with the fuel. In the instant turboprop engine the vortex is generated by the fuel injection nozzle itself so the holes of the combustion chamber wall in this area are only to produce an upper vortex that keep the flame and the heat away from the walls of the combustion chamber.

[0052] Similarly, the other holes 24.4 in the wall of the instant combustion chamber 24.1 are basically provided to allow more air entering the inner space 24.5 of the combustion chamber 24.1 in order to improve the combustion and to keep the heat away from the combustion chamber walls 24.2.

[0053] While the instant turboprop engine 10 can be realized with different kinds of combustion chambers, a combustion chamber 24.1 as disclosed herein is beneficial because it improves the efficiency of the gas turbine assembly 20.

[0054] A beneficial feature of the instant combustor 24 as disclosed herein is the design of the inner wall portion and the outer wall portion in the region of the nozzle at the rear and of the combustion chamber. As is apparent from figures 3 to 4, the inner cross-sectional diameter of the inner space of the combustion chamber - as defined by the radial distance between the inner wall portion and the outer wall portion of the combustion chamber wall - initially decreases (narrows) towards the open end of the combustion chamber nozzle and ultimately widens again, thus causing a Venturi effect where radial distance between the inner wall portion and the outer wall portion is smallest.

[0055] Keyhole shaped orifices (holes) 24.4.1 in the outer wall portion 24.2.3 allow entering of compressed air in the nozzle area of the combustion chamber 24.1. The entering of compressed air as promoted by the Venturi effect caused by the particular shape of the inner wall portion 24.2.1 and the outer wall portion 24.2.3 in the area of the combustion chamber annular nozzle portion 24.3.

[0056] The desired effect is improved by the design of the inner wall portion 24.2.1 of the combustion chamber wall 24.2. As can be seen for instance in figure 4, the distance of the inner wall portion 24.2.1 from the longitudinal axis of the gas turbine assembly 20 initially increases in the direction of a combustion gas flow and then decreases again thus defining an apex 24.6. Thus, together with the shape of the outer wall portion 24.2.3, the Venturi effect is promoted.

[0057] The additional air sucked into the nozzle portion 24.3 of the combustion chamber 24.1 due to the Venturi effect increases the mass flow of air exiting the combustion chamber 24.1 and streaming to the nozzle guide vane 26.1 of the gas turbine stage 26. This is achieved by the shape of the inner wall portion 24.2.1 and the outer wall portion 24.2.3. The shape provides that the inner cross-sectional diameter of the annular inner space of the combustion chamber 24.1 initially decreases (narrows) towards the open end of the combustion chamber nozzle 24.3 and ultimately widens again, thus causing the aforementioned Venturi effect where the radial distance between the inner wall portion 24.2.1 and the outer wall portion 24.2.3 is smallest.

[0058] The Venturi effect created by the annular Venturi nozzles portion of the combustion chamber improves the mass flow exiting from the combustion chamber and is fed to the axial turbine of the gas turbine assembly, thus improving the efficiency of the gas turbine assembly 20.

[0059] The preferred shape of the combustion chamber's annular nozzle portion 24.3 preferably is achieved by varying the distance of the inner wall portion 24.2.1 from a longitudinal axis of the gas turbine assembly 20 along the longitudinal axis of the gas turbine assembly 20. The distance initially increases in the direction of a combustion gas flow and then decreases again thus defining an apex 24.6 that together with the outer wall portion 24.2.3 of the combustion chamber wall 24.2 defines the Venturi nozzle 24.7.6 for accelerating the

hot combustion exhaust gases and for causing a reduced static pressure in inner space 24.5 close to the combustion chamber annular nozzle 24.3.

[0060] The combustion chamber 24.1 is surrounded by the open space 23 that during operation is filled with compressed air. Where the outer wall portion 24.2.3 narrows towards to an open end of the annular nozzle portion 24.3 of the combustion chamber 24.1, orifices or holes 24.4.1 are provided. The holes 24.4.1 are placed where during operation a reduced static pressure exists in the inner space 24.5, thus allowing air entering from the surrounding open space 23 into the inner space 24.5 and increasing the mass flow of the hot combustion gases exiting the combustion chamber 24.1. This improves the efficiency of the gas turbine assembly.

[0061] As mentioned above, the holes 24.4.1 provided in the narrowing outer wall portion 24.2.3 have a keyhole shape.

[0062] Further, the outer wall portion 24.2.3 comprises a generally cylindrical sub-portion 24.2.5 in which an annular vortex generating protrusion 24.2.6 is arranged, that protrudes into the inner space 24.5 enclosed by the combustion chamber wall 24.2. The annular vortex generating protrusion 24.2.6 improves mixing of fuel and compressed air and provides for an equal and complete combustion, thus improving the efficiency of the gas turbine assembly.

[0063] The annular vortex generating protrusion 24.2.6 comprises an upstream wall portion 24.2.7 facing towards the fuel injection nozzles 24.7 and a downstream wall portion 24.2.8 facing away from the fuel injection nozzles 24.7. The vortex generating holes 24.4.2 are arranged in the downstream wall portion 24.2.8. This further improves the efficiency of the gas turbine assembly.

[0064] Further, the inner wall portion 24.2.1 comprises a frusto-conical shaped wall sub-portion 24.2.12 with a diameter that increases towards the annular Venturi nozzles portion 24.3 of the combustion chamber 24.1. The frusto-conical shaped wall sub-portion 24.2.12 provides that the annular free space between the inner wall portion 24.2.1 and the outer wall portion 24.2.3 decreases, thus causing an acceleration of the hot combustion gases during operation and a decreasing static pressure in the annular free space between the inner wall portion 24.2.1 and the outer wall portion 24.2.3. The frusto-conical shaped wall sub-portion 24.2.12 of the inner wall portion 24.2.1 is provided with holes 24.4 allowing compressed air from the surrounding open space 23 entering into the inner space 24.5. This increases the mass flow of the hot combustion gases exiting the combustion chamber 24.1. The increased mass flow further improves the efficiency of the gas turbine assembly. The holes 24.5 in the frusto-conical shaped wall sub-portion 24.2.8 of the inner wall portion 24.2.1 are arranged in eight rows along the longitudinal axis of the gas turbine assembly 20. The rows are equally spaced with respect to the circumferential direction of the

frusto-conical shaped wall sub-portion 24.2.8. Each row comprises five holes 24.5 of different size and diameter, respectively.

[0065] The combustor comprises four fuel injection nozzles 24.7 that are equally spaced from each other with respect to the circumferential direction of the cylindrical sub-portion 24.2.5. This arrangement of fuel injection nozzles supports producing a homogeneous stream of hot combustion gases for driving the axial gas turbine of the gas turbine assembly. As is apparent from figure 2, the cylindrical sub-portion 24.2.5 of the outer wall portion 24.2.3 is provided with four openings 24.2.9 for mounting the fuel injection nozzles 24.7.

[0066] Further parts of the combustor 24 not shown herein but known to the skilled person in general are an igniter system and spark plugs 24.8. The combustor 24 is provided with four fuel injection nozzles 24.7 equally spaced around the circumference of the front part of the combustion chamber. The combustor 24 is further provided with two spark plugs 24.8 that are arranged downstream of two of the fuel injection nozzles 24.7.

The fuel injection nozzle 24.7

[0067] As disclosed above, a combustor 24 of a gas turbine assembly 20 typically is provided with multiple fuel injection nozzles 24.7 as shown in figures 10 to 12. The fuel injection nozzles 24.7 are feeding the fuel, for instance kerosene, into the inner space of the combustion chamber 24.1. The main purpose of each fuel injection nozzle 24.7 is to vaporize the fuel that is injected into the combustion chamber 24.1 with high pressure. Fuel injection nozzles 24.7 may have a central fuel duct 24.7.1 that is surrounded by a coaxial air duct 24.7.2. Fuel is fed into a proximal end of the fuel duct 24.7.1 and can exit the fuel duct at a fuel nozzle 24.7.3 at the distal end of the fuel duct 24.7.1. Typically, a fuel injection nozzle 24.7 is provided with a fuel intake connector 24.7.4 and a fuel return connector 24.7.5 that both are connected to the proximal end of the fuel duct 24.7.1 for allowing the fuel to circulate and to supply several fuel injection nozzles 24.7 in series.

[0068] The air duct 24.7.2 surrounding the fuel duct 24.7.1 provides that fuel exiting at a fuel nozzle 24.7.3 at the distal end of the fuel duct 24.7.1 is surrounded by an airstream that prevents the fuel from sticking to parts of the fuel injection nozzle 24.7.

[0069] The fuel injection nozzle 24.7 of the instant turboprop engine 10 is provided with a Venturi nozzle 24.7.6 formed at the distal end of the air duct 24.7.2 surrounding the fuel nozzle 24.7.3 of the fuel duct 24.7.1. Directly in line with the fuel duct 24.7.1 in front of the fuel nozzle 24.7.3 of the fuel duct 24.7.1 a baffle body 24.7.7 is arranged. The baffle body 24.7.7 has the shape of an inverted cone and is held by a pin 24.7.8 in the middle of the Venturi nozzle 24.7.6 at the distal orifice of the air duct 24.7.2. The baffle body 24.7.7 has a cone tip 24.7.9 facing away from the fuel nozzle 24.7.3 and a

baffle face 24.7.10 facing towards the fuel nozzle 24.7.3.

[0070] The arrangement of a Venturi nozzle 24.7.6 for the fuel injector air stream in front of the fuel nozzle 24.7.3 of the fuel duct 24.7.1 combined with the baffle body 24.7.7 provides for an intense mixing of fuel and air. Even if the fuel is injected with a lower pressure than usual.

[0071] Further, the air in the coaxial air duct 24.7.2 is enriched with 1% to 8% of hydrogen further improving the mixture provided by the fuel injection nozzle 24.7.

[0072] Fuel exiting the fuel nozzle 24.7.3 at the end of the fuel duct 24.7.1 hits the baffle body 24.7.7 and thus is vaporized even if the pressure in the fuel duct 24.7.1 is not high enough to cause vaporization of the fuel alone.

[0073] The baffle body 24.7.7 - shaped as an inverted cone - together with the Venturi shape of the air duct's Venturi nozzle 24.7.6 surrounding the baffle body 24.7.7 in front of the fuel duct nozzle 24.7.3 causes a Venturi effect that accelerates the stream of air mixed with fuel. This further improves vaporization of the fuel.

[0074] The reduced fuel pressure in the fuel duct 24.7.1 results in less fuel being injected into the combustion chamber 24. While this generally improves the efficiency, it also leads to less power provided by the combusted mixture of fuel and air. Adding a small amount of hydrogen to the mixture does not increase the temperature of the combusted fuel mixture but makes the combustion 60% more clean than a prior art combustion.

[0075] The Venturi nozzle 24.7.6 with the baffle body 24.7.7 in front of the fuel nozzle 24.7.3 of the fuel duct 24.7.1 improves mixing of the fuel with air even at lower fuel pressures. Additionally adding some amount of hydrogen makes the combustion cleaner and thus reduces air pollution. In combination, a lower fuel consumption and less pollution is achieved by means of the novel fuel injection nozzle 24.7.

[0076] Preferably, the novel fuel injection nozzle 24.7 is used in a combustor 24 as disclosed above. As already mentioned, the fuel injection nozzle 24.7 already provides a very good mixing of fuel and air and thus reduces or eliminates the need for causing vortices in the inner space of the combustion chamber 24.1. This in turn improves the efficiency of the combustion chamber 24.1.

[0077] The overall efficiency of the novel combustor 24 with the novel fuel injection nozzle 24.7 is further improved by the design of the combustion chamber nozzle 24.3 that increases the mass stream exiting the combustion chamber 24.1 by drawing air into the combustion chamber nozzle 24.3 as the result of a Venturi effect achieved by the shape of the exhaust nozzle 24.3 of the combustion chamber 24.1.

[0078] It is noted, that both, the particular combustion chamber and the particular fuel injection nozzle can be used separately and implemented independent from each other in different gas turbine engines.

[0079] The instant combustion chamber has a unique design in the general inside shape that uses the inner and external ring to generate a Venturi effect to accelerate the flow to the exit of the combustion chamber making a high-

pressure flow of the combustion to be used more efficiently.

[0080] The gas turbine assembly 20 comprises the compressor 22, the combustor 24 and the axial gas turbine 26.

[0081] Gas turbine 26 of gas turbine assembly 20 is a single stage axial gas turbine. Accordingly, gas turbine 26 comprises one static nozzle guide vane assembly 26.1 and one turbine wheel 26.2 that rotates during operation of gas turbine 26. Turbine wheel 26.2 is connected to the turbine shaft 28 that is also connected to the centrifugal impeller 22.1 of compressor 22. Thus, gas turbine 26 can drive the compressor 22. Turbine shaft 28 further is connected to the main shaft 30 to which the propeller 12 is mounted. The drive train from the turbine shaft 28 to the main shaft 30 comprises the helical reduction gearing 40, the centrifugal clutch 34 and the planetary reduction gear 32. The turbine shaft 28 is operatively connected to the centrifugal clutch 34 by the helical reduction gearing 40. The helical reduction gearing 40 comprises a pinion on the turbine shaft 28 and a main gear that is driven by the pinion. An input assembly of the centrifugal clutch 34 is connected to the main gear of the helical reduction gearing 40. The centrifugal clutch 34 provides that turbine shaft 28 only drives the planetary reduction gear 32 and thus propeller 12 if the rotation speed of the gas turbine assembly 20 is high enough.

The axial gas turbine 26

[0082] Regarding the axial gas turbine 26, it is important, that the flow characteristics of the gas turbine 26 are carefully matched with those of the compressor 22 and the combustor 24 to obtain a maximum efficiency and performance of the gas turbine assembly 20 during operation. In case the nozzle guide vane 26.1 would allow to lower maximum flow, then a back pressure would build up causing the compressor 22 to surge. On the other hand, too high flow through the nozzle guide vane 26.1 might cause the compressor to choke. In either condition a loss of efficiency very rapidly occurs.

[0083] Regarding the axial gas turbine 26, it is noted, that the guide blades 26.1.3 of nozzle guide vane 26.1 have a cross section corresponding to an airfoil shape. Passages between adjacent guide blades 26.1.3 form a convergent duct. The guide blades 26.1.3 are arranged between the outer ring 26.1.1 and the inner ring 26.1.2 in a manner that allows for expansion of the hot combustion gases flowing between the guide blades 26.1.3.

[0084] Similarly, the turbine blades 26.2.1 also have cross sections with an airfoil shape. The turbine blades 26.2.1 are designed to provide passages between adjacent turbine blades 26.2.1 that give a steady acceleration of the flow of hot combustion gases up to where the area between the turbine blades 26.2.1 is smallest and the velocity of the hot combustion gases is high enough as required at the exit to produce the required degree of reaction.

The nozzle guide vane 26.1 of the axial gas turbine 26

[0085] The axial gas turbine 26 comprises an improved nozzle guide vane 26.1 that directs the stream of hot combustion gases towards turbine blades of turbine wheel 26.2. As pointed out above, in the embodiment disclosed herein, the axial gas turbine 26 has a single turbine stage, i.e. only one turbine wheel.

[0086] The improved nozzle guide vane 26.1 comprises an outer ring 26.1.1, an inner ring 26.1.2 and guide blades 26.1.3 extending between the inner ring 26.1.2 and the outer ring 26.1.1 in a radial direction; see figures 5 and 6. The guide blades 26.1.3 of nozzle guide vane 26.1 redirect the flow of hot combustion gases coming out of the combustion chamber's annular nozzle 24.3 and gives a spin to the stream of hot combustion gases in the direction of the rotation of the turbine blades.

[0087] The outer ring 26.1.1 has an inner wall portion defining a feed gas passage 26.1.5 for feeding the hot combustion gases to the guide blades of the nozzle guide vane 26.1.

[0088] The diameter of the feed gas passage 26.1.5 as defined by the inner wall 26.1.4 of the outer ring 26.1.1 initially decreases in the direction of flow of the hot combustion gases. This has the effect that the stream of hot combustion gases is accelerated prior to reaching the guide blades 26.3. This implies, that the outer ring 26.1.1 protrudes with respect to the guide blades 26.1.3 against the direction of flow of the hot combustion gases. As can be taken from figure 6c, the longitudinal extension of the outer ring 26.1.1 - i.e. the extension of the outer ring in the direction of air flow or in the longitudinal direction of shaft 28 - is 1,5 to 3 times larger than the extension of the inner ring 26.1.2 and the extension of the guide blades 26.1.3 in the longitudinal direction. Accordingly, a longitudinal extension of the feed gas passage along a longitudinal axis of the gas turbine assembly is about 1,2 to 2,3 times of the extension of the guide blades of the nozzle guide vane along a longitudinal axis of the gas turbine assembly.

[0089] The diameter of the inner wall portion of the outer ring 26.1.1 increases where the guide blades 26.1.3 contact the inner wall portion of the outer ring 26.1.1. Accordingly the inner wall of the outer ring 26.1.1 has a smallest inner diameter where hot combustion gases are hitting the guide blades 26.1.3 during operation of the gas turbine 26.

[0090] An outer diameter of an outer wall portion of the inner ring 26.1.2 decreases where the guide blades 26.1.3 contact the outer wall portion of the inner ring 26.1.2. Thus, the distance between the outer wall 26.1.6 of the inner ring 26.1.2 and the inner wall 26.1.4 of the outer ring 26.1.1 increases in the direction of gas flow where the guide blades 26.1.3 are arranged. This improves the efficiency of the gas turbine 26 because it reduces losses caused by the nozzle guide vane 26.1.

[0091] The outer ring 26.1.1, the guide blades 26.1.3 and the inner ring 26.1.2 are an integral part made of

metal.

[0092] The nozzle guide vane 26.1 comprises 20 guide blades 26.1.3. The number of nozzle guide blades preferably is different from the number of turbine blades 26.2.1 of the turbine wheel 26.2.

[0093] The inner diameter of the inner wall portion of the outer ring 26.1.1 at the entrance of the feed gas passage 26.1.5 corresponds to an outer diameter of the annular exhaust nozzle 24.3 of the combustion chamber 24.1 of the combustor 24 at the exit of the annular exhaust nozzle 24.3.

[0094] The inner diameter of the inner wall portion of the outer ring at the entrance of the feed gas passage is between 140 mm and 170 mm, for instance 155 mm.

[0095] Regarding the combustor 24, an improved fuel injection nozzle 24.7 and an improved combustion chamber 24.1 are provided. For improving the gas turbine assembly 20, an improved nozzle guide vane 26.1 and a self-lubricating turbine main shaft 28 are provided. These improvements may be implemented independently from each other, i.e. the improved fuel injection nozzle or the improved combustion chamber or the improved nozzle guide vane or the self-lubricating turbine main shaft or a combination thereof may be implemented with any known or future gas turbine engine.

Reference numerals

[0096]

10	turboprop engine
12	propeller
14	air intake
20	gas turbine assembly
22	compressor of the gas turbine assembly
22.1	impeller
22.2	diffuser
23	open space surrounding the combustor's combustion chamber
24	combustor
24.1	combustion chamber of gas turbine assembly
24.2	combustion chamber wall
24.2.1	inner wall portion of the combustion chamber wall
24.2.2	front wall portion of the combustion chamber wall
24.2.3	outer wall portion of the combustion chamber wall
24.2.4	cylindrical sub-portion of the outer wall portion
24.2.5	annular vortex generating protrusion
24.2.6	upstream wall portion of the annular vortex generating protrusion
24.2.7	downstream wall portion of the annular vortex generating protrusion
24.2.8	frusto-conical shaped wall sub-portion of the inner wall portion

24.2.9	opening for mounting a fuel injection nozzle	
24.3	annular Venturi nozzles portion of the combustion chamber	
24.4	holes in the combustion chamber wall	
24.4.1	holes in the annular Venturi nozzle portion of the combustion chamber	5
24.4.2	holes in the vortex generating protrusion	
24.5	inner space of the combustion chamber	
24.6	apex of the inner combustion chamber wall	
24.7	fuel injection nozzle	10
24.7.1	fuel duct of the fuel injection nozzle	
24.7.2	air duct of the fuel injection nozzle	
24.7.3	fuel nozzle of the fuel injection nozzle	
24.7.4	fuel intake connector	
24.7.5	fuel return connector	15
24.7.6	Venturi nozzle	
24.7.7	baffle body	
24.7.8	pin for holding the baffle body	
24.7.9	cone tip of the baffle body	
24.7.10	baffle face of the baffle body	20
24.8	spark plug	
26	axial gas turbine stage of the gas turbine assembly	
26.1	nozzle gas vane of the axial gas turbine	
26.1.1	outer ring of the nozzle gas vane	25
26.1.2	inner ring of the nozzle gas vane	
26.1.3	guide blades of the nozzle gas vane	
26.1.4	inner wall of the outer ring of the nozzle gas vane	
26.1.5	feed gas passage	30
26.1.6	outer wall of the inner ring of the nozzle gas vane	
26.2	turbine wheel of the axial gas turbine	
26.2.1	turbine blade	
28	gas turbine shaft	35
28.1	shaft tunnel for the gas turbine shaft	
30	main shaft, propeller shaft	
32	planetary reduction gear	
34	centrifugal clutch	
36	starter/generator	40
38	starter gearbox	
40	helical reduction gearing	

Claims

1. Combustor (24) for a gas turbine assembly (20), said combustor comprising a plurality of fuel injection nozzles (24.7) and an annular combustion chamber (24.1) that comprises an inner space (24.5) that is enclosed by a combustion chamber wall (24.2) with an inner wall portion (24.2.1), a front wall portion (24.2.2) and an outer wall portion (24.2.3), wherein the front wall portion (24.2.2) closes the combustion chamber (24.1) at a combustion chamber front end and wherein the innerwall portion (24.2.1) and the outer wall portion (24.2.3) define an open annular nozzle (24.3) at the rear side of the combustion chamber (24.1), wherein the fuel injection nozzles

are circumferentially arranged around the outer wall portion (24.2.3) and protrude into the inner space (24.5) enclosed by the combustion chamber wall (24.2),

characterized in that the innerwall portion (24.2.1) and the outerwall portion (24.2.3) are shaped so as to provide that the inner cross-sectional diameter of the annular inner space of the combustion chamber (24.1) initially decreases (narrows) towards the open end of the combustion chamber nozzle (24.3) and ultimately widens again, thus causing a Venturi effect where a radial distance between the inner wall portion (24.2.1) and the outer wall portion (24.2.3) is smallest.

2. Combustor (24) according to claim 1, wherein the distance of the inner wall portion (24.2.1) from a longitudinal axis of the gas turbine assembly (20) initially increases in the direction of a combustion gas flow and then decreases again thus defining an apex (24.6) that together with the outer wall portion (24.2.3) of the combustion chamber wall (24.2) defines a Venturi nozzle (24.7.6) for accelerating the hot combustion exhaust gases and causing a lowered static pressure in the inner space (24.5) close to the combustion chamber annular nozzle (24.3).
3. Combustor (24) according to claim 1 or 2, wherein the combustion chamber (24.1) is surrounded by an open space (23) that during operation is filled with compressed air and wherein the outer wall portion (24.2.3) narrows towards to an open end of the annular nozzle portion (24.3) of the combustion chamber (24.1) and wherein holes (24.4.1) are provided in the narrowing outer wall portion (24.2.3), said holes (24.4.1) being placed where during operation a reduced static pressure exists in the inner space (24.5), thus allowing air entering from the surrounding open space (23) into the inner space (24.5) and increasing the mass flow of the hot combustion gases exiting the combustion chamber (24.1).
4. Combustor (24) according to claim 1, wherein the holes (24.4.1) provided in the narrowing outer wall portion (24.2.3) have a keyhole shape.
5. Combustor (24) according to at least one of claims 1 to 4, wherein the outer wall portion (24.2.3) comprises a generally cylindrical sub-portion (24.2.4) in which an annular vortex generating protrusion (24.2.5) is arranged, that protrudes into the inner space (24.5) enclosed by the combustion chamber wall (24.2).
6. Combustor (24) according to claim 5, wherein annular vortex generating protrusion (24.2.5) comprises an upstream wall portion (24.2.6) facing to-

wards the fuel injection nozzles (24.7) and a downstream wall portion (24.2.7) facing away from the fuel injection nozzles (24.7) and wherein vortex generating holes (24.4.2) are arranged in the downstream wall portion (24.2.7).

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7. Combustor (24) according to at least one of claims 1 to 6, wherein the inner wall portion (24.2.1) comprises a frusto-conical shaped wall sub-portion (24.2.12) with a diameter that increases towards the annular Venturi nozzles portion (24.3) of the combustion chamber (24.1) and provides that the annular free space between the innerwall portion (24.2.1) and the outerwall portion (24.2.3) decreases, thus causing an acceleration of the hot combustion gases during operation and a decreasing static pressure in the annular free space between the inner wall portion (24.2.1) and the outer wall portion (24.2.3).

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8. Combustor (24) according to claim 7, wherein the frusto-conical shaped wall sub-portion (24.2.8) of the inner wall portion (24.2.1) is provided with holes (24.4) allowing compressed air from the surrounding open space (23) entering into the inner space (24.5) and increasing the mass flow of the hot combustion gases exiting the combustion chamber (24.1).

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9. Combustor (24) according to at least one of claims 1 to 6, wherein the combustor comprises four fuel injection nozzles (24.7) that are equally spaced from each other.

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10. Turboprop engine (10) comprising a gas turbine assembly (20) with a compressor (22), a combustor (24) and an axial gas turbine (26), wherein the gas turbine (26) comprises a nozzle guide vane (26.1) and a turbine wheel (26.2), and wherein the combustor (24) is a combustor according to at least one of claims 1 to 9.

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11. Turboprop engine according to claim 10, wherein the nozzle guide vane (26.1) is arranged between an annular exhaust nozzle (24.3) of the combustion chamber (24.1) of the combustor (24) and the turbine wheel (26.2), the turbine wheel (26.2) is connected to a turbine shaft (28) and the nozzle guide vane (26.1) is arranged to guide hot combustion gases from the combustion chamber (24.1) to turbine blades (26.2.1) of the turbine wheel (26.2),

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wherein the nozzle guide vane (26.1) comprises guide blades (26.1.3) radially extending between an inner ring (26.1.2) of the nozzle guide vane (26.1) and an outer ring (26.1.1) of the nozzle guide vane (26.1), the outer ring (26.1.1) having an inner wall portion (26.1.4) defining a feed gas passage (26.1.5) for feeding

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the hot combustion gases to the guide blades (26.1.3) of the nozzle guide vane (26.1), wherein an inner diameter of the feed gas passage (26.1.5) as defined by the inner wall (26.1.4) of the outer ring (26.1.1) at the entrance of the feed gas passage (26.1.5) corresponds to an outer diameter of the annular exhaust nozzle (24.3) of the combustion chamber (24.1) of the combustor (24) at the exit of the annular exhaust nozzle (24.3).

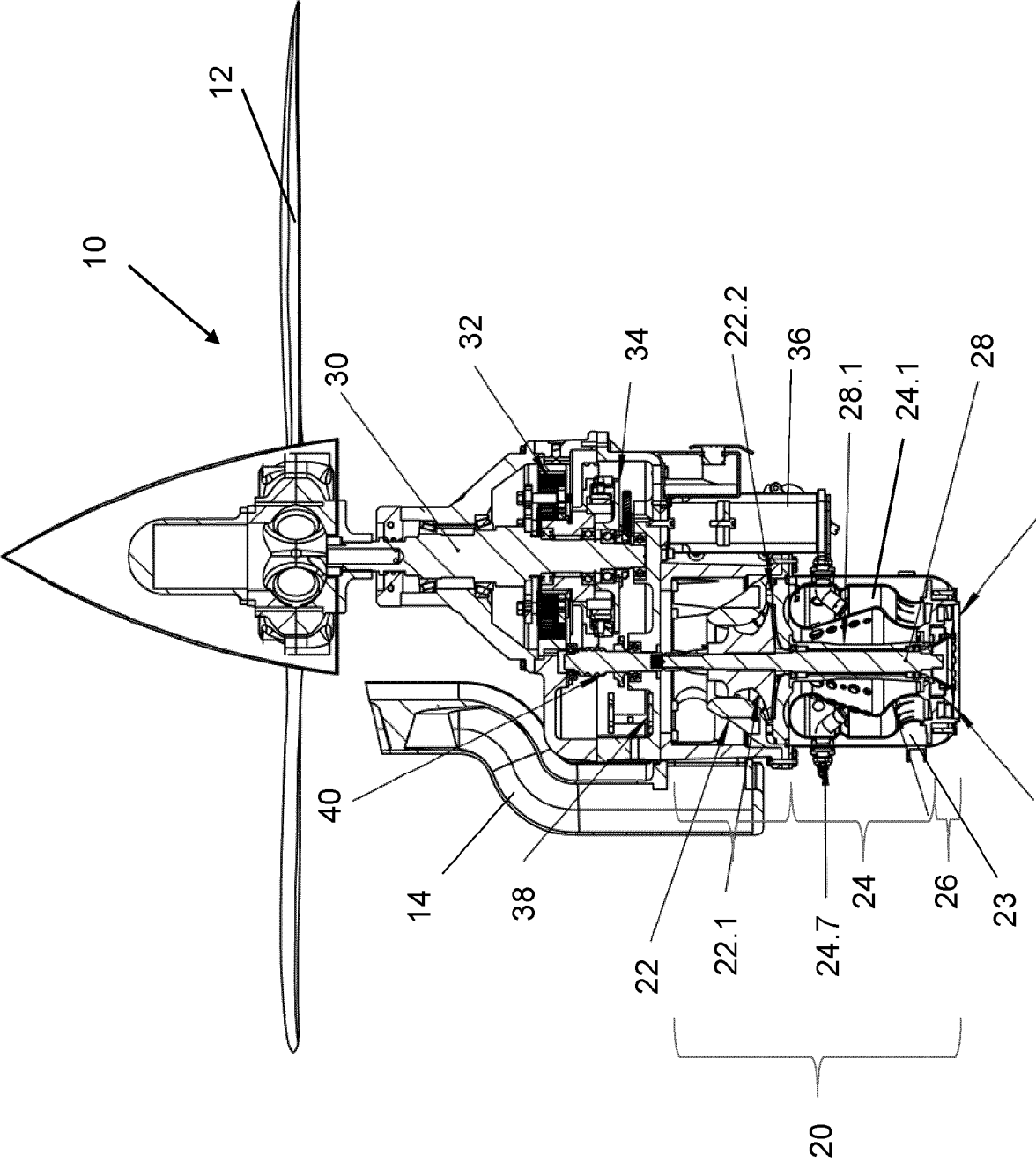


Fig. 1 26.2

26.1

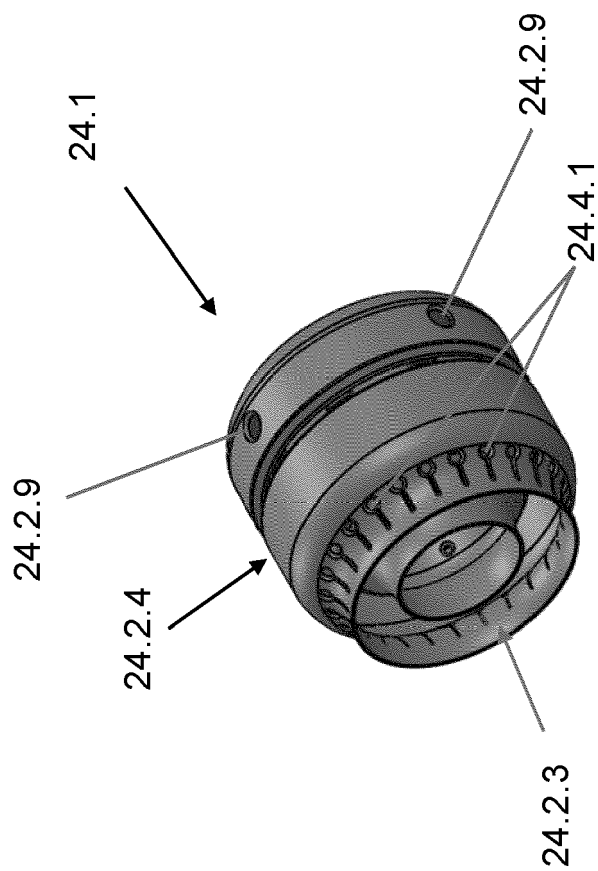


Fig. 2

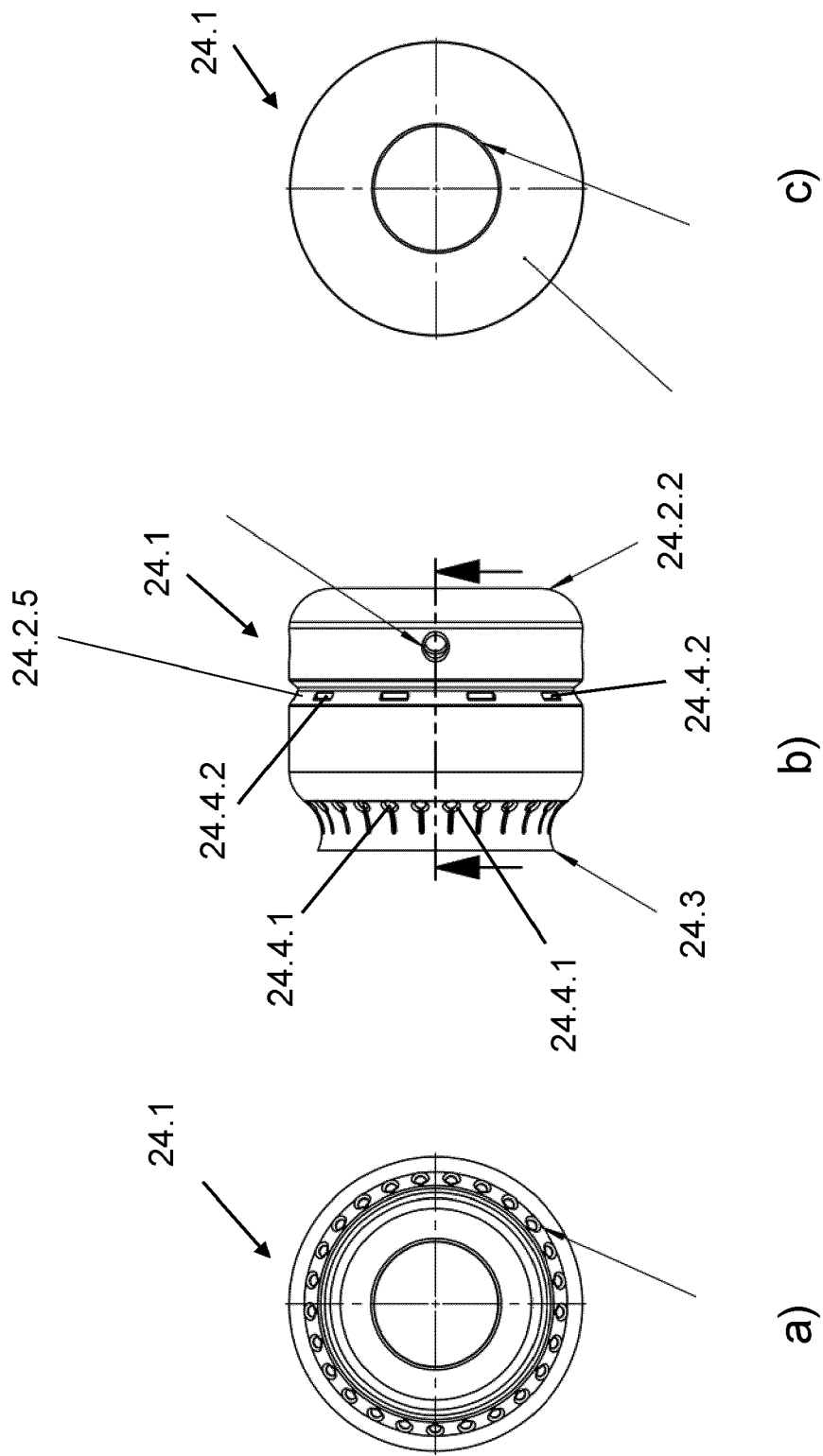


Fig. 3

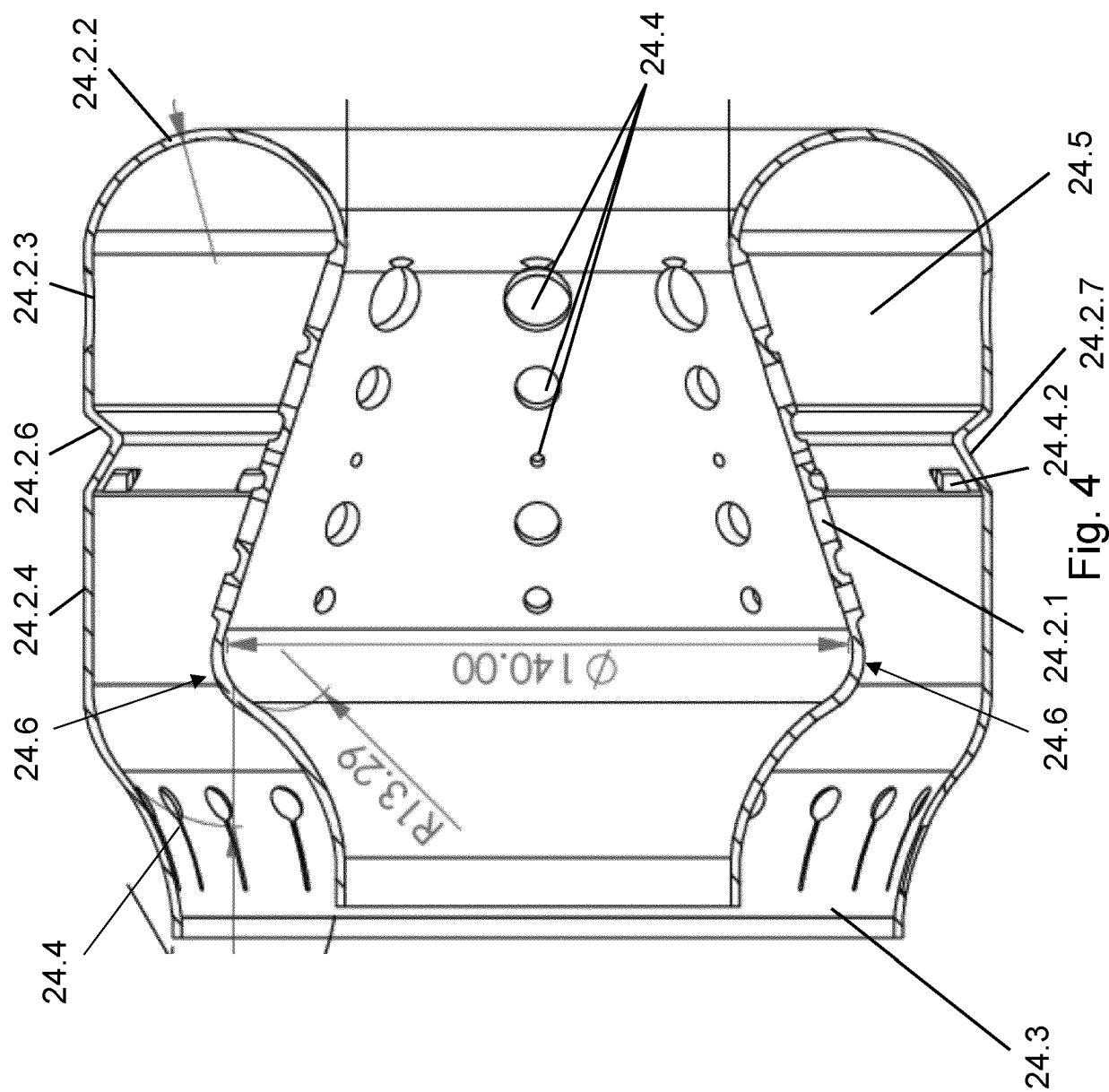




Fig. 5

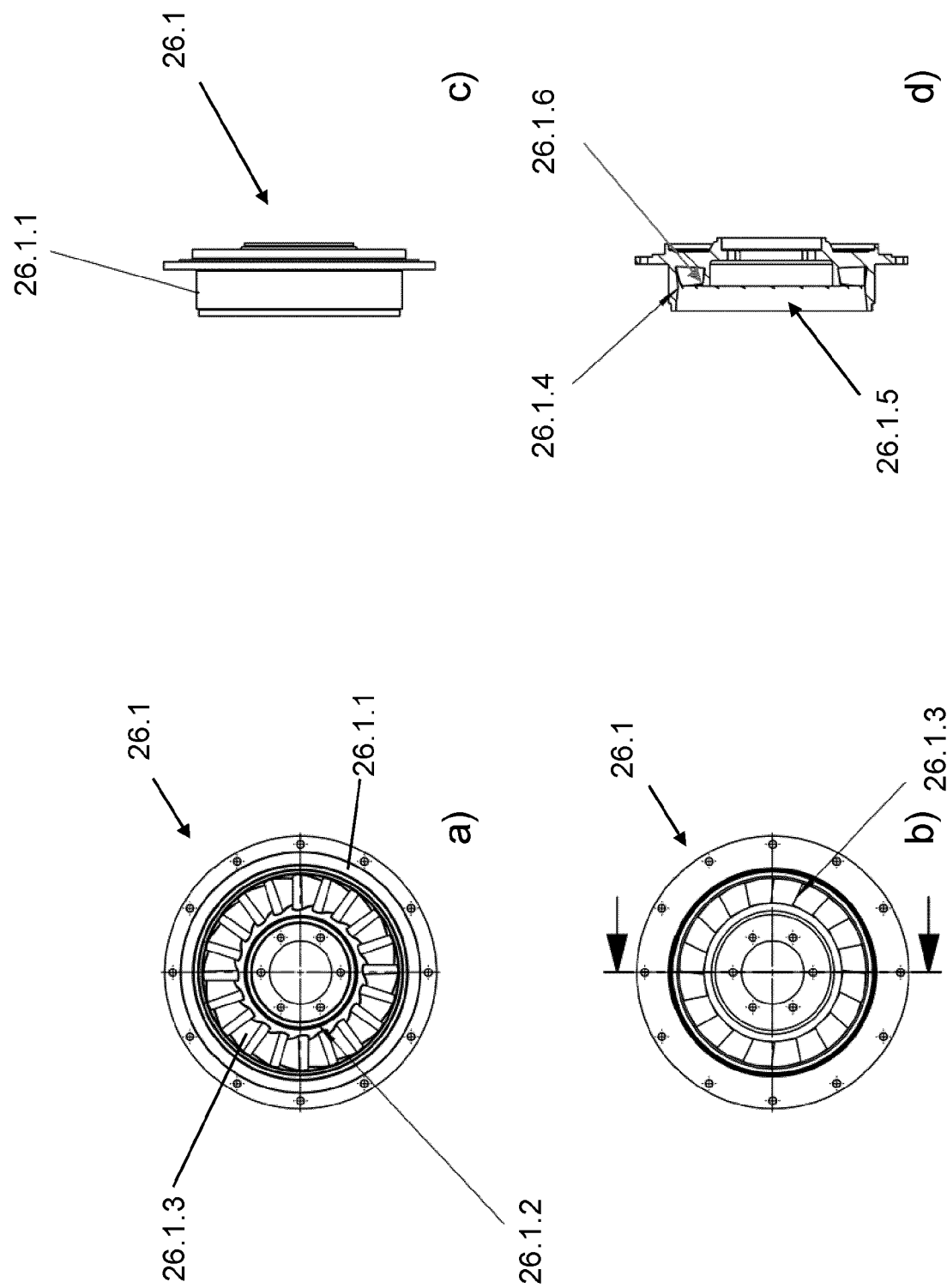


Fig. 6

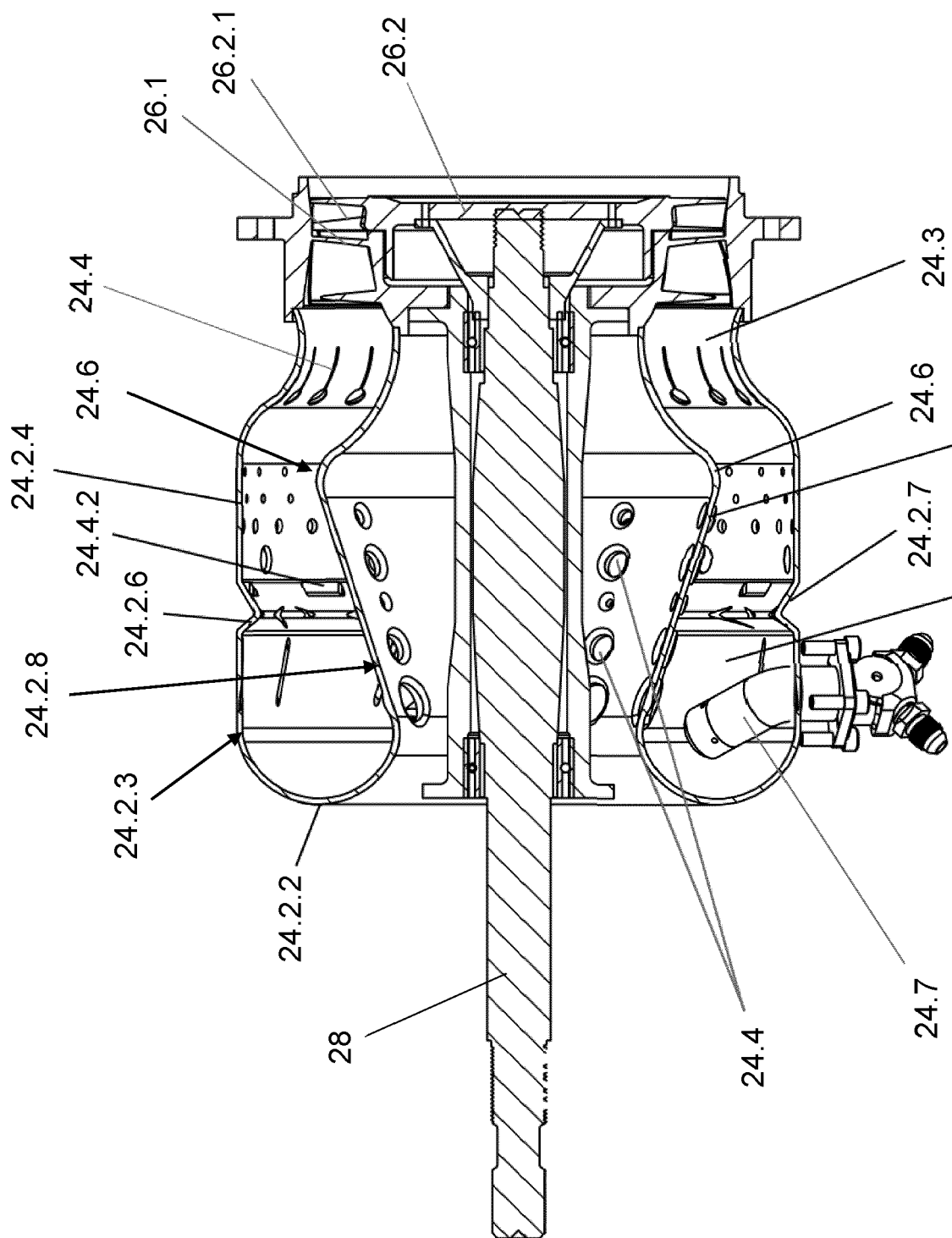


Fig. 7 24.5 24.2.1

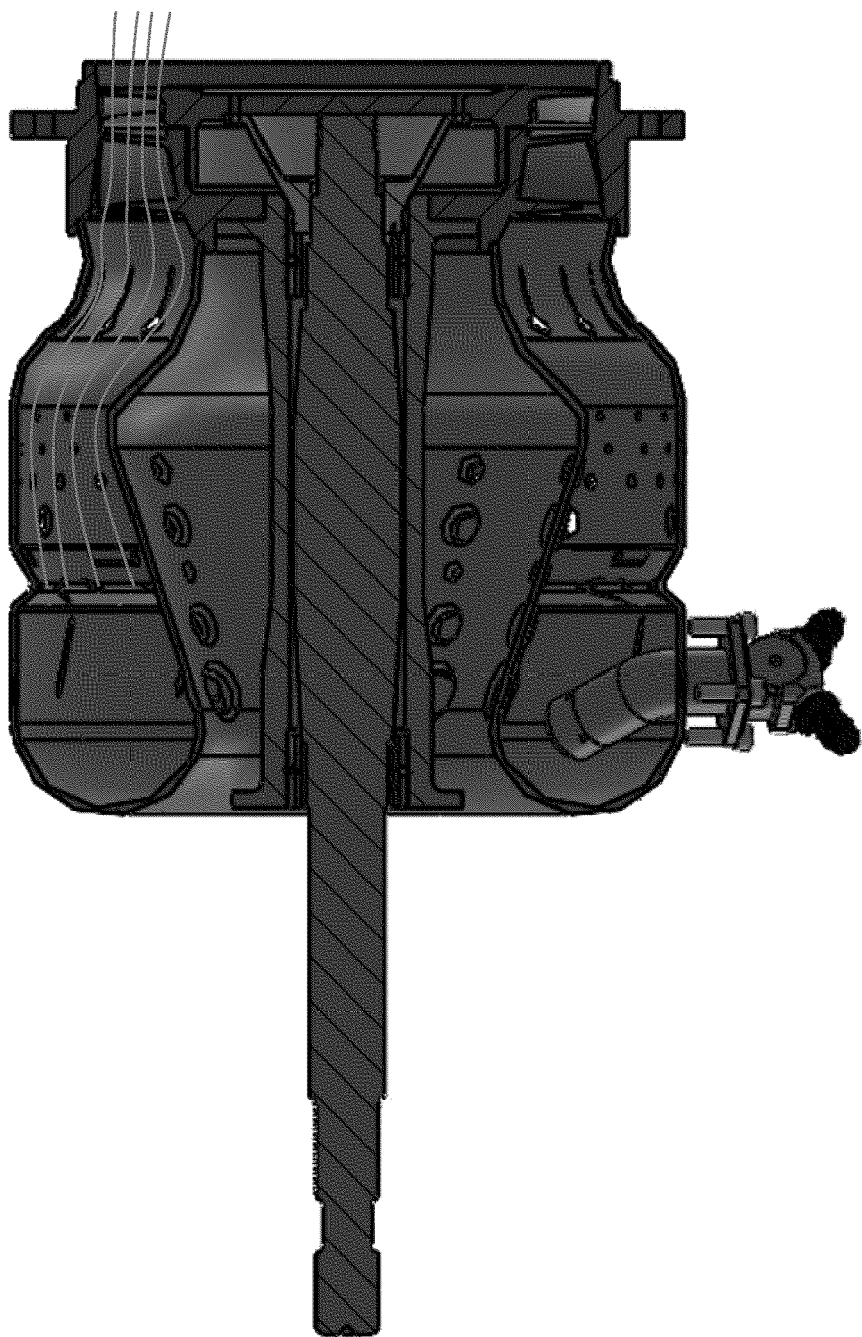


Fig. 8

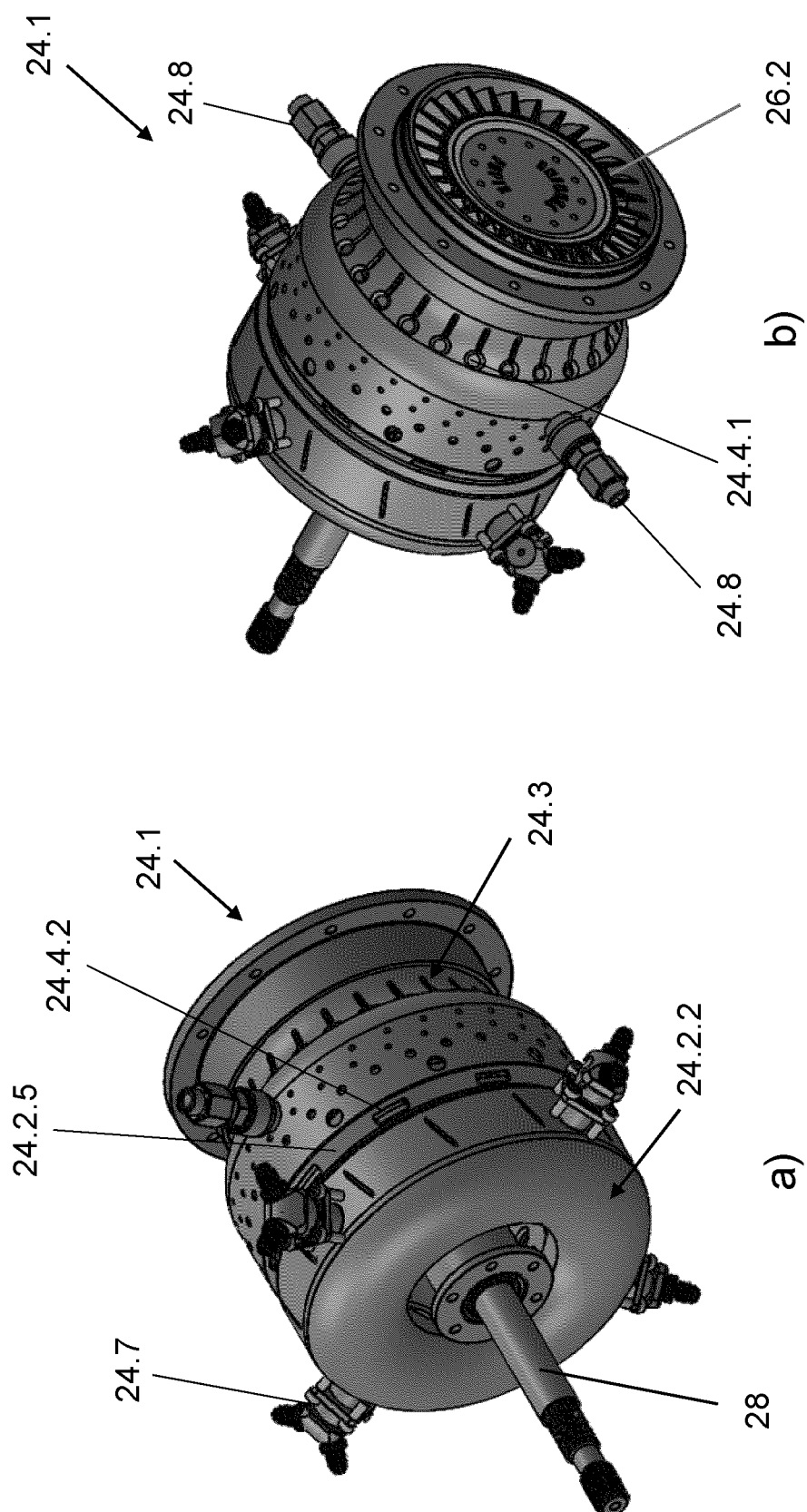


Fig. 9

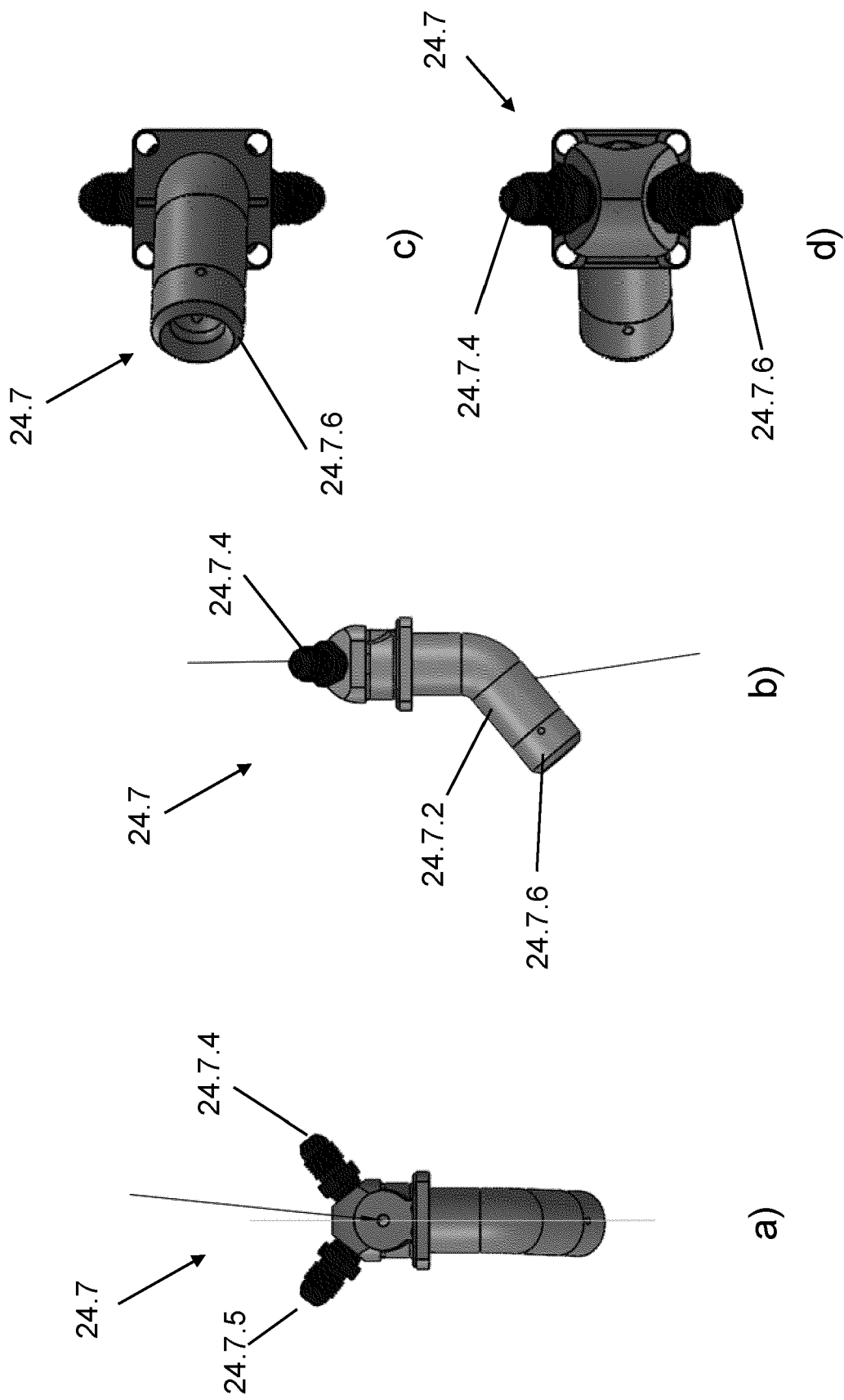


Fig. 10

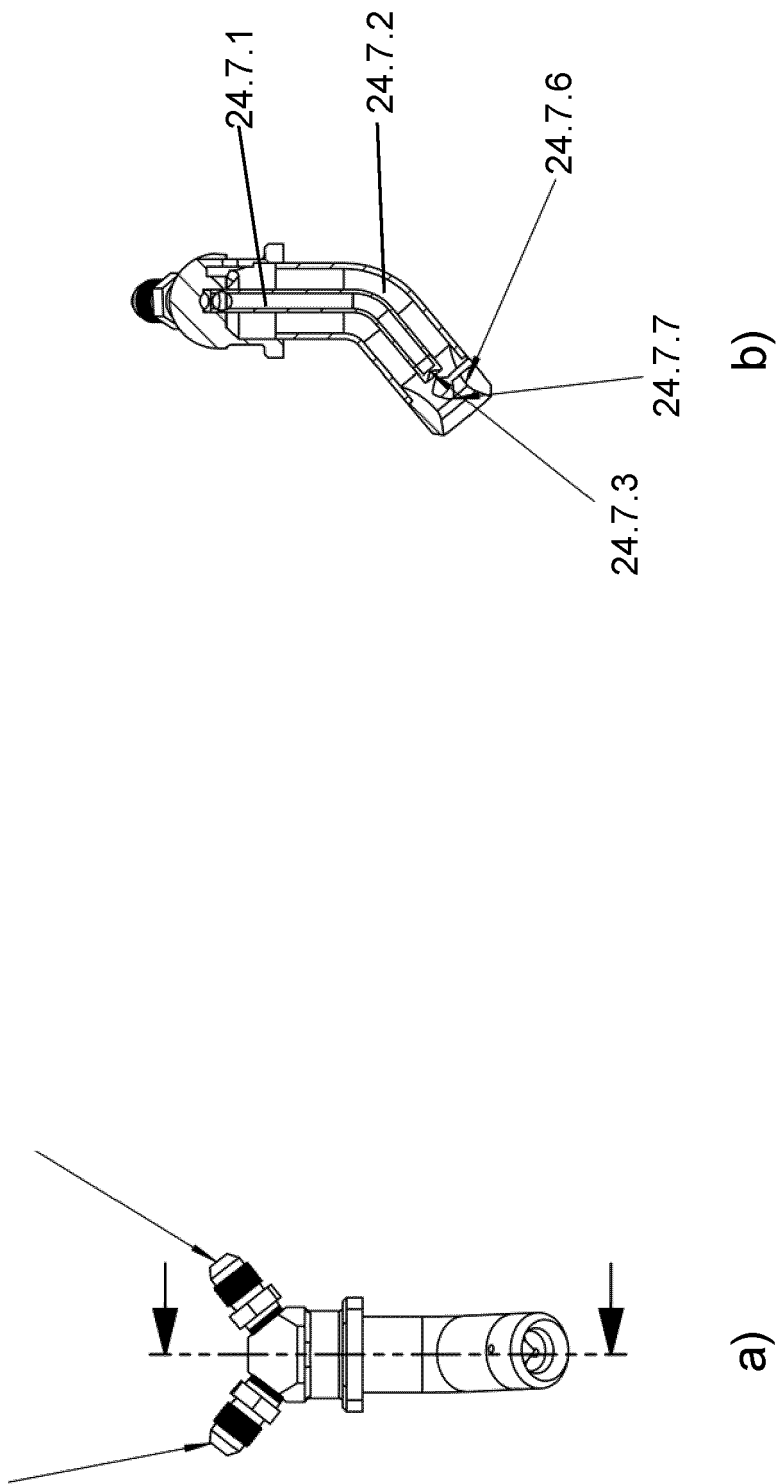


Fig. 11

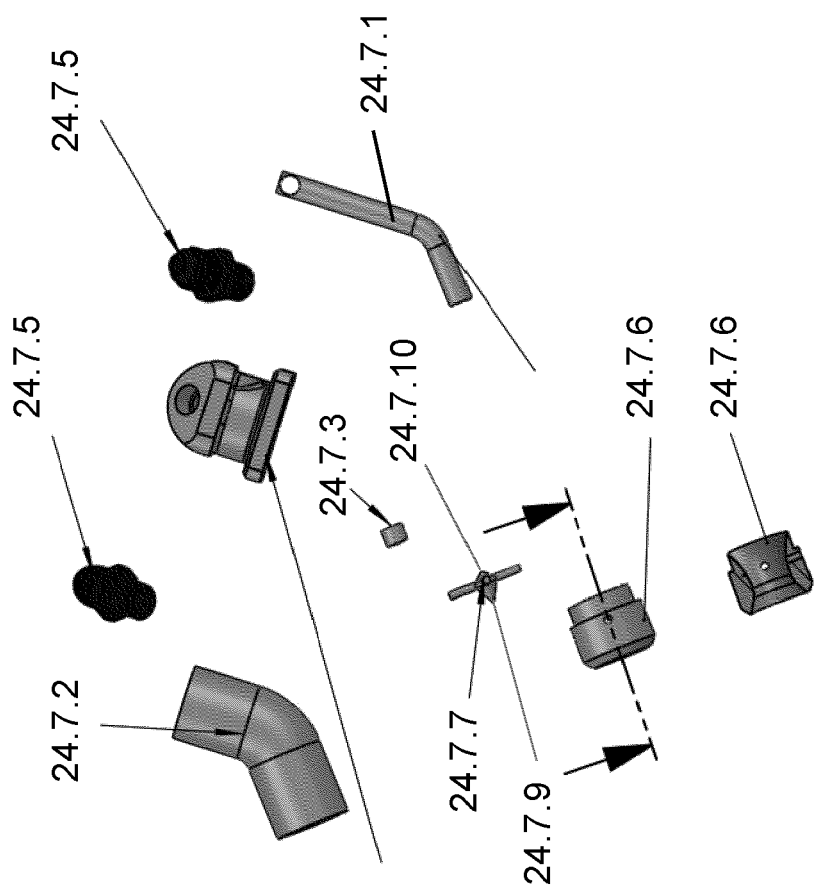


Fig. 12



EUROPEAN SEARCH REPORT

Application Number

EP 23 20 8336

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2004/034998 A1 (BEACOM WILLIAM F [US]) 26 February 2004 (2004-02-26)	1, 2, 5, 9	INV. F23R3/16
Y	* paragraph [0028] - paragraph [0030]; figure 2 *	3, 4, 6-8, 10, 11	F23R3/28 F23R3/42 F23R3/50
Y	US 4 996 838 A (MELCONIAN JERRY O [US]) 5 March 1991 (1991-03-05) * column 5, line 30 - line 57; figure 1 *	3, 4, 6-8	
Y	US 2007/193248 A1 (BESSAGNET FLORIAN ANDRE FRANCO [FR] ET AL) 23 August 2007 (2007-08-23) * paragraphs [0033] - [0042]; figures 4-6 *	4	
Y	US 2019/323355 A1 (SHAHPAR SHAHROKH [GB] ET AL) 24 October 2019 (2019-10-24) * paragraphs [0064], [0074] - [0076]; figures 2, 4 *	10, 11	
X	US 2019/120493 A1 (BOARDMAN GREGORY ALLEN [US] ET AL) 25 April 2019 (2019-04-25) * paragraphs [0028], [0031], [0039] - [0042]; figures 1-4 *	1, 5-7, 9, 10	TECHNICAL FIELDS SEARCHED (IPC) F23R
X	US 4 567 724 A (MONGIA HUKAM C [US] ET AL) 4 February 1986 (1986-02-04) * column 5, line 31 - line 54; figure 3 *	1, 2, 9	
X	US 2003/205050 A1 (TEETS J MICHAEL [US]) 6 November 2003 (2003-11-06) * paragraph [0022]; figures 2, 6, 8 *	1, 5, 6, 9	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 20 March 2024	Examiner Mougey, Maurice
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 20 8336

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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20-03-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004034998 A1	26-02-2004	US 6644916 B1 US 2004034998 A1	11-11-2003 26-02-2004
US 4996838 A	05-03-1991	NONE	
US 2007193248 A1	23-08-2007	CA 2577507 A1 CN 101016997 A EP 1818613 A1 FR 2897143 A1 JP 4982203 B2 JP 2007212126 A US 2007193248 A1	08-08-2007 15-08-2007 15-08-2007 10-08-2007 25-07-2012 23-08-2007 23-08-2007
US 2019323355 A1	24-10-2019	CN 110397504 A EP 3561387 A1 US 2019323355 A1	01-11-2019 30-10-2019 24-10-2019
US 2019120493 A1	25-04-2019	CN 109708147 A US 2019120493 A1	03-05-2019 25-04-2019
US 4567724 A	04-02-1986	EP 0100134 A1 JP S621486 B2 JP S5918315 A US 4545196 A US 4567724 A	08-02-1984 13-01-1987 30-01-1984 08-10-1985 04-02-1986
US 2003205050 A1	06-11-2003	AU 5748201 A CA 2407717 A1 CN 1502007 A EP 1295018 A1 JP 4851674 B2 JP 2004507700 A KR 20030036174 A US 2003205050 A1 WO 0183963 A1	12-11-2001 08-11-2001 02-06-2004 26-03-2003 11-01-2012 11-03-2004 09-05-2003 06-11-2003 08-11-2001