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(54) **PASSIVE PURGE INJECTORS**

(57) A method of injecting fuel in a gas turbine engine includes injecting gaseous fuel from a gaseous fuel circuit (106) of an injector (100) in a first mode, wherein flow of gaseous fuel from the gaseous fuel circuit (106) constricts air flow from an air circuit (108). The method includes injecting liquid fuel from a liquid fuel circuit in a second mode, idling flow in the gaseous fuel circuit (106) and flowing air through the air circuit (108) for passive purge to prevent liquid fuel from migrating into the gaseous fuel circuit (106). The method includes injecting a gaseous fuel that lies within a range of different Wobbe Index values, wherein regardless of where the gaseous fuel falls in the range, it does not prevent operation in the first and second modes as described above.

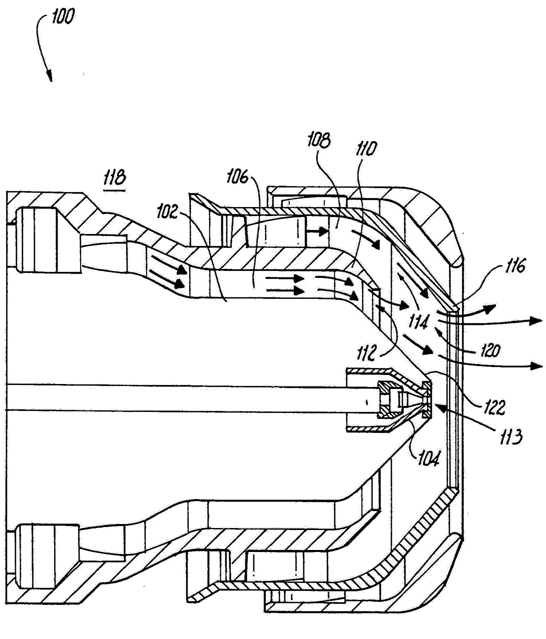

Fig. 1

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present disclosure relates to injectors, and more particularly to multiple circuit injectors with passive purge for inactive circuits.

2. Description of Related Art

[0002] Dual-fuel gas-turbine fuel injectors often require active purging of the idle fuel circuit with air in order to prevent unwanted fouling and liquid fuel collecting in the idle gas circuit. This active purging requires costly additional subsystems, which can also add a parasitic efficiency loss to the engine. Passive-purge concepts have been used to obviate the need for active purging; however, traditional passive-purge injectors only function for a relatively narrow range of Wobbe Index fuels around the design point. The Wobbe Index is a way of comparing energy density of one fuel to another, and varies proportionally with calorific value and inversely with the square root of specific gravity. For a given energy output requirement, a fuel with a higher Wobbe Index value can be supplied at a lower flow rate than a fuel with a lower Wobbe Index value. If gaseous fuel is used with a Wobbe Index value sufficiently lower than the design point for a given traditional passive purge injector, then the gaseous fuel will tend to backflow into the diffuser cavity and lead to possible engine damage.

[0003] The conventional techniques have been considered satisfactory for their intended purpose. However, there is an ever present need for improved passive purge injectors, specifically regarding the flexibility of the energy content in the gaseous fuel. This disclosure provides a solution for this problem.

SUMMARY OF THE INVENTION

[0004] A method of injecting fuel in a gas turbine engine includes injecting gaseous fuel from a gaseous fuel circuit of an injector in a first mode, wherein flow of gaseous fuel from the gaseous fuel circuit constricts air flow from an air circuit outboard or inboard of the gaseous fuel circuit in the first mode. The method includes injecting liquid fuel from a liquid fuel circuit in a second mode, wherein the second mode includes idling flow in the gaseous fuel circuit and flowing air through the air circuit for passive purge to prevent liquid fuel from migrating into the gaseous fuel circuit. Switching the air circuit between constricted flow in the first mode and unconstricted flow in the second mode is accomplished by activating or idling the gaseous fuel circuit, respectively. Injecting gaseous fuel includes injecting a gaseous fuel that lies within a range of different Wobbe Index values ranging from a first Wobbe Index value to a second Wobbe index value, wherein regardless of where the gaseous fuel falls in the range of different Wobbe Index values, it does not prevent operation in the first mode constricting air flow from the air circuit in the first mode, and wherein regardless of where the gaseous fuel falls in the range of different Wobbe Index values, it does not prevent operation in the second mode preventing liquid fuel migrating into the gas circuit in the second mode.

[0005] The first Wobbe Index value and the second Wobbe Index value can differ by a factor up to 3. It is also contemplated that the first Wobbe Index value and the second Wobbe Index value can differ by a factor of 3 or more.

[0006] Constricting air flow from the air circuit in the first mode can include flowing gaseous fuel from the gaseous fuel circuit in a flow path that crosses an outlet opening of the air circuit, restricting how much air can flow through the air circuit. Flowing gaseous fuel in a flow path that crosses the outlet opening of the air circuit can include flowing the gaseous fuel from a converging lip bounding an outlet of the gaseous fuel circuit to a converging lip bounding the outlet opening of the air circuit. The converging lip bounding the outlet of the gaseous fuel circuit can impart a momentum vector on gas flowing out of the gaseous fuel circuit to at least partially block off the outlet opening of the air circuit. Back-flowing gaseous fuel into a compressor discharge cavity supplying air to the air circuit can be prevented in the first mode. In the first mode some air can be discharged through the constricted air circuit, and gaseous fuel from the gaseous fuel circuit and air from the air circuit can both exit the injector through a common exit passage. Constricting air flow from the air circuit in the first mode can include constricting up to 65% of the air flow through the air circuit compared to air flow through the air circuit in the second mode.

[0007] Flowing air through the air circuit for passive purge can include impinging air from the air circuit onto an outer surface of a liquid injector inboard of the gaseous fuel circuit. Passive purge to prevent liquid fuel from migrating into the gaseous fuel circuit can include scrubbing liquid fuel from a conical surface of a liquid injector inboard of the gaseous flow circuit with impinging air flow from the air circuit. Impinging air from the air circuit onto the outer surface of the liquid injector can include issuing air from an outlet opening of the air circuit defined between two converging lips of the injector. Back-flowing liquid fuel into a compressor discharge cavity supplying air to the air circuit can be prevented in the second mode. It is also contemplated that migrating liquid fuel into the gaseous fuel circuit and/or growing carbon on a conical surface of a liquid injector inboard of the gaseous flow circuit can be prevented in the second mode.

[0008] A fuel injector can include a liquid injector having a liquid fuel circuit, a gaseous fuel circuit outboard or inboard of the liquid fuel circuit, and an air circuit outboard or inboard of the gaseous fuel circuit. The gaseous fuel circuit and liquid fuel circuit can be configured to operate in the two modes described above. A converging lip can bound an outlet of the gaseous fuel circuit, wherein the converging lip is configured to impart a momentum vector on gas flowing out of the gaseous fuel circuit to at least partially block off the outlet opening of the air circuit in the first mode.

[0009] In another aspect, a fuel injecting arrangement includes a body comprising:

at least one liquid fuel circuit having at least one liquid fuel outlet;
at least one air flow circuit having at least one air outlet positioned radially of the liquid fuel outlet; and
a gaseous fuel circuit having a gaseous fuel outlet positioned radially of the at least one liquid fuel outlet and radially of the at least one air outlet, the fuel injecting arrangement being configured such that the air flow is constricted from flowing out the at least one air outlet that is immediately radially adjacent to the gaseous fuel outlet when gaseous fuel is flowing out from the gaseous fuel outlet, while also preventing back flow of gaseous fuel into the at least one air outlet that is immediately radially adjacent to the gaseous fuel outlet for a Wobbe Index ranging from a nominal value to a value that is 1/3 to 1/4 of the nominal value. The fuel injecting arrangement is further configured such that when liquid fuel is flowing out from the at least one liquid fuel outlet and the gaseous fuel circuit is idle, air flowing from the at least one air outlet that is immediately radially adjacent to the gaseous fuel outlet prevents liquid from settling on the gaseous fuel outlet or back flowing into the gaseous flow circuit through the gaseous fuel outlet.

[0010] A converging lip can bound an outlet of the gaseous fuel circuit forming a conical shape, wherein the converging lip is configured to impart a momentum vector on gas flowing out of the gaseous fuel circuit to at least partially block off the outlet opening of the air circuit in the first mode, such that gaseous fuel flowing through the gaseous fuel circuit is directed at least partially radially inwardly prior to being mixed with air.

[0011] In another aspect a fuel injecting arrangement includes a body comprising:

at least one liquid fuel circuit having at least one liquid fuel outlet;
at least one air flow circuit having at least one air outlet positioned radially outward of the liquid fuel outlet; and

a gaseous fuel circuit having a gaseous fuel outlet positioned radially between the at least one liquid fuel outlet the at least one air outlet, the gaseous fuel outlet having a frustoconical shape such that gaseous fuel flowing out from the gaseous fuel outlet is directed partially radially inwardly prior to being mixed with air.

[0012] These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description of the preferred embodiments taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

Fig. 1 is a cross-sectional side elevation view of an exemplary embodiment of an injector constructed in accordance with the present disclosure, showing the injector in a first mode with gaseous fuel issuing from the gaseous fuel circuit; and
Fig. 2 is a cross-sectional side elevation view of the injector of Fig. 1, showing the injector in a second mode with the gaseous fuel circuit idle, wherein passive purging of liquid fuel is provided by air from the air circuit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject disclosure. For purposes of explanation and illustration, and not limitation, a partial view of an exemplary embodiment of an injector in accordance with the disclosure is shown in Fig. 1 and is designated generally by reference character 100. Other aspects of injectors in accordance with the disclosure are provided in Fig. 2, as will be described. The systems and methods described herein can be used to provide passive purge of liquid fuel in dual-fuel, e.g., gaseous and liquid fuel, injection for gas turbine engines over a wide range of Wobbe Index values for the gaseous fuel.

[0015] Fuel injector 100 includes a liquid injector 102 having a liquid fuel circuit 104 (two or more liquid fuel circuits can be used, e.g., a primary for low power and a secondary high power), a gaseous fuel circuit 106 outboard of the liquid fuel circuit 104, and an air circuit 108 outboard of the gaseous fuel circuit 106. Those skilled in the art will readily appreciate that although depicted in the order described above, the circuits can be ordered with gaseous fuel circuit 106 inboard of the liquid fuel circuit 104, and with the air circuit 108 inboard of the gaseous fuel circuit 106 without departing from the scope of this disclosure. The gaseous fuel circuit 106 and liquid fuel circuit 104 are configured to operate in the two modes described below and shown respectively in Fig. 1 and Fig. 2. A converging lip 110 bounds the outlet 112 of the gaseous fuel circuit 106 forming a conical shape.

[0016] In the first mode, a method of injecting fuel in a gas turbine engine includes injecting gaseous fuel from a gaseous fuel circuit, e.g. gaseous fuel circuit 106, of an injector, e.g., injector 100. Flow of gaseous fuel from the gaseous fuel circuit constricts air flow from an air circuit, e.g. air circuit 108, outboard of the gaseous fuel circuit in the first mode. The converging lip 110 is configured to impart a momentum vector, represented by the flow arrows in Fig. 1, on gas flowing out of the gaseous fuel circuit 106 to at least partially block off the outlet opening 114 of the air circuit 108 in the first mode, such that gaseous fuel flowing through the gaseous fuel circuit 106 is directed at least partially radially inwardly prior to being mixed with air.

[0017] Constricting air flow from the air circuit in the first mode can include flowing gaseous fuel from the gaseous fuel circuit in a flow path that crosses an outlet opening, e.g. outlet opening 114, of the air circuit, restricting how much air can flow through the air circuit, as indicated by the flow arrows in Fig. 1. This can include flowing the gaseous fuel from converging lip 110 to a converging lip 116 bounding the outlet opening 114 of the air circuit, i.e. as shown in Fig. 1 by the flow arrows of gaseous fuel circuit 106 crossing outlet opening 114 from tip to tip of the lips 110 and 116. A compressor discharge cavity, e.g., the space designated by reference character 118, supplies air to the air circuit. By the flow patterns in the first mode, back-flowing gaseous fuel into the compressor discharge cavity 118 can be prevented. It is also contemplated that migrating fuel into the gaseous fuel circuit 106 and/or growing carbon on the conical surface 122 of the liquid injector 102 inboard of the gaseous flow circuit can be prevented in the second mode. In the first mode some air can be discharged through the constricted air circuit 108, as indicated by the flow arrows in Fig. 1 in air circuit 108, and gaseous fuel from the gaseous fuel circuit and air from the air circuit can both exit the injector through a common exit passage 120. The amount of air constriction in the first mode will vary depending on the Wobbe Index of the gaseous fuel being used, with fuels at low end of allowable Wobbe Index range reducing air flow to near zero. Constricting air flow from the air circuit in the first mode can include constricting up to 65% or more of the air flow through the air circuit compared to air flow through the air circuit in the second mode, which is described below.

[0018] With reference now to Fig. 2, the method includes injecting liquid fuel from a liquid fuel circuit, e.g., liquid fuel circuit 104, in the second mode as represented schematically in Fig. 2 by the droplets issuing from the outlet 113 of the liquid fuel circuit 104. The second mode includes idling flow in the gaseous fuel circuit and flowing air through the air circuit for passive purge to prevent liquid fuel from migrating into the gaseous fuel circuit, as indicated by the flow arrows in air circuit 108 in Fig. 2. Back-flowing liquid fuel into a compressor discharge cavity 118 can also be prevented in the second mode. Switching the air circuit between constricted flow in the first mode and unconstricted flow in the second mode is accomplished by activating or idling the gaseous fuel circuit, respectively.

[0019] Flowing air through the air circuit for passive purge includes impinging air from the air circuit onto an outer surface 122 of the liquid injector 102. This scrubs liquid fuel from a conical surface 122 with impinging air flow from the air circuit. Impinging air from the air circuit onto the outer surface of the liquid injector can include issuing air from an outlet opening, e.g., outlet opening 114, of the air circuit defined between two converging lips, e.g. lips 110 and 116, of the injector.

[0020] The method includes injecting gaseous fuel that lies within a range of different Wobbe Index values ranging from a first Wobbe Index value to a second Wobbe Index value, wherein regardless of where the gaseous fuel falls within the range of different Wobbe Index values, it does not prevent operation in the first and second modes as described herein. The first Wobbe Index value and the second Wobbe Index value can differ by a factor up to 3 or more. For example, this allows use of a given fuel injector constructed in accordance with this disclosure in gas turbine engines at various locations where the gas supplies are very different from one another in Wobbe Index values, i.e., this allows for greater flexibility in what installations/locations the injectors can be used compared to traditional injectors. This also allows for switching, or gradual change in a given gas supply, from a first gaseous fuel supplied to the gaseous fuel circuit to a second gaseous fuel, wherein the first gaseous fuel has a different Wobbe Index value from the second gaseous fuel, i.e. this allows for greater operational flexibility than traditional injectors. A nominal value for the range of Wobbe Index could be for natural gas at 1370 BTU/scf (or anywhere in a wider range for natural gas of 1310-1390 BTU/scf), and the range can go down to 1/3 to 1/4 of that nominal value, for example for low BTU landfill gas ("BTU" refers to British thermal units (where 1 BTU equals 1055.06 Joules) and "scf" refers to standard cubic feet, an amount of natural gas contained at standard temperature and pressure in one cubic foot, where one cubic foot equals 0.0283 cubic meters).

[0021] Since the Wobbe Index value of a fuel varies proportionally with calorific value and inversely with the square root of specific gravity, the lower the Wobbe Index value of a given fuel, the greater the flow rate of the fuel will have to be to maintain a desired energy output. In traditional injectors, switching fuels from a higher Wobbe Index value to a lower value would have been problematic because the flow rate for a low Wobbe Index fuel is typically high enough to upset the pressure balance with outboard air purge circuits, causing backflow of gaseous fuel into the purge air circuits. However, in injectors in accordance with this disclosure, switching from the first gaseous fuel to the second gaseous fuel does not prevent operation in the first mode constricting air flow from the air circuit in the first mode, and wherein switching from the first fuel to the second fuel does not prevent operation in the second mode preventing liquid fuel migrating into the gas circuit in the second mode. This is due to the flow patterns shown in Figs. 1 and 2 for the first and second modes, respectively. The air and gaseous fuel circuits can be designed for a given application to operate as described herein using computational fluid dynamics (CFD) analysis, modeling for two different Wobbe Index values in the gaseous fuel circuit to span the range of desired Wobbe Index values.

[0022] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for passive purge in dual fuel injectors with superior properties including increased acceptable range in Wobbe Index for gaseous fuels compared to traditional passive purge injection, without back-flowing gaseous or liquid fuel into the compressor discharge cavity. While the apparatus and methods of the subject disclosure have been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the scope of the subject disclosure.

Claims

1. A method of injecting fuel in a gas turbine engine comprising:

injecting gaseous fuel from a gaseous fuel circuit of an injector in a first mode, wherein flow of gaseous fuel from the gaseous fuel circuit constricts air flow from an air circuit outboard or inboard of the gaseous fuel circuit in the first mode;
injecting liquid fuel from a liquid fuel circuit in a second mode, wherein the second mode includes idling flow in the gaseous fuel circuit and flowing air through the air circuit for passive purge to prevent liquid fuel from migrating into the gaseous fuel circuit, wherein switching the air circuit between constricted flow in the first mode and unconstricted flow in the second mode is accomplished by activating or idling the gaseous fuel circuit, respectively; and
wherein injecting gaseous fuel includes injecting a gaseous fuel that lies within a range of different Wobbe Index values ranging from a first Wobbe Index value to a second Wobbe Index value, and wherein, wherein regardless of where the gaseous fuel falls in the range of different Wobbe Index values, it does not prevent operation in the first mode constricting air flow from the air circuit in the first mode, and wherein regardless of where the gaseous fuel falls in the range of different Wobbe Index values, it does not prevent operation in the second mode preventing liquid fuel migrating into the gas circuit in the second mode.

2. The method as recited in claim 1, wherein the first Wobbe Index value and the second Wobbe Index value differ by a factor up to 3.

3. The method as recited in claim 1, wherein the first Wobbe Index value and the second Wobbe Index value differ by a factor of 3 or more.

4. The method as recited in claim 1, 2 or 3, wherein constricting air flow from the air circuit in the first mode includes flowing gaseous fuel from the gaseous fuel circuit in a flow path that crosses an outlet opening of the air circuit, restricting how much air can flow through the air circuit.

5. The method as recited in claim 4, wherein flowing gaseous fuel in a flow path that crosses the outlet opening of the air circuit includes flowing the gaseous fuel from a converging lip bounding an outlet of the gaseous fuel circuit to a converging lip bounding the outlet opening of the air circuit.

6. The method as recited in claim 5, wherein the converging lip bounding the outlet of the gaseous fuel circuit imparts a momentum vector on gas flowing out of the gaseous fuel circuit to at least partially block off the outlet opening of the air circuit.

7. The method as recited in any preceding claim, wherein flowing air through the air circuit for passive purge includes impinging air from the air circuit onto an outer surface of a liquid injector inboard of the gaseous fuel circuit,
wherein, optionally, impinging air from the air circuit onto the outer surface of the liquid injector includes issuing air from an outlet opening of the air circuit defined between two converging lips of the injector.

8. The method as recited in any preceding claim, wherein, at least one of back-flowing liquid fuel into a compressor discharge cavity supplying air to the air circuit, migrating liquid fuel into the gaseous fuel circuit, or growing carbon on a conical surface of a liquid injector inboard of the gaseous flow circuit is prevented in the second mode.

9. The method as recited in any preceding claim, wherein, back-flowing gaseous fuel into a compressor discharge cavity supplying air to the air circuit is prevented in the first mode.

10. The method as recited in any preceding claim, wherein in the first mode some air is discharged through the constricted air circuit, and wherein gaseous fuel from the gaseous fuel circuit and air from the air circuit both exit the injector through a common exit passage.

11. The method as recited in any preceding claim, wherein constricting air flow from the air circuit in the first mode includes constricting up to 65% of the air flow through the air circuit compared to air flow through the air circuit in the second mode.

12. The method as recited in any preceding claim, wherein passive purge to prevent liquid fuel from migrating into the gaseous fuel circuit includes scrubbing liquid fuel from a conical surface of a liquid injector inboard of the gaseous flow circuit with impinging air flow from the air circuit.

13. A fuel injecting arrangement comprising:

a body comprising:

at least one liquid fuel circuit having at least one liquid fuel outlet;
at least one air flow circuit having at least one air outlet positioned radially of the liquid fuel outlet; and
a gaseous fuel circuit having a gaseous fuel outlet positioned radially of the at least one liquid fuel outlet and radially of the at least one air outlet,
the fuel injecting arrangement being configured such that the air flow is constricted from flowing out the at least one air outlet that is immediately radially adjacent to the gaseous fuel outlet when gaseous fuel is flowing out from the gaseous fuel outlet, while also preventing back flow of gaseous fuel into the at least one air outlet that is immediately radially adjacent to the gaseous fuel outlet for a Wobbe Index ranging from a nominal value to a value that is 1/3 to 1/4 of the nominal value,
the fuel injecting arrangement further being configured such that when liquid fuel is flowing out from the at least one liquid fuel outlet and the gaseous fuel circuit is idle, air flowing from the at least one air outlet that is immediately radially adjacent to the gaseous fuel outlet prevents liquid from settling on the gaseous fuel outlet or back flowing into the gaseous flow circuit through the gaseous fuel outlet.

14. The fuel injector as recited in claim 13, wherein a converging lip bounds an outlet of the gaseous fuel circuit forming a conical shape, wherein the converging lip is configured to impart a momentum vector on gas flowing out of the gaseous fuel circuit to at least partially block off the outlet opening of the air circuit in the first mode, such that gaseous fuel flowing through the gaseous fuel circuit is directed at least partially radially inwardly prior to being mixed with air.

15. A fuel injecting arrangement comprising:

a body comprising:

at least one liquid fuel circuit having at least one liquid fuel outlet;
at least one air flow circuit having at least one air outlet positioned radially outward of the liquid fuel outlet; and
a gaseous fuel circuit having a gaseous fuel outlet positioned radially between the at least one liquid fuel outlet the at least one air outlet, the gaseous fuel outlet having a frustoconical shape such that gaseous fuel flowing out from the gaseous fuel outlet is directed partially radially inwardly prior to being mixed with air.

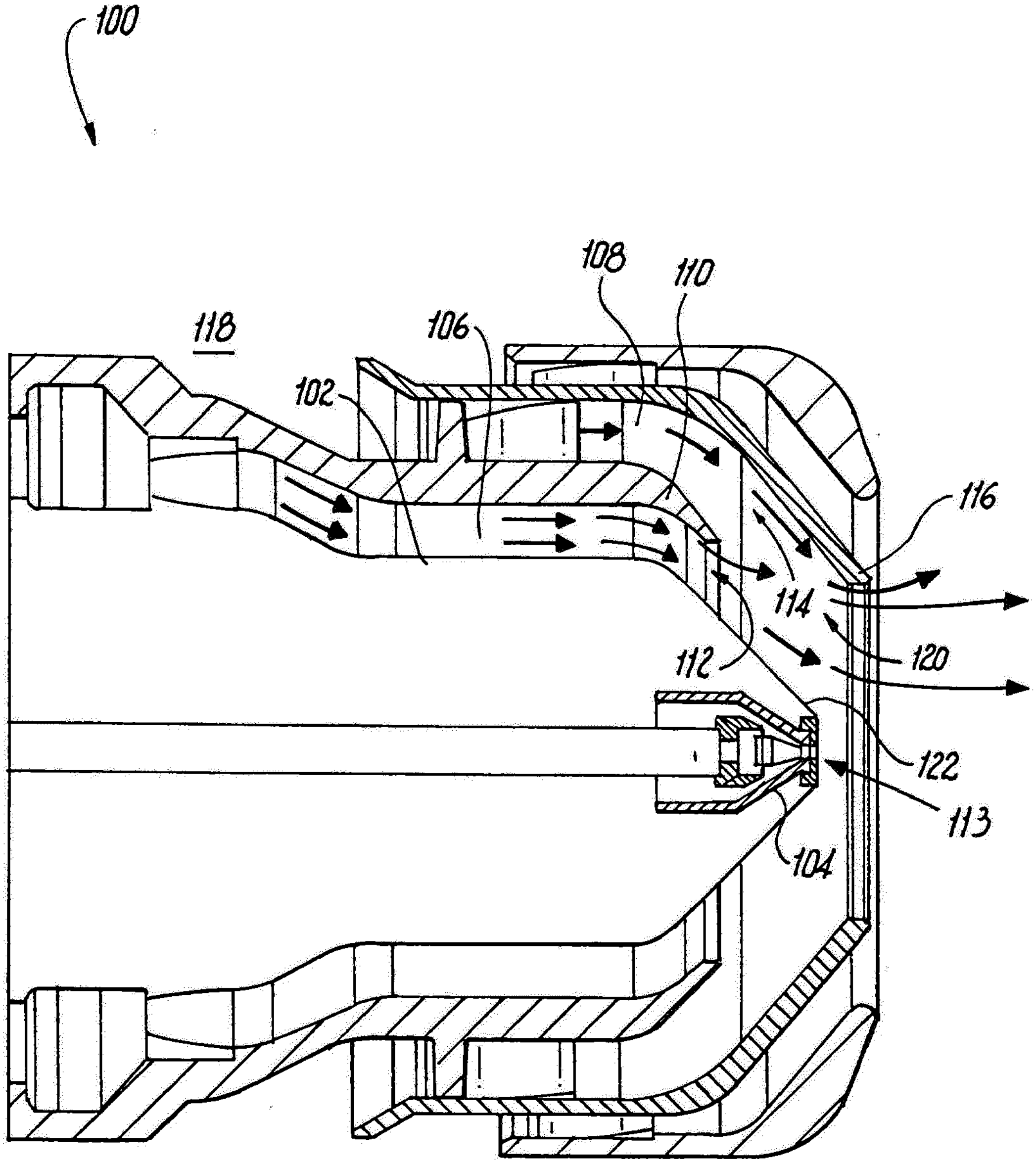

Fig. 1

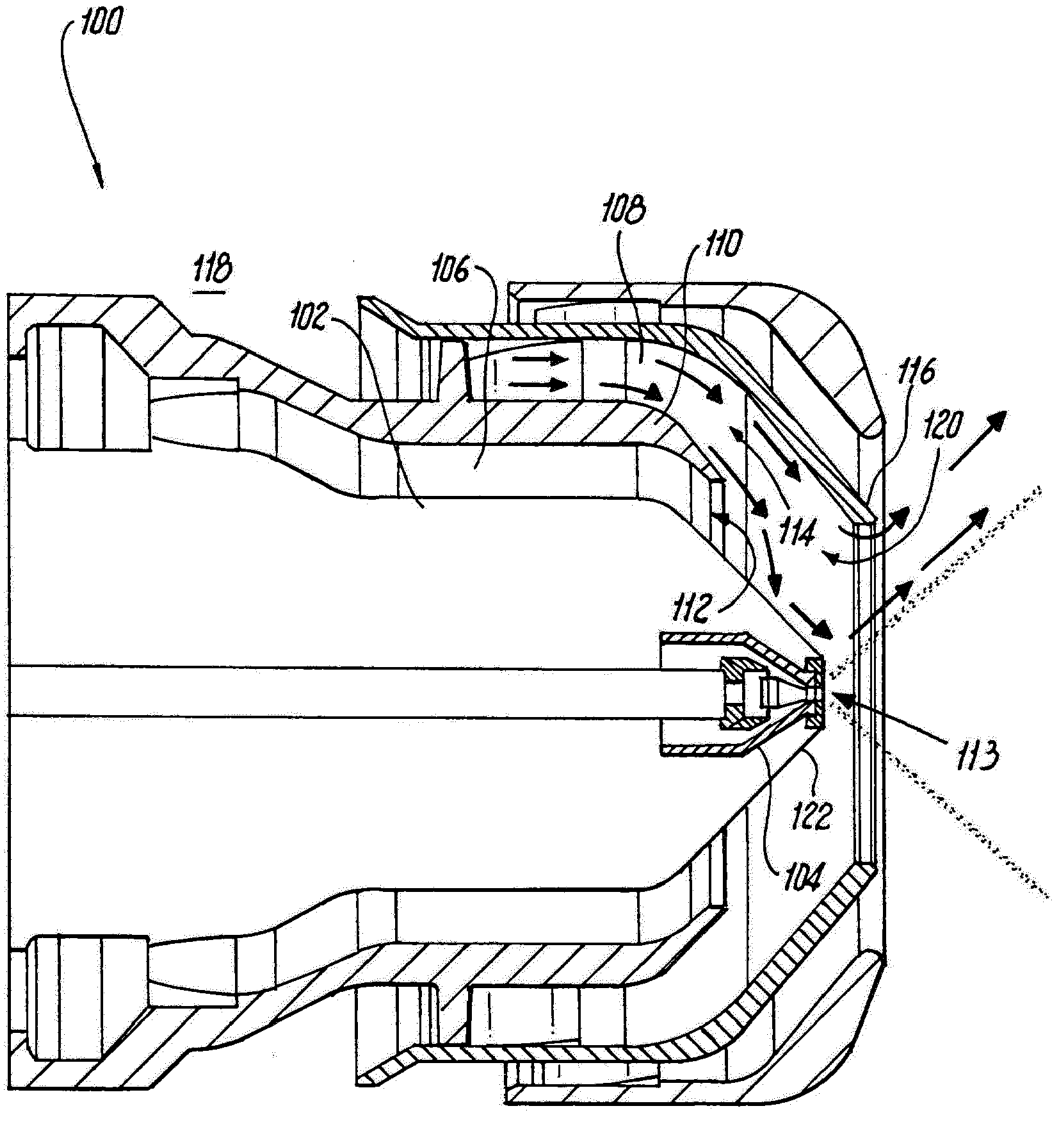

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 7925

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	3 July 2018	Harder, Sebastian

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 15 7925

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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