(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 July 2016 (28.07.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/118244 A1

(51) International Patent Classification:
H01S 3/04 (2006.01)

(21) International Application Number:
PCT/US2015/064969

(22) International Filing Date:
10 December 2015 (10.12.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/106,003 21 January 2015 (21.01.2015) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

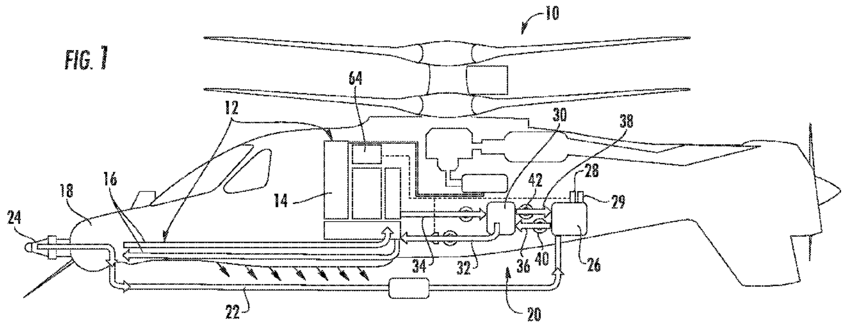
— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: COOLING SYSTEM FOR ROTORCRAFT LASER SYSTEM

FIG. 1



(57) Abstract: A cooling system for a rotorcraft laser system is provided. The cooling system includes at least one laser carrying component operatively coupling a laser turret and a laser generating assembly. The cooling system also includes at least one fuel line fluidly coupled to a fuel tank containing a fuel. The cooling system further includes a heat exchanger containing a portion of the laser carrying component and the fuel line to transfer heat therebetween to cool the laser carrying component.

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COOLING SYSTEM FOR ROTORCRAFT LASER SYSTEM

BACKGROUND OF THE INVENTION

[0001] The embodiments herein generally relate to rotorcraft laser systems and, more particularly, to a cooling system for such laser systems, as well as a method of cooling rotorcraft laser systems.

[0002] Fiber lasers are increasingly becoming potent tactical weapons on vehicles. In one example, fiber lasers are employed on an aircraft, such as a helicopter. Use of turreted guns on rotorcraft can be limited by the number of rounds carried on the aircraft, which drives the desire for laser weapons. While implementation of fiber lasers improves on the issue associated with the ammunition storage aspect, challenges with fiber laser systems are present. In particular, some fiber laser systems waste significant energy in the form of heat. This wasted energy can be up to or even above 70% of the total energy. Therefore, waste heat dissipation of a laser system onboard a tactical rotorcraft poses significant challenges and limits the efficient use of such systems on rotorcraft.

BRIEF DESCRIPTION OF THE INVENTION

[0003] According to one embodiment, a cooling system for a rotorcraft laser system is provided. The cooling system includes at least one laser carrying component operatively coupling a laser turret and a laser generating assembly. The cooling system also includes at least one fuel line fluidly coupled to a fuel tank containing a fuel. The cooling system further includes a heat exchanger containing a portion of the laser carrying component and the fuel line to transfer heat therebetween to cool the laser carrying component.

[0004] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the at least one fuel line extends between the fuel tank and a refueling probe.

[0005] In addition to one or more of the features described above, or as an alternative, further embodiments may include a fuel temperature gage operatively coupled to the fuel tank to determine a temperature of the fuel stored therein.

[0006] In addition to one or more of the features described above, or as an alternative, further embodiments may include a coolant tank containing a coolant for cooling the laser generating assembly.

[0007] In addition to one or more of the features described above, or as an alternative, further embodiments may include a fuel supply line configured to route the fuel from the fuel tank to the coolant tank for cooling of the coolant stored therein and a fuel return line configured to route the fuel back to the fuel tank after cooling of the coolant.

[0008] In addition to one or more of the features described above, or as an alternative, further embodiments may include a fuel supply line check valve disposed in the fuel supply line to regulate a flow rate of the fuel and a fuel return line check valve disposed in the fuel return line to regulate a flow rate of the fuel.

[0009] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the laser carrying component comprises a fiber cable.

[0010] In addition to one or more of the features described above, or as an alternative, further embodiments may include a water tank, a water supply line configured to route water from the water tank to the laser generating assembly, and a water return line configured to route water back to the water tank after cooling the laser generating assembly.

[0011] In addition to one or more of the features described above, or as an alternative, further embodiments may include a water temperature gage operatively coupled to the water tank to determine a temperature of the water stored therein and a water volume gage operatively coupled to the water tank to determine a volume of the water.

[0012] In addition to one or more of the features described above, or as an alternative, further embodiments may include an exhaust line fluidly coupled to the water tank and configured to expel steam from the water tank and to an engine exhaust.

[0013] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the fuel is the primary heat sink for the laser generating assembly, the water being the secondary heat sink for the laser generating assembly.

[0014] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the water is the primary heat sink for the laser generating assembly, the fuel being the secondary heat sink for the laser generating assembly.

[0015] According to another embodiment, a cooling system for a rotorcraft laser system is provided. The cooling system includes a laser generating assembly. Also included is a liquid tank. Further included is a liquid supply line configured to route liquid from the liquid tank to the laser generating assembly. Yet further included is a liquid return line configured to route liquid back to the liquid tank after cooling the laser generating assembly.

[0016] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the liquid tank is a water tank, the liquid supply line is a water supply line configured to route water from the water tank to the laser generating assembly, and the liquid return line is a water return line configured to route water back to the water tank after cooling the laser generating assembly.

[0017] In addition to one or more of the features described above, or as an alternative, further embodiments may include an exhaust line fluidly coupled to the water tank and configured to expel steam from the water tank and to an engine exhaust.

[0018] According to yet another embodiment, a method of cooling a rotorcraft laser system is provided. The method includes generating a laser with a laser generating assembly. The method also includes routing a laser through a laser carrying component from the laser generating assembly to a laser turret. The method further includes routing water from a water tank to the laser generating assembly for cooling of the laser generating assembly.

[0019] In addition to one or more of the features described above, or as an alternative, further embodiments may include refueling a fuel tank with fuel routed from a refueling probe along at least one fuel line to the fuel tank. Also included is transferring heat from the laser carrying component to the fuel in the fuel line.

[0020] In addition to one or more of the features described above, or as an alternative, further embodiments may include routing fuel from the fuel tank to the laser generating assembly for cooling of the laser generating assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0022] FIG. 1 is a schematic view of a rotary wing aircraft with a laser system according to a first embodiment;

[0023] FIG. 2 is a schematic view of a rotary wing aircraft with a laser system according to a second embodiment; and

[0024] FIG. 3 is a schematic view of a rotary wing aircraft with a laser system according to a third embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Referring to FIG. 1, illustrated is a rotary wing aircraft 10 having a laser system 12. It is to be understood that the term “helicopter” is a sub-class of the term “rotorcraft,” but the terms may be used interchangeably herein. Although a particular helicopter configuration is illustrated and described in the disclosed embodiment, other vehicles with integrated laser systems may also benefit from the embodiments described herein. The laser system 12 facilitates generation of a laser onboard the helicopter 10 and guided control of the laser away from the helicopter 10. The laser system 12 is beneficial in numerous applications, such as tactical weaponry, for example.

[0026] The laser system 12 includes a laser generating assembly 14 located onboard the helicopter 10. The location of the laser generating assembly 14 may vary depending upon the particular embodiment of the helicopter 10. The laser generating assembly 14 includes a plurality of components and subassemblies that in conjunction generate a laser. Such components relate to power management, weapons targeting, aircraft integration, fiber laser module(s) and thermal cooling, for example. The preceding list is merely illustrative and not intended to be limiting. Irrespective of the precise components of the laser generating assembly 14, the generated laser is routed along a laser carrying component 16, such as fiber cables piping, to a laser turret 18 for transmission of the laser away from the helicopter 10 to a target. The laser carrying component 16 is operatively coupled to the laser turret 18 and the laser generating assembly 14. It is to be appreciated that a plurality of laser carrying components 16 may be included to provide multiple laser paths, which may lead to a single laser turret or a plurality of laser turrets. As shown in the illustrated embodiment, one carrying component routes the generated laser to the laser turret 18 and one serves as a return line back to the laser generating assembly 14.

[0027] The laser system 12 requires cooling during operation to avoid wasted energy in the form of heat dissipation. A cooling system 20 is provided onboard the helicopter 10 to address this issue. As one will appreciate from the description herein, the cooling system 20 advantageously includes fluids that are needed for other onboard operations of the helicopter, such that reliance on coolants that are specifically and solely employed for cooling of the laser system 12 is reduced or avoided.

[0028] A fuel line 22 extends between, and is fluidly coupled between, a refueling probe 24 and a fuel tank 26. The fuel line 22 comprises refueling plumbing used for refueling operations that may be performed during flight or on the ground. It is to be appreciated that multiple refueling probes, lines and/or fuel tanks may be included. A portion of the fuel line 22 is positioned to be in proximity to a portion of the laser carrying component(s) 16. The portions of the fuel line 22 and the laser carrying component(s) 16 disposed in proximity to each other exchange heat with one another. In one embodiment, the fuel line 22 and the laser carrying components 16 are enclosed within a structure (not shown).

Cooling of the laser carrying components 16 is achieved by formation of the heat exchanger with the fuel line 22. The fuel routed within the fuel line 22 is capable of absorbing a significant amount of heat, while remaining in a condition suitable for its intended use as storage in the fuel tank 26 or for combustion. Instrumentation is provided to monitor one or more characteristics of the fuel. For example, a fuel temperature gage 28 is operatively coupled to the fuel tank 26 to determine a temperature of the fuel stored therein. Additionally, a fuel level gage 29 may also be included to determine the fuel level within the fuel tank 26. Other sensors or gages may be included to determine other fuel conditions.

[0029] In addition to cooling of the laser carrying component 16, cooling of the laser generating assembly 14 is desirable and provided by the cooling system 20 described herein. In the embodiment illustrated in FIG. 1, the laser generating assembly 14 is directly or indirectly cooled by the fuel. A coolant tank 30 is provided and configured to contain a coolant therein. In one embodiment, the coolant stored in the coolant tank 30 is actually the fuel and in another embodiment the coolant is a separate coolant. Irrespective of whether the coolant tank 30 stores fuel or a separate coolant, the content is fluidly coupled with the laser generating assembly 14 via a coolant supply line 32 and a coolant return line 34. The coolant from the coolant tank 30 is routed along the laser generating assembly 14 to absorb heat from the assembly to facilitate the overall cooling effort of the laser system 12.

[0030] As described above, the coolant routed along the laser generating assembly 14 may be fuel or a separate coolant. In the embodiment of a separate coolant, the coolant is cooled by the fuel to reduce the power required to maintain the coolant at a certain temperature. In such an embodiment, the fuel stored in the fuel tank 26 is routed along a fuel supply line 36 from the fuel tank 26 to a location in close proximity with the coolant tank 30 for cooling of the coolant therein. The fuel is then returned to the fuel tank 26 via a fuel return line 38. The fuel supply line 36 and the fuel return line 38 each include a valve 40, 42, respectively, to regulate a flow rate of the fuel. It is to be appreciated that all fuel lines may include such valves for flow regulation.

[0031] In an embodiment where the fuel is actually the coolant stored in the coolant tank 30, the fuel supply line 36 and the fuel return line 38 actually route the fuel into and out of the coolant tank 30 to supply and retrieve fuel.

[0032] In the above described embodiments of FIG. 1, fuel is employed as a heat sink for cooling of the laser system 12. Advantageously, the helicopter can be repeatedly refueled, thereby providing a theoretically continuous supply of a coolant that is used to cool the laser system 12.

[0033] Referring now to FIG. 2, another embodiment of the cooling system 20 is illustrated. In the illustrated embodiment, water is employed as the heat sink to facilitate cooling of the laser system 12. In particular, the cooling system 20 includes a water tank 50 configured to store water therein. It is to be appreciated that more than one water tank may be used to store water for the cooling purposes described herein. A water supply line 52 routes water from the water tank 50 to the laser generating assembly 14 for cooling of the components of the assembly. During passage of the water along the laser generating assembly 14, the water absorbs heat from the assembly to reduce the wasted energy associated with heat dissipation. Subsequent to cooling the laser generating assembly 14, the water is returned to the water tank 50 via a water return line 54.

[0034] The conditions of the water must be monitored due to the use of the water as a heat sink. Instrumentation is provided to monitor one or more characteristics of the water. For example, a water temperature gage 56 is operatively coupled to the water tank 50 to determine a temperature of the water stored therein. Additionally, a water volume gage 58 may also be included to determine the water level within the water tank 50. Other sensors or gages may be included to determine other water conditions.

[0035] As the water is heated, steam may form depending on the amount of heat absorbed. As the water transitions to steam, the steam is exhausted via an exhaust line 60 fluidly coupling the water tank 50 and an engine exhaust 62. The ability to simply exhaust steam provides an environmentally clean cooling solution and reduces or avoids the need for the use of potentially volatile chemicals.

[0036] Referring now to FIG. 3, yet another embodiment of the cooling system 20 is illustrated. The cooling system 20 is a hybrid of the embodiments described above. In particular, the fuel and the water that are stored on board in the fuel tank 26 and the water tank 50, respectively, are employed for cooling of the laser system. In other words, a combination of the water-based and fuel-based heat sinks is used to provide cooling of the laser generating assembly 14. Specifically, one subsystem provides routing of the fuel from the fuel tank 26 to the coolant tank 30 and to the laser generating assembly 14 in the manner described in detail above. It is to be understood that the fuel may be used to simply absorb heat from a separate coolant stored in the coolant tank 30 or may be directly used to cool the laser generating assembly 14, as described above. Similarly, the water cooling system described above is also employed.

[0037] In the cooling system relying on a combination of fuel and water, it is to be appreciated that the fuel may be used as the primary heat sink for the laser system 12, with the water being used as a secondary heat sink. In such an embodiment, the water is not routed for cooling purposes until a threshold operating condition associated with the fuel occurs. For example, upon detection of a certain fuel temperature or fuel level within the fuel tank 26, the cooling system 20 will transition to use of the water as the heat sink by ceasing flow of the fuel and initiating flow of the water from the water tank 50. Conversely, the water may be used as the primary heat sink for the laser system 12, with the fuel being used as a secondary heat sink. Similar to the scenario described above, the fuel is not routed for cooling purposes until a threshold operating condition associated with the water occurs. Furthermore, it is contemplated that the water and the fuel are employed as a heat sink simultaneously.

[0038] Although water and fuel are referred to in the description herein, it is to be understood that any other suitable liquid that is readily available on the rotorcraft may be employed as the heat sink for the laser system 12.

[0039] In any of the embodiments described herein, a thermal control unit 64 may be included to monitor various conditions of the overall system. The thermal control unit 64 is in operative communication with a variety of components of the laser system 12 and the cooling system 20. For example, the thermal control unit 64 is in communication with the gages 28, 29 of the fuel tank 26, the gages 56, 58 of the water tank 50, and valves in the fluid supply lines. The thermal control unit 64 is configured to receive a variety of data and determine operations to be executed in response to the received data. This may include closing and opening valves to regulate the water flow and/or fuel flow in response to detected threshold temperatures, pressures and volumes of the fluids within the tanks 26, 30 and 50.

[0040] Advantageously, using water and/or fuel as a heat sink for the laser system 12 allows for multiple uses of the fluids that are already needed onboard. Additionally, the use of fuel theoretically offers unlimited cooling due to refueling capabilities of the helicopter 10.

[0041] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

CLAIMS:

What is claimed is:

1. A cooling system for a rotorcraft laser system comprising:

at least one laser carrying component operatively coupling a laser turret and a laser generating assembly;

at least one fuel line fluidly coupled to a fuel tank containing a fuel; and

a heat exchanger containing a portion of the laser carrying component and the fuel line to transfer heat therebetween to cool the laser carrying component.

2. The cooling system of claim 1, wherein the at least one fuel line extends between the fuel tank and a refueling probe.

3. The cooling system of claim 1 or 2, further comprising a fuel temperature gage operatively coupled to the fuel tank to determine a temperature of the fuel stored therein.

4. The cooling system of any of the preceding claims, further comprising a coolant tank containing a coolant for cooling the laser generating assembly.

5. The cooling system of claim 4, further comprising:

a fuel supply line configured to route the fuel from the fuel tank to the coolant tank for cooling of the coolant stored therein; and

a fuel return line configured to route the fuel back to the fuel tank after cooling of the coolant.

6. The cooling system of claim 5, further comprising:

a fuel supply line check valve disposed in the fuel supply line to regulate a flow rate of the fuel; and

a fuel return line check valve disposed in the fuel return line to regulate a flow rate of the fuel.

7. The cooling system of any of the preceding claims, wherein the laser carrying component comprises a fiber cable.

8. The cooling system of any of the preceding claims, further comprising:

a water tank;

a water supply line configured to route water from the water tank to the laser generating assembly; and

a water return line configured to route water back to the water tank after cooling the laser generating assembly.

9. The cooling system of claim 8, further comprising:

a water temperature gage operatively coupled to the water tank to determine a temperature of the water stored therein; and

a water volume gage operatively coupled to the water tank to determine a volume of the water.

10. The cooling system of claim 8 or 9, further comprising an exhaust line fluidly coupled to the water tank and configured to expel steam from the water tank and to an engine exhaust.

11. The cooling system of any of claims 8-10, wherein the fuel is the primary heat sink for the laser generating assembly, the water being the secondary heat sink for the laser generating assembly.

12. The cooling system of any of claims 8-10, wherein the water is the primary heat sink for the laser generating assembly, the fuel being the secondary heat sink for the laser generating assembly.

13. A cooling system for a rotorcraft laser system comprising:

a laser generating assembly;

a liquid tank;

a liquid supply line configured to route liquid from the liquid tank to the laser generating assembly; and

a liquid return line configured to route liquid back to the liquid tank after cooling the laser generating assembly.

14. The cooling system of claim 13, wherein the liquid tank is a water tank, the liquid supply line is a water supply line configured to route water from the water tank to the laser generating assembly, and the liquid return line is a water return line configured to route water back to the water tank after cooling the laser generating assembly.

15. The cooling system of claim 14, further comprising an exhaust line fluidly coupled to the water tank and configured to expel steam from the water tank and to an engine exhaust.

16. A method of cooling a rotorcraft laser system comprising:

generating a laser with a laser generating assembly;

routing a laser through a laser carrying component from the laser generating assembly to a laser turret; and

routing water from a water tank to the laser generating assembly for cooling of the laser generating assembly.

17. The method of claim 16, further comprising:

refueling a fuel tank with fuel routed from a refueling probe along at least one fuel line to the fuel tank; and

transferring heat from the laser carrying component to the fuel in the fuel line.

18. The method of claim 17, further comprising routing fuel from the fuel tank to the laser generating assembly for cooling of the laser generating assembly.

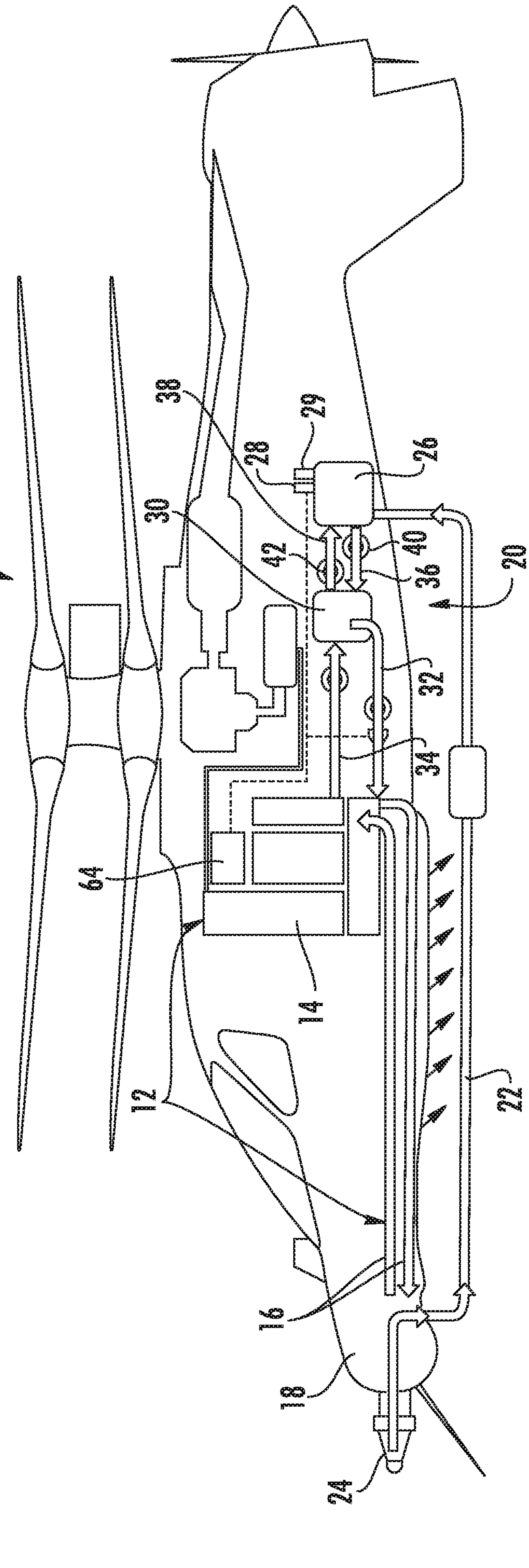

FIG. 1

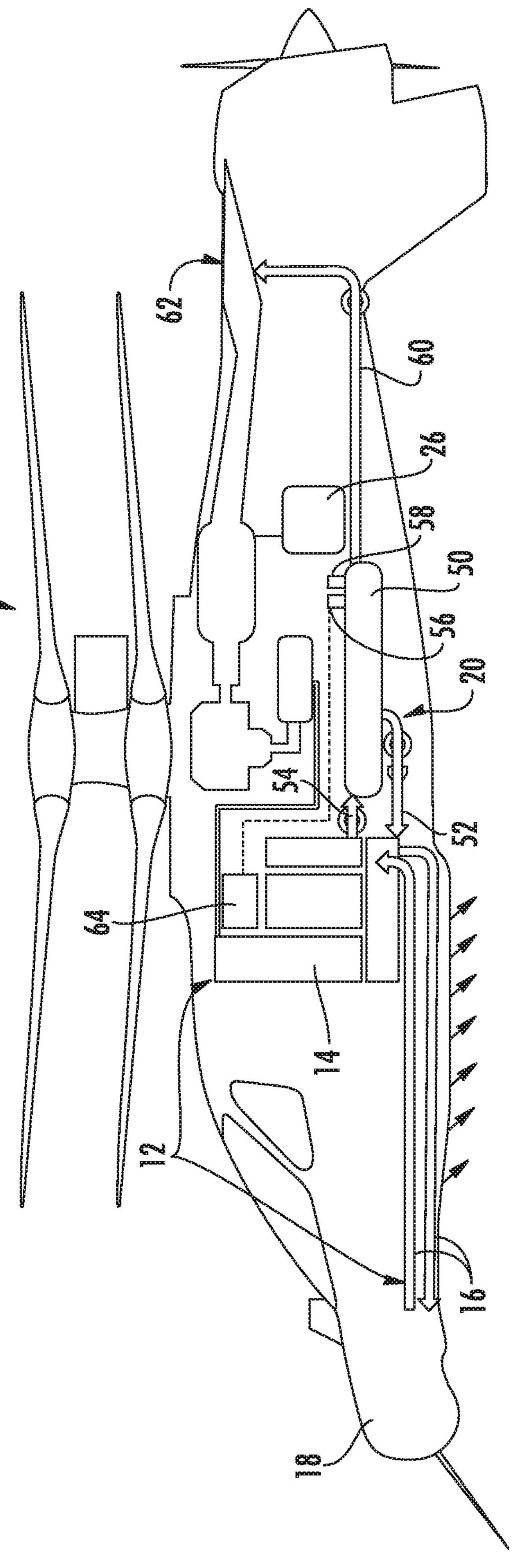

FIG. 2

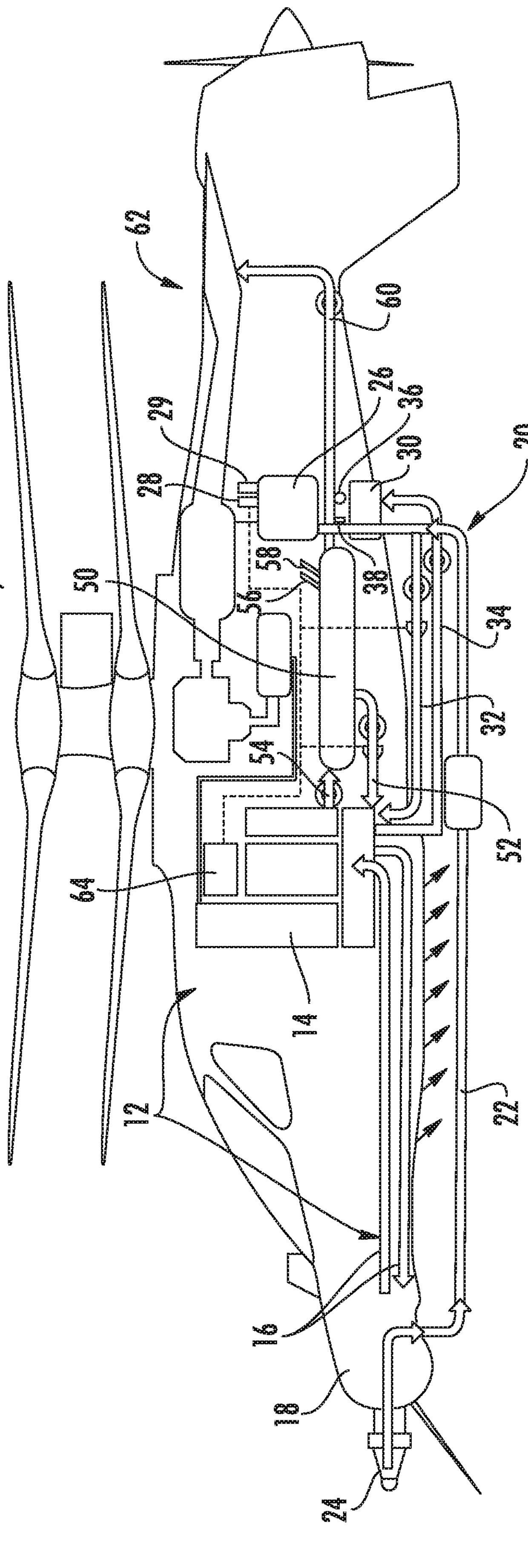

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 15/64969

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01S 3/04 (2016.01)
CPC - H01S 3/04
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)
IPC(8): H01S 3/04 (2016.01)
CPC: H01S 3/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8): H01S 3/041, H01S 3/042, H01S 3/094, H01S 3/0941, H01S 3/0943, H02K 9/00, F41H 13/00 (2016.01) CPC: H01S 3/041, H01S 3/042, H01S 3/094, H01S 3/0941, H01S 3/0943, H02K 9/00, F41H 13/00, F41H

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase; ProQuest Dialog; Google Patents; Google Web; Google Scholar Search Terms: laser, coherent light, fuel, fuel*, cool*, turret*, conduit, fiber*, fibre*, laser*, ball*, dome*, fiber*, fibre*, tub*, conduit*, waveguide*, heat*, thermal*, heat exchanger*, oxidizer, helicopter*, rotary wing, rotorcraft, VTOL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y --- A	US 2007/0206177 A1 (Anschel et al.) 06 September 2007 (06.09.2007). Fig. 8A; Title; Abstract; para [0002], [0037], [0072], [0077]-[0078], [0083].	1 ---- 2-3
Y --- A	US 5,974,072 A (Hartlove et al.) 26 October 1999 (26.10.1999). Col 7, ln 38-43.	1 ---- 2-3
A	US 2012/0248242 A1 (Gagne et al.) 04 October 2012 (04.10.2012). Fig. 3; para [0014].	1-3
A	US6,575,402 B1 (Scott) 10 June 2003 (10.06.2003). Fig. 1B; col 2, ln 66-col 3, ln 7).	1-3
A	US 6,690,696 B2 (Byren et al.) 10 February 2004 (10.02.2004). Fig. 1; col 3, ln 25-36.	1-3

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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

Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2016	05 MAY 2016

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 15/64969

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-12
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-3, directed to a cooling system for a rotorcraft laser system, including at least one laser carrying component coupling a laser turret and a laser generating assembly.

Group II: Claims 13-15, directed to a cooling system for a rotorcraft laser system, including a liquid tank, and supply and return lines.

Group III: Claims 16-18, directed to a method of cooling a rotorcraft laser system, including the step of generating a laser with a laser generating assembly.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-3

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invention.

☐ No protest accompanied the payment of additional search fees.

-*-Continuation of Box III-Observations where unity of invention is lacking-*-

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Group I requires the special technical feature of a heat exchanger, not required by Groups II or III.

Group II requires the special technical features of liquid supply and return lines, not required by Groups I or III.

Group III requires the special technical features of the steps of generating a laser, and routing water from a water tank to a laser generating assembly, not required by Groups I or II.

The only shared technical features that would otherwise unify Groups I-III are a cooling system for a rotorcraft laser system, including a laser carrying component or laser generating assembly, and a liquid coolant. However, these common technical features do not represent a contribution to the prior art because they are anticipated by US 2012/0160958 A1 to Stewart (hereinafter 'Stewart').

Stewart teaches a cooling system (56 in Fig. 3; para [0019]-[0020]) for a rotorcraft (50 Fig. 3; para [0019]-[0020]), wherein the term "aircraft" (para [0007]) is defined for all embodiments to include rotorcraft (para [0012]), laser system (payload 54 is described as potentially being a laser system, which inherently incorporates at least one of a laser carrying component and/or a laser generating assembly; para [0018]), and a liquid coolant (working fluid 68 is, during at least a portion of its working cycle, a liquid; para [0021]).

As the common features of Groups I-III were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

The only technical feature(s) shared by Groups I-II that would otherwise unify the groups is at least one fluid line for the liquid coolant for a rotorcraft laser system. However, these technical features do not represent a contribution to the prior art because they are obvious over Stewart in view of US 5,692,558 A to Hamilton et al. (hereinafter 'Hamilton').

Stewart teaches a cooling system (56 in Fig. 3; para [0019]-[0020]) for a rotorcraft (50 Fig. 3; para [0019]-[0020]), wherein the term "aircraft" (para [0007]) is defined for all embodiments to include rotorcraft (para [0012]), laser system (payload 54 is described as potentially being a laser system, which inherently incorporates at least one of a laser carrying component and/or a laser generating assembly; para [0018]), and a liquid coolant (working fluid 68 is, during at least a portion of its working cycle, a liquid; para [0021]). Hamilton teaches the use of fuel to cool aircraft electronics (16 in Fig. 1; col 2, ln 19-21), wherein the fuel is transported from a fuel tank (14 in Fig. 1; col 2, ln 19-21) to the electronics via at least one fluid line (not numbered in Fig. 1). It would have been obvious to one having ordinary skill in the art that the cooling system taught by Stewart could have been modified to use fuel delivered to the laser system via at least one fluid line, as taught by Hamilton.

As the common features of Groups I-II were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

The only technical feature(s) shared by Groups I and III that could otherwise have unified the groups is a laser turret associated with the cooling system. However, this technical feature does not represent a contribution to the prior art because it is obvious over Stewart in view of US 8,654,314 B2 to King et al. (hereinafter 'King').

Stewart teaches a cooling system (56 in Fig. 3; para [0019]-[0020]) for a rotorcraft [(50 Fig. 3; para [0019]-[0020]), wherein the term "aircraft" (para [0007]) is defined for all embodiments to include rotorcraft (para [0012])] laser system (payload 54 is described as potentially being a laser system, which inherently incorporates at least one of a laser carrying component and/or a laser generating assembly; para [0018]), and a liquid coolant (working fluid 68 is, during at least a portion of its working cycle, a liquid; para [0021]). King teaches a laser beam delivery system (col 5, ln 16-30) for rotorcraft (col 5, ln 16-30) that includes a laser turret (112 in Fig. 1; col 5, ln 66 -col 6, ln 5). It would have been obvious to one having ordinary skill in the art that the cooling system taught by Stewart could have been applied to a laser system that includes a turret, as taught by King.

As the common features of Groups I and III were known In the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Therefore, Groups I-III lack unity under PCT Rule 13 because they do not share the same or corresponding special technical feature(s).

Note: This report has not been established with respect to claims 4-12 because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).