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(54) Title: AIRCRAFT ENGINE FUEL SYSTEM AND METHOD OF OPERATING THE SAME

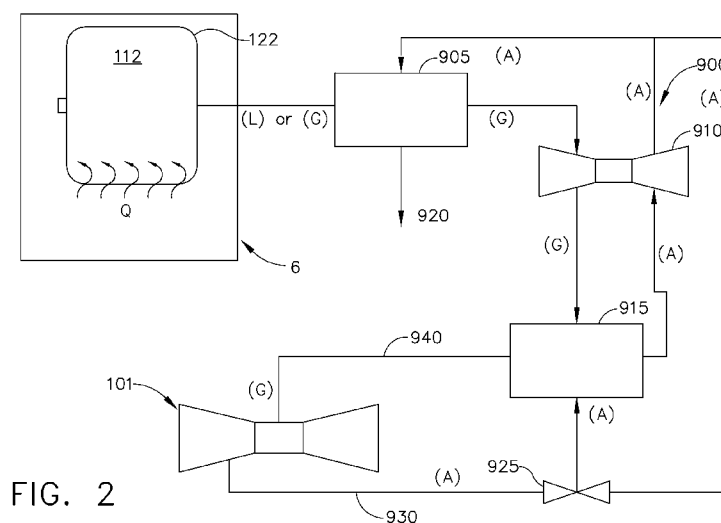


FIG. 2

(57) Abstract: An aircraft engine fuel system 900 is disclosed having a gas turbine engine 101, a turbocharger 910, a compressor bleed air system 930 for providing compressor air (A) from the gas turbine engine 101 to the turbocharger 910, and a fuel delivery system 940 for providing compressed gaseous fuel (G) from the turbocharger 910 to the gas turbine engine 101, whereby the compressor air (A) powers the turbocharger 910 and the turbocharger 910 pumps the compressed gaseous fuel (G) to the gas turbine engine 101. Also disclosed is a method of operating an aircraft engine fuel system 900 including the steps of: operating a gas turbine engine 101; extracting compressor air (A) from the gas turbine engine 101; routing the compressor air (A) to a turbocharger 910; and operating the turbocharger 910 to pump a compressed gaseous fuel (G) to the gas turbine engine 101.



AIRCRAFT ENGINE FUEL SYSTEM AND METHOD OF OPERATING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application Serial No. 61/498264, filed June 17, 2011, the disclosure of which is hereby incorporated in its entirety by reference herein.

BACKGROUND OF THE INVENTION

[0002] The technology described herein relates generally to aircraft systems, and more specifically to aircraft engine fuel systems.

[0003] Certain cryogenic fuels such as liquefied natural gas (LNG) may be cheaper than conventional jet fuels. However, such cryogenic fuels require careful management of temperatures, pressures, and other parameters both in storage and en route to the aircraft engine where they will be utilized to generate power.

[0004] Aircraft engines, at least during certain operating conditions, have reserve capacity to drive additional components and systems. However, there remains a need for simplified and more efficient systems for storing and transporting cryogenic fuels in aircraft engine fuel systems.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In one aspect, an aircraft engine fuel system 900 having a gas turbine engine 101, a turbocharger 910, a compressor bleed air system 930 for providing compressor air (A) from the gas turbine engine 101 to the turbocharger 910, and a fuel delivery system 940 for providing compressed gaseous fuel (G) from the turbocharger 910 to the gas turbine engine 101, whereby the compressor air (A) powers the turbocharger 910 and the turbocharger 910 pumps the compressed gaseous fuel (G) to the gas turbine engine 101.

[0006] In another aspect, a method of operating an aircraft engine fuel system 900 including the steps of: operating a gas turbine engine 101; extracting compressor air (A) from the gas turbine engine 101; routing the compressor air (A) to a turbocharger 910; and operating the turbocharger 910 to pump a compressed gaseous fuel (G) to the gas turbine engine 101.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The technology described herein may be best understood by reference to the following description taken in conjunction with the accompanying drawing figures in which:

[0008] FIG. 1 is an isometric view of an exemplary aircraft system having a dual fuel propulsion system; and

[0009] FIG. 2 is a schematic view of an exemplary embodiment of an aircraft engine fuel system.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Referring to the drawings herein, identical reference numerals denote the same elements throughout the various views.

[0011] FIG. 1 shows an aircraft system 5 according to an exemplary embodiment of the present invention. The exemplary aircraft system 5 has a fuselage 6 and wings 7 attached to the fuselage. The aircraft system 5 has a propulsion system 100 that produces the propulsive thrust required to propel the aircraft system in flight. Although the propulsion system 100 is shown attached to the wing 7 in FIG. 1, in other embodiments it may be coupled to other parts of the aircraft system 5, such as, for example, the tail portion 16.

[0012] The exemplary aircraft system 5 has a fuel storage system 10 for storing one or more types of fuels that are used in the propulsion system 100. The exemplary aircraft system 5 shown in FIG. 1 uses two types of fuels, as explained further below herein. Accordingly, the exemplary aircraft system 5 comprises a first

fuel tank 21 capable of storing a first fuel 11 and a second fuel tank 22 capable of storing a second fuel 12. In the exemplary aircraft system 5 shown in FIG. 1, at least a portion of the first fuel tank 21 is located in a wing 7 of the aircraft system 5. In one exemplary embodiment, shown in FIG. 1, the second fuel tank 22 is located in the fuselage 6 of the aircraft system near the location where the wings are coupled to the fuselage. In alternative embodiments, the second fuel tank 22 may be located at other suitable locations in the fuselage 6 or the wing 7. In other embodiments, the aircraft system 5 may comprise an optional third fuel tank 123 capable of storing the second fuel 12. The optional third fuel tank 123 may be located in an aft portion of the fuselage of the aircraft system, such as for example shown schematically in FIG. 1.

[0013] As further described later herein, the propulsion system 100 shown in FIG. 1 is a dual fuel propulsion system that is capable of generating propulsive thrust by using the first fuel 11 or the second fuel 12 or using both first fuel 11 and the second fuel 12. The exemplary dual fuel propulsion system 100 comprises a gas turbine engine 101 capable of generating a propulsive thrust selectively using the first fuel 11, or the second fuel 21, or using both the first fuel and the second fuel at selected proportions. The first fuel may be a conventional liquid fuel such as a kerosene based jet fuel such as known in the art as Jet-A, JP-8, or JP-5 or other known types or grades. In the exemplary embodiments described herein, the second fuel 12 is a cryogenic fuel that is stored at very low temperatures. In one embodiment described herein, the cryogenic second fuel 12 is Liquefied Natural Gas (alternatively referred to herein as “LNG”). The cryogenic second fuel 12 is stored in the fuel tank at a low temperature. For example, the LNG is stored in the second fuel tank 22 at about -265 Deg. F at an absolute pressure of about 15 psia. The fuel tanks may be made from known materials such as titanium, Inconel, aluminum or composite materials.

[0014] The exemplary aircraft system 5 shown in FIG. 1 comprises a fuel delivery system 50 capable of delivering a fuel from the fuel storage system 10 to the propulsion system 100. Known fuel delivery systems may be used for delivering the conventional liquid fuel, such as the first fuel 11. In the exemplary embodiments described herein, and shown in FIG. 1, the fuel delivery system 50 is configured to

deliver a cryogenic liquid fuel, such as, for example, LNG, to the propulsion system 100 through conduits that transport the cryogenic fuel.

[0015] The exemplary embodiment of the aircraft system 5 shown in FIG. 1 further includes a fuel cell system 400, comprising a fuel cell capable of producing electrical power using at least one of the first fuel 11 or the second fuel 12. The fuel delivery system 50 is capable of delivering a fuel from the fuel storage system 10 to the fuel cell system 400. In one exemplary embodiment, the fuel cell system 400 generates power using a portion of a cryogenic fuel 12 used by a dual fuel propulsion system 100.

[0016] Aircraft systems such as the exemplary aircraft system 5 described above and illustrated in FIG.1, as well as methods of operating same, are described in greater detail in commonly-assigned, co-pending patent application Serial No. PCT/US11/54396 filed September 30, 2011, entitled “Dual Fuel Aircraft System and Method for Operating Same”, the disclosure of which is hereby incorporated in its entirety by reference herein.

[0017] FIG. 2 illustrates an exemplary embodiment of an aircraft engine fuel system 900. The system shown in FIG. 2 comprises a cryogenic fuel tank 122 capable of storing a cryogenic liquid fuel 112. In one embodiment, the cryogenic liquid fuel 112 is LNG. Other alternative cryogenic liquid fuels may also be used. In the exemplary fuel system 900, the cryogenic liquid fuel 112, such as, for example, LNG, is at a first pressure “P1”. The pressure P1 is preferably close to atmospheric pressure, such as, for example, 15 psia.

[0018] Cryogenic fuel tank 122 is shown being located within an aircraft fuselage 6, although other installation locations may be utilized. Heat from the aircraft environment, as illustrated by the letter Q and the arrows crossing the wall of the tank 122, may be added to the liquid within the tank to raise the temperature of the cryogenic liquid fuel 112.

[0019] Fuel from tank 122 may exit as either a liquid (L) phase or a gaseous phase (G) en route to a heat exchanger 905 which adds additional heat to the fuel 112

which then flows in a gaseous state (G) to the compressor section of a gas-to-gas turbocharger 910, which may be of any suitable commercially available design. Turbocharger 910 pressurizes and pumps the gaseous fuel (G) through a second heat exchanger 915 which adds additional heat and energy to the fuel before it flows through a fuel delivery system 940 to a gas turbine engine 101 for combustion.

[0020] Compressor air (A) is extracted from the gas turbine engine 101 via compressor bleed air system 930. Compressor air (A) is typically at a higher temperature and pressure than atmospheric environmental air and thus offers a potential resource for thermal and kinetic energy. Compressor air (A) may thus be used to provide the high temperature or “hot” side resource for heat exchangers.

[0021] Compressor air (A) is routed through heat exchanger 915 to exchange heat and energy with the gaseous fuel (G) as previously described. A valve 925 may be used to selectively control the flow of compressor air (A) between the heat exchanger 915 and the heat exchanger 905, which is the first heat exchanger the fuel reaches after leaving the tank 122. The valve 925 may also be utilized to bypass compressor air (A) around the turbocharger 910.

[0022] After leaving the heat exchanger 915, the compressor air (A) then flows through the turbine section of turbocharger 910 where it serves to deliver energy to and drive the turbocharger to pressurize and pump the gaseous fuel (G) as previously described.

[0023] The compressor air (A) then leaves the turbocharger 910 and then flows through the heat exchanger 905, where it delivers heat to the fuel to either convert it from a liquid (L) to a gaseous state (G) or to enhance the energy of fuel in a gaseous state (G). After much of the thermal and kinetic energy of the compressor air (A) has been extracted through heat exchangers 905 and 915 and turbocharger 910, the compressor air (A) may exit the aircraft engine fuel system 900 as shown at 920 and then serve other purposes such as being routed through other aircraft systems such as environmental control systems (ECS) or be returned to the gas turbine engine 101 with lower pressure and temperature for cooling of key components, as desired.

[0024] While the exemplary embodiment of FIG. 2 depicts the use of two heat exchangers 905 and 915, depending upon the operating parameters of the system it may be desirable to have a single heat exchanger or more than two heat exchangers. The turbocharger 910 may be placed anywhere in the system including upstream or downstream of, or between, heat exchangers. Similarly, heat exchangers may be placed upstream or downstream of the turbocharger 910 with respect to fuel system flow.

[0025] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

WHAT IS CLAIMED IS:

1. An aircraft engine fuel system 900 comprising:
 - a gas turbine engine 101;
 - a turbocharger 910;
 - a compressor bleed air system 930 for providing compressor air (A) from said gas turbine engine 101 to said turbocharger 910; and
 - a fuel delivery system 940 for providing compressed gaseous fuel (G) from said turbocharger 910 to said gas turbine engine 101;whereby said compressor air (A) powers said turbocharger 910 and said turbocharger 910 pumps said compressed gaseous fuel (G) to said gas turbine engine 101.
2. An aircraft engine fuel system according to claim 1 further comprising at least one heat exchanger 915, 905 to transfer heat from said compressor air (A) to said compressed gaseous fuel (G).
3. An aircraft engine fuel system according to claim 2 wherein said at least one heat exchanger 915 is located between said gas turbine engine 101 and said turbocharger 910.
4. An aircraft engine fuel system according to claim 2 wherein said at least one heat exchanger 905 is located in said fuel delivery system 940 upstream of said turbocharger 910.
5. An aircraft engine fuel system according to claim 2 wherein said at least one heat exchanger 915 is located in said fuel delivery system 940 downstream of said turbocharger 910.
6. An aircraft engine fuel system according to claim 1 wherein said turbocharger 910 is a gas-to-gas turbocharger 910.

7. An aircraft engine fuel system according to claim 1 further comprising least two heat exchangers 905, 915.

8. An aircraft engine fuel system according to claim 7 wherein at least one heat exchanger 905 is located upstream of said turbocharger 910 with respect to fuel delivery system 940 flow and at least one heat exchanger 915 is located downstream of said turbocharger 910 with respect to fuel delivery system 940 flow.

9. An aircraft engine fuel system according to claim 1 further comprising a valve 925 to selectively bypass compressor air (A) around said turbocharger 910.

10. An aircraft engine fuel system 900 comprising:

a gas turbine engine 101;

a gas-to-gas turbocharger 910;

a compressor bleed air system 930 for providing compressor air (A) from said gas turbine engine 101 to said turbocharger 910;

a fuel delivery system 940 for providing compressed gaseous fuel (G) from said turbocharger 910 to said gas turbine engine 101;

at least one heat exchanger 905 located upstream of said turbocharger 910 with respect to fuel delivery system 940 flow and at least one heat exchanger 915 located downstream of said turbocharger 910 with respect to fuel delivery system 940 flow; and

a valve 925 to selectively bypass compressor air (A) around said turbocharger 910;

whereby said compressor air (A) powers said turbocharger 910 and said turbocharger 910 pumps said compressed gaseous fuel (G) to said gas turbine engine 101.

11. A method of operating an aircraft engine fuel system 900 comprising the steps of:

operating a gas turbine engine 101;

extracting compressor air (A) from said gas turbine engine 101;

routing said compressor air (A) to a turbocharger 910; and

operating said turbocharger 910 to pump a compressed gaseous fuel (G) to said gas turbine engine 101.

12. A method of operating an aircraft engine fuel system 900 according to claim 11 further comprising the step of routing said compressor air (A) and said compressed gaseous fuel (G) through at least one heat exchanger 905, 915.

13. A method of operating an aircraft engine fuel system 900 according to claim 12 wherein said step of routing said compressor air (A) and said compressed gaseous fuel (G) through at least one heat exchanger 905, 915 occurs before said compressor air (A) is routed through said turbocharger 910.

14. A method of operating an aircraft engine fuel system 900 according to claim 12 wherein said step of routing said compressor air (A) and said compressed gaseous fuel (G) through at least one heat exchanger 905, 915 occurs after said compressor air (A) is routed through said turbocharger 910.

15. A method of operating an aircraft engine fuel system 900 according to claim 12 wherein heat is transferred from said compressor air (A) to said compressed gaseous fuel (G) in said at least one heat exchanger 905, 915.

16. A method of operating an aircraft engine fuel system 900 according to claim 11 further comprising the step of operating a valve 925 to selectively bypass compressor air (A) around said turbocharger 910.

17. A method of operating an aircraft engine fuel system 900 according to claim 12 wherein said routing of said compressor air (A) and said compressed gaseous fuel

(G) is through at least two heat exchangers 905, 915 with at least one heat exchanger 905 being upstream of said turbocharger 910 and at least one heat exchanger 915 being downstream of said turbocharger 910.

18. A method of operating an aircraft engine fuel system 900 according to claim 11 wherein said turbocharger 910 is a gas-to-gas turbocharger 910.

19. A method of operating an aircraft engine fuel system 900 according to claim 11 further comprising the step of routing said compressor air (A) to other aircraft systems.

20. A method of operating an aircraft engine fuel system 900 comprising the steps of:

operating a gas turbine engine 101;

extracting compressor air (A) from said gas turbine engine 101;

routing said compressor air (A) through at least one heat exchanger 915;

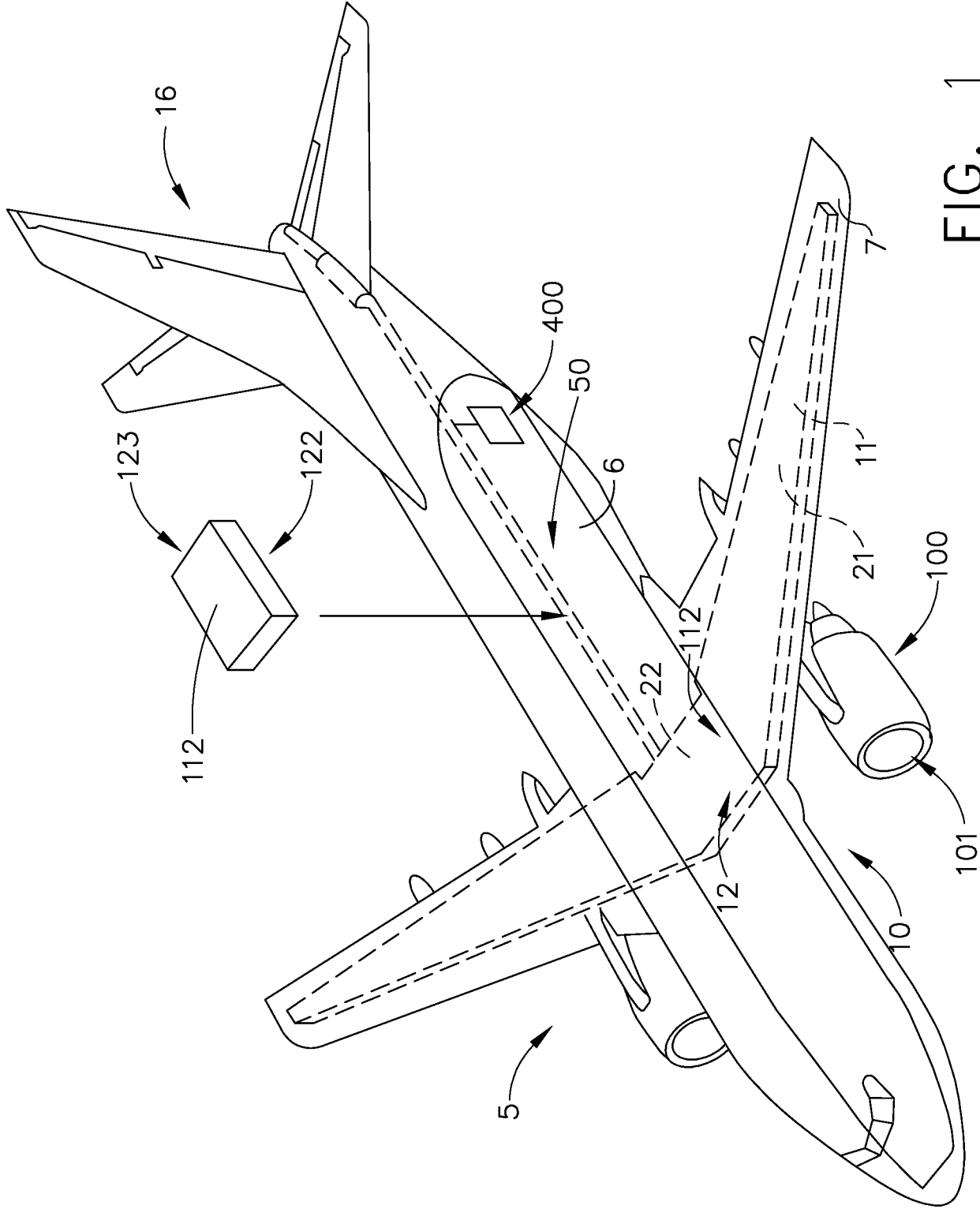
routing said compressor air (A) to a turbocharger 910;

operating said turbocharger 910 to pump a compressed gaseous fuel (G) to said gas turbine engine 101; and

routing said compressed gaseous fuel (G) through said at least one heat exchanger 915 before delivery to said gas turbine engine 101;

whereby heat is transferred from said compressor air (A) to said compressed gaseous fuel (G) in said at least one heat exchanger 915.

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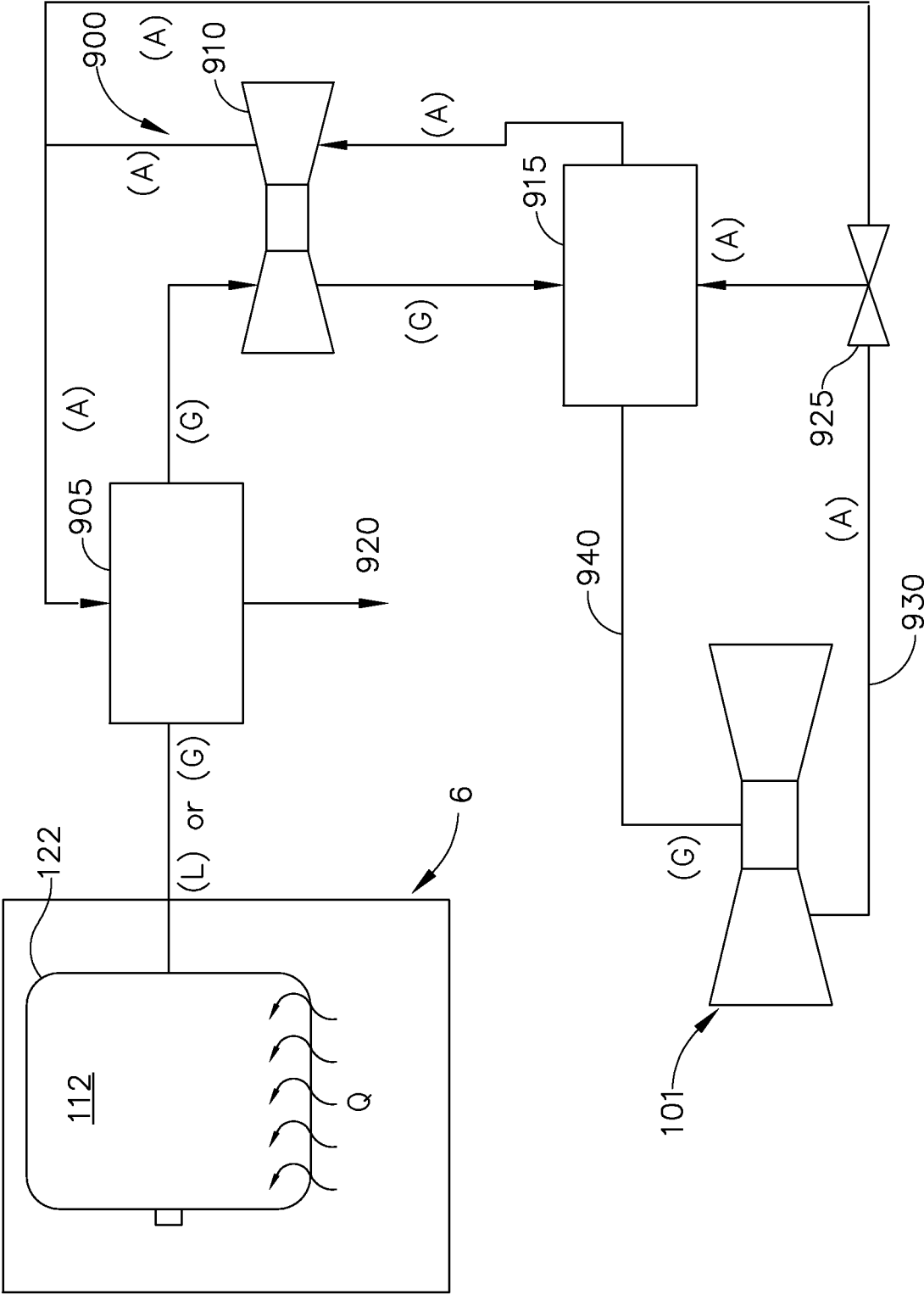


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/067461

A. CLASSIFICATION OF SUBJECT MATTER

INV. F02C3/22 F02C7/224 F02C9/40 B64D37/30
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02C B64D F02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 2 409 001 A (ROLLS ROYCE PLC [GB]) 15 June 2005 (2005-06-15) figure 1 page 1, paragraph 1 page 4 - page 6	1-20
Y	----- EP 1 975 388 A1 (SIEMENS AG [DE]) 1 October 2008 (2008-10-01) figures 2,4 paragraphs [0037] - [0040], [0042], [0045]	1-20
A	----- US 5 329 757 A (FAULKNER HENRY B [US] ET AL) 19 July 1994 (1994-07-19) figure 1 column 1, line 10 - column 1, line 15 column 1, line 54 - column 1, line 57 column 3, line 59 - column 4, line 9 ----- -/-	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"E" earlier document but published on or after the international filing date

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/067461

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FULTON ET AL: "Cryogenic-Fueled Turbofans: Kuznetsov Bureau's pioneer work on LH2 and LNG dual-fuel engines", AIRCRAFT ENGINEERING AND AEROSPACE TECHNOLOGY, EMERALD GROUP PUBLISHING, BRADFORD, GB, vol. 19931100, no. 65, 1 November 1993 (1993-11-01), pages 8-11, XP008147106, ISSN: 1748-8842, DOI: 10.1108/EB037431 the whole document -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/067461

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