US 20170138461A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2017/0138461 A1**

Chory et al. (43) **Pub. Date: May 18, 2017**

(54) **LUBRICATION SYSTEMS**

(71) Applicant: **Sikorsky Aircraft Corporation**, Stratford, CT (US)

(72) Inventors: **Anthony G. Chory**, Trumbull, CT (US); **Erin Carter**, Wallingford, CT (US)

(21) Appl. No.: **15/223,731**

(22) Filed: **Jul. 29, 2016**

Related U.S. Application Data

(60) Provisional application No. 62/204,128, filed on Aug. 12, 2015.

Publication Classification

(51) **Int. Cl.**

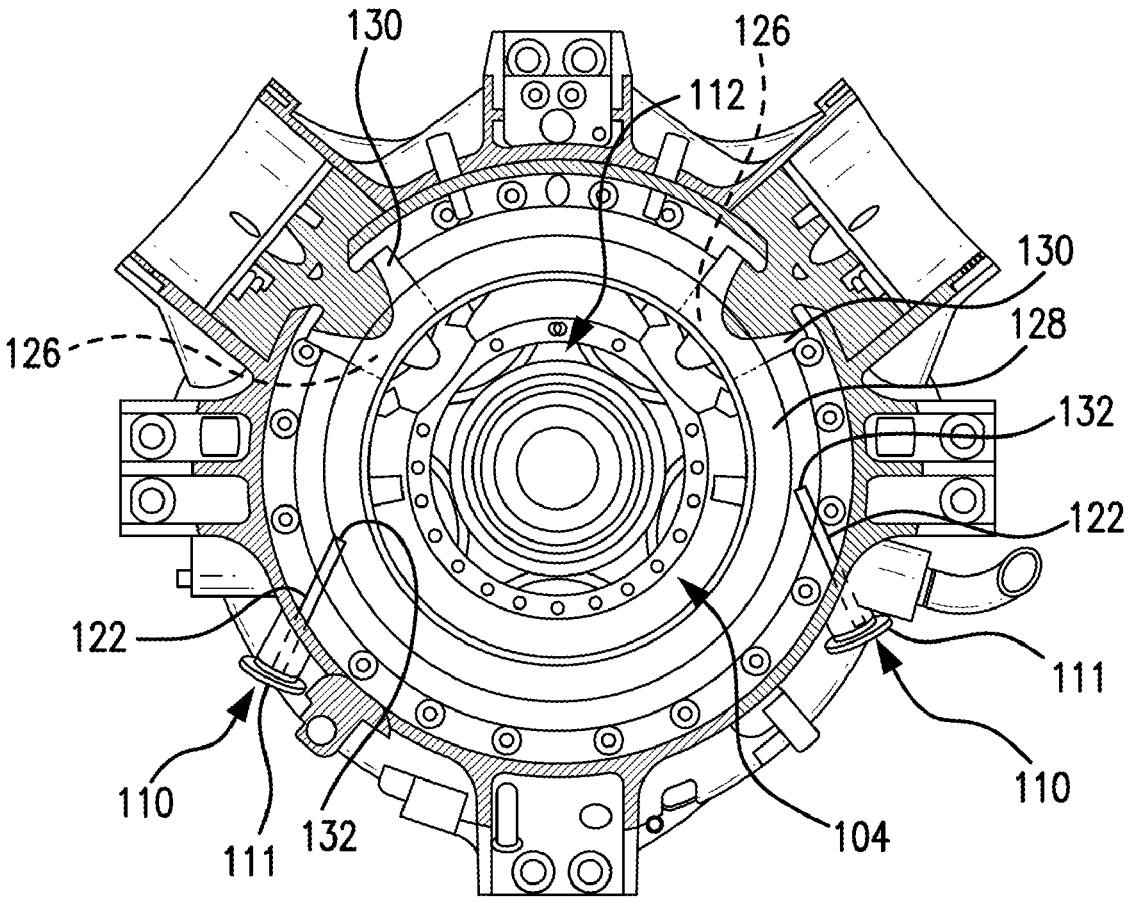
F16H 57/04	(2006.01)
B64C 27/14	(2006.01)
F16H 57/027	(2006.01)

(52) **U.S. Cl.**

CPC ***F16H 57/0435*** (2013.01); ***F16H 57/0439*** (2013.01); ***F16H 57/0438*** (2013.01); ***F16H 57/027*** (2013.01); ***F16H 57/045*** (2013.01); ***F16H 57/0495*** (2013.01); ***F16H 57/0458*** (2013.01); ***B64C 27/14*** (2013.01)

(57) **ABSTRACT**

A gearbox assembly with emergency lubrication system includes a housing with an interior including a lubricant sump. The housing includes a breather port and a visual inspection port. The breather port is sized for at least one of relieving internal pressure or admitting air. The visual inspection port is located to allow visual inspection of a component in an interior of the housing. A transmission is disposed within the interior of the housing in fluid communication with the lubricant sump. An emergency lubricant reservoir is in fluid communication with the transmission through the breather port and/or the visual inspection port. A method of retrofitting a gear box assembly with an emergency lubrication system includes removing plugs from visual inspection ports of a gearbox housing, removing a breather from a breather port of the gearbox housing, and installing jet plugs into the respective visual inspection ports and breather port.



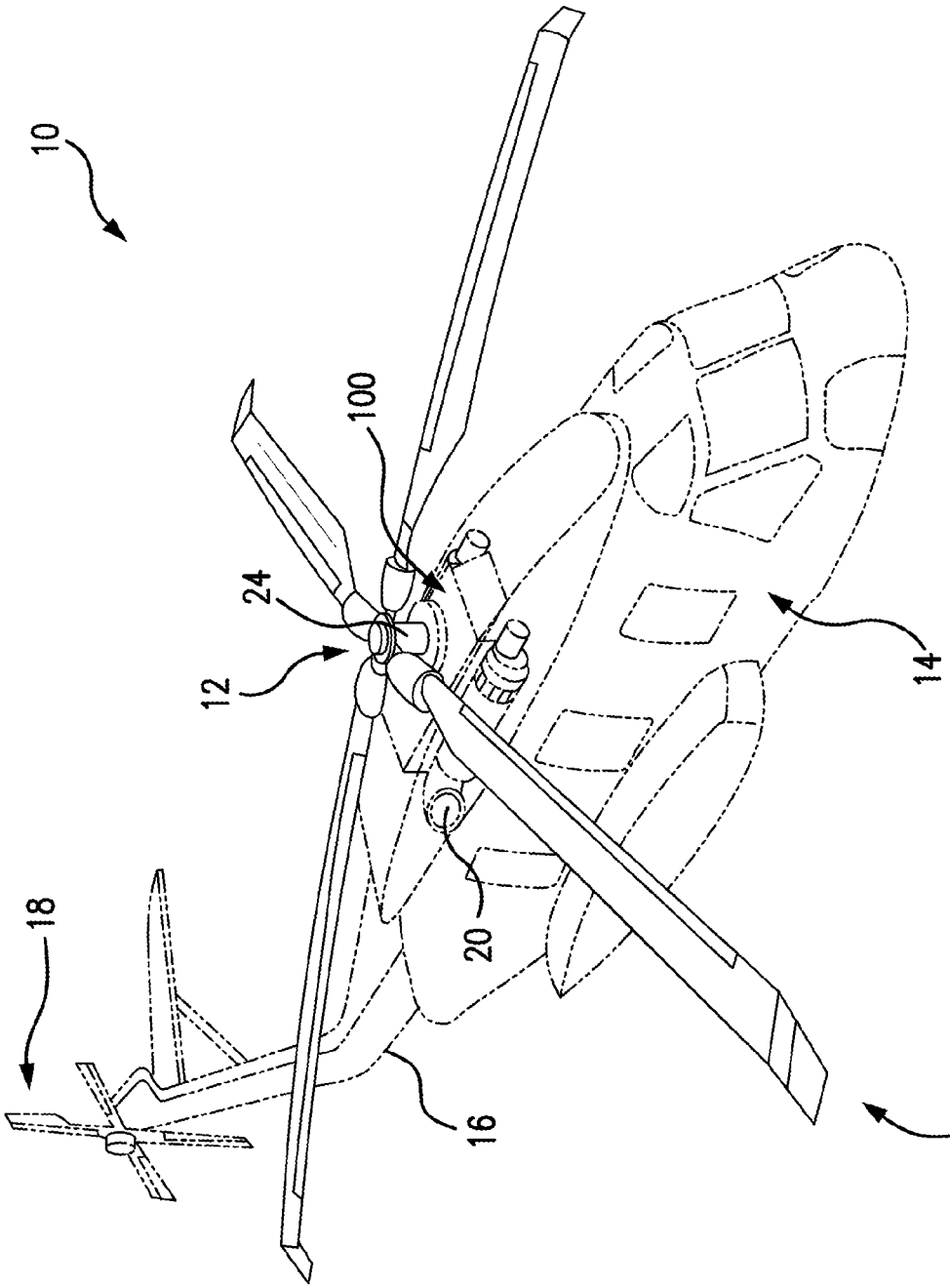


FIG. 1

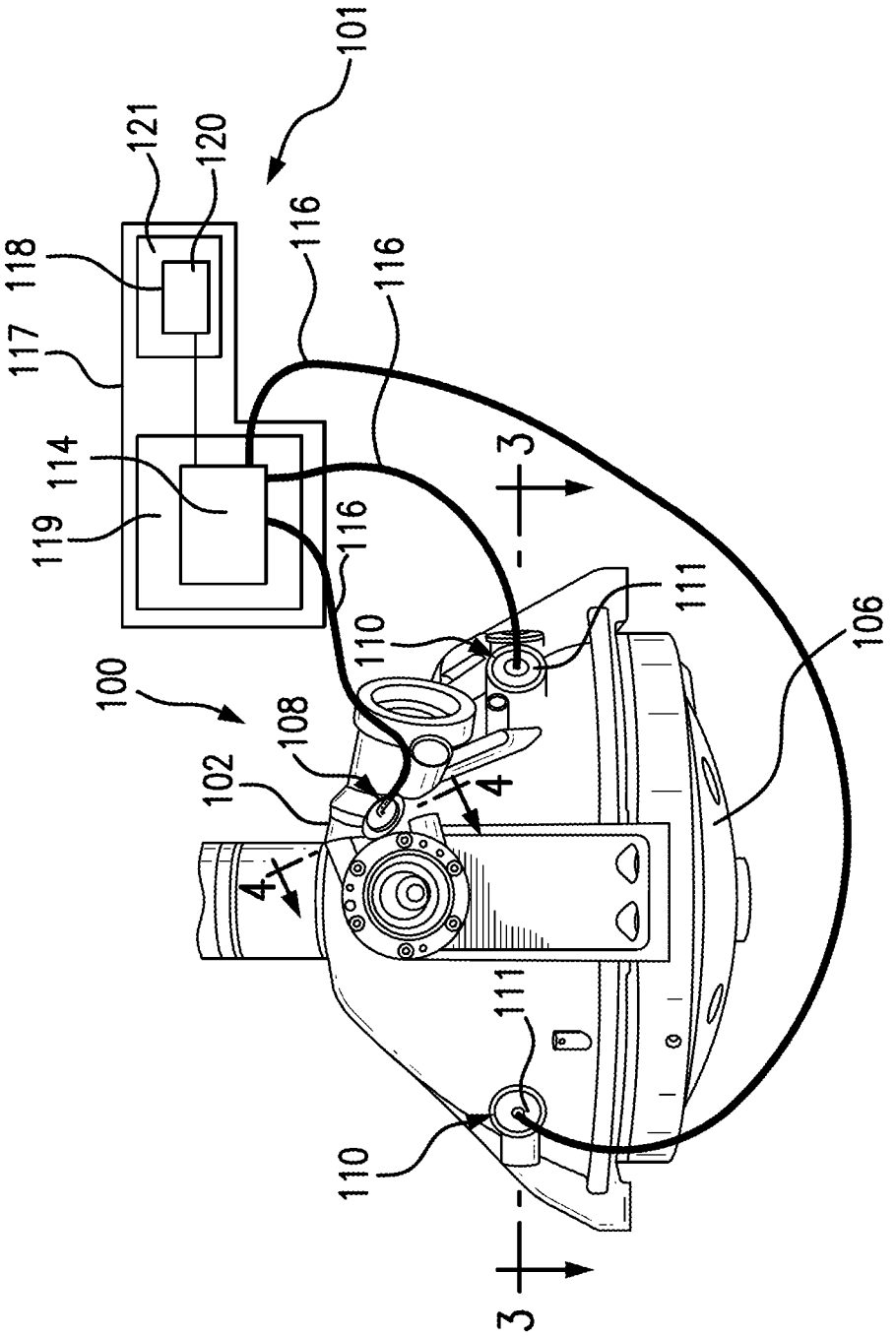

101
121
120
118
116
116
117
114
119
116
3
3
111
110
106
100
108
102
4
4
111
110

FIG. 2

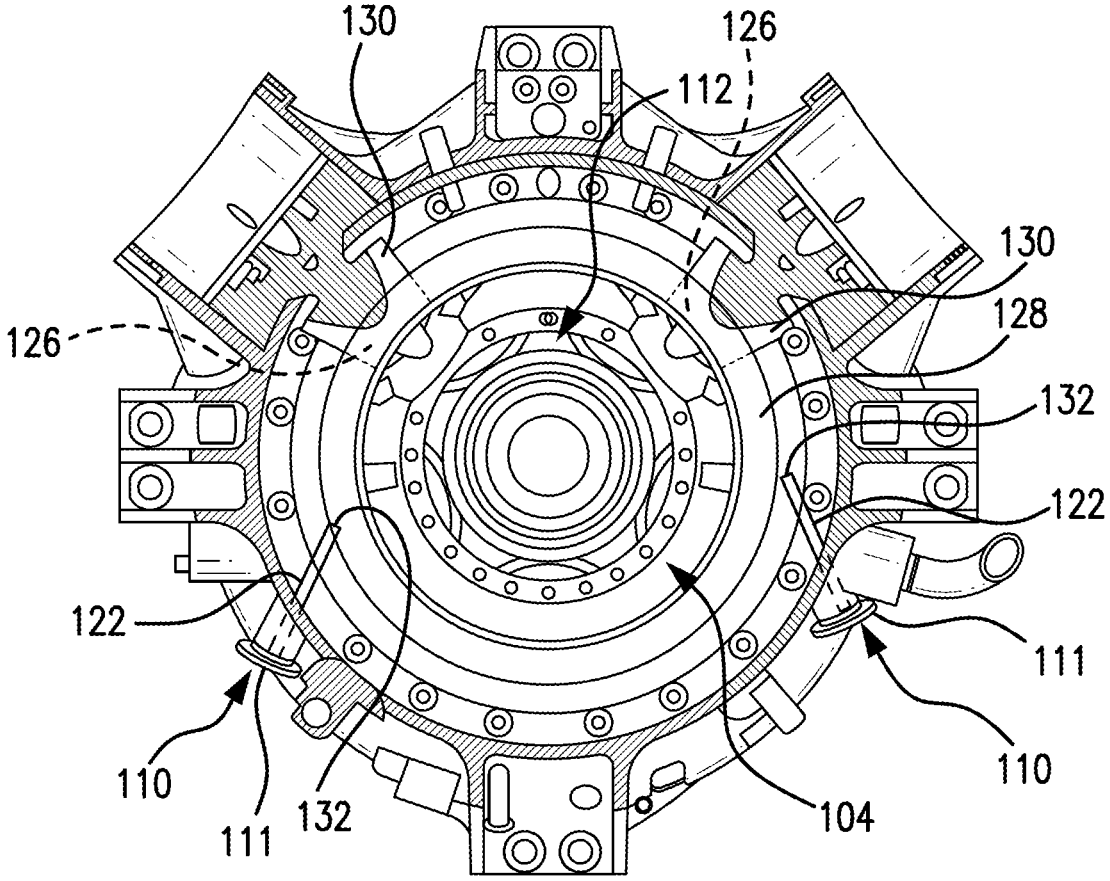

130
126
112
130
126
128
132
122
122
111
110
110
111
132
104

FIG. 3

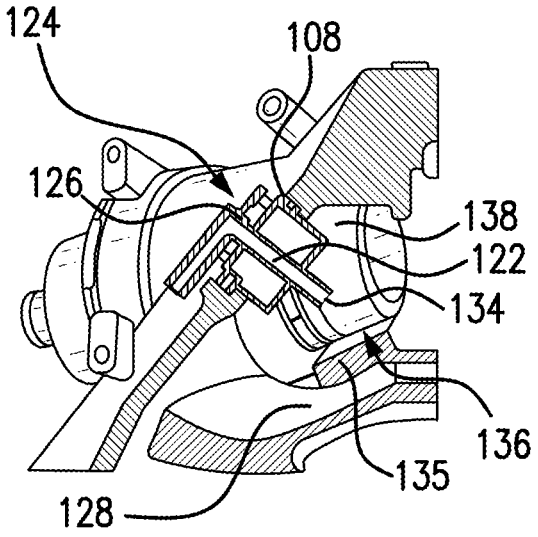

124
108
126
138
122
134
136
135
128

FIG. 4

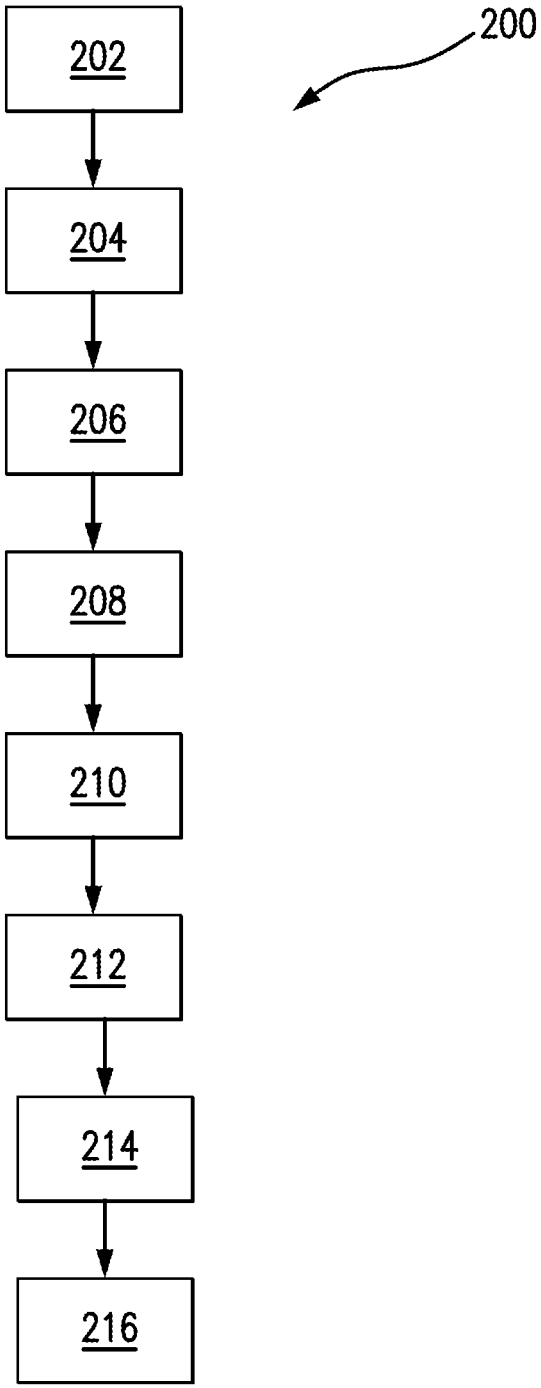


FIG. 5

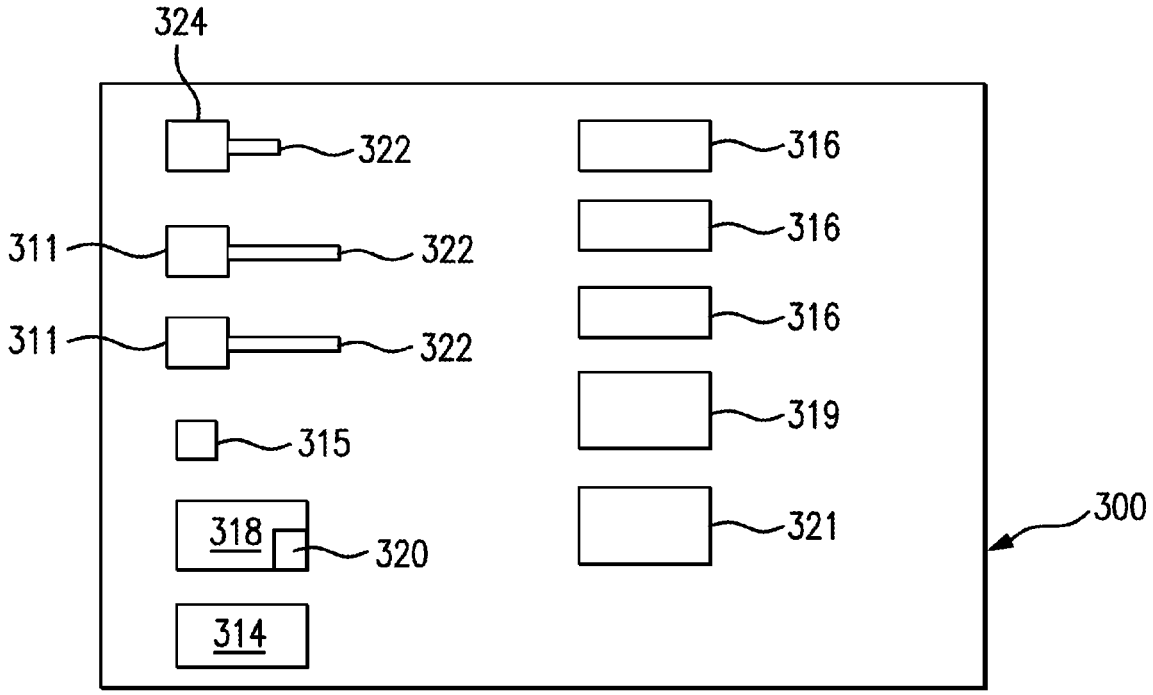


FIG. 6

LUBRICATION SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. §119(e) to U.S. Provisional Application No. 62/204,128, filed Aug. 12, 2015, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present disclosure relates to transmissions, and more particularly to lubrication systems for mechanical power transmissions.

[0004] 2. Description of Related Art

[0005] Rotorcraft transmissions commonly include transmission elements like gears and bearings that transmit rotational power through the transmission. Because these elements can be subject to heating and wear from friction while transmitting rotational power, rotorcraft transmissions typically include lubrication systems for supplying lubricant to the transmission components. Such lubrication systems generally irrigate the transmission components with a continuous flow of lubricant. This allows the transmission to transmit mechanical power while limiting heat and wear from friction between transmission components.

[0006] In some rotorcraft transmissions, operation under reduced lubricant flow conditions can accelerate transmission component wear. Aircraft certification bodies like the Federal Aviation Administration (FAA) therefore generally require that rotorcraft transmissions be able to operate for a minimum period of time with reduced or no lubricant flow—typically for at least thirty (30) minutes—under oil-out conditions. Transmissions may employ various elements to satisfy these requirements, such as additive injection, lubricant misting, glycol-based cooling, or supplemental lubrication circuits.

[0007] Such conventional lubrication methods and lubrication systems have generally been considered satisfactory for their intended purpose. However, there is still a need in the art for improved lubrication methods and lubrication systems. The present disclosure provides a solution for this need.

SUMMARY OF THE INVENTION

[0008] A gearbox assembly with emergency lubrication system includes a housing with an interior including a lubricant sump. The housing includes a breather port and a visual inspection port. The breather port is sized for at least one of relieving internal pressure or admitting air. The visual inspection port is located to allow visual inspection of a component in an interior of the housing. A transmission is disposed within the interior of the housing in fluid communication with the lubricant sump. An emergency lubricant reservoir is in fluid communication with the transmission through the breather port and/or the visual inspection port.

[0009] In certain embodiments, the gearbox assembly includes lubrication lines. It is contemplated that each lubrication line can connect the emergency lubrication reservoir to a respective one of the breather port or the visual inspection port. The gearbox assembly can include a lubricant pump operatively connected to the emergency lubricant reservoir. The breather port and the visual inspection port can include respective jet tubes to direct lubricant to a desired transmission component. The breather port can include a breather disposed therein. It is contemplated that the breather can include annular filter surrounding the jet tube.

[0010] In accordance with certain embodiments, the transmission includes a main bevel gear mesh and a tail take-off gear mesh. The housing includes a second visual inspection port having a further respective jet tube. The emergency lubricant reservoir is in fluid communication with the transmission through the second visual inspection port and the further respective jet tube. Outlets of the two jet tubes of the visual inspection ports can be oriented toward the main bevel gear mesh and an outlet of the jet tube of the breather port can be oriented toward the tail take-off gear mesh.

[0011] In another aspect, a method of retrofitting a gear box assembly with an emergency lubrication system includes removing plugs from visual inspection ports of a gearbox housing, removing a breather from a breather port of the gearbox housing, and installing jet plugs into the respective visual inspection ports and breather port. Each jet plug includes a respective jet tube. In certain embodiments, the method includes removing nuts and washers from screws of an accessory module of a gear box assembly. The method can include installing a first emergency lubrication reservoir by mating the screws on the accessory module with holes on a first reservoir mount, and/or it can include installing a second emergency lubrication reservoir by mating the screws on the accessory module with holes on a second reservoir mount. The second emergency lubrication reservoir can include a pump. It is contemplated that the method can include securing the first and second emergency lubrication reservoirs onto the accessory module, and/or can include installing lubrication lines between the jet tubes of the breather port and inspection ports to at least one of the first and second emergency lubrication reservoirs.

[0012] In accordance with certain embodiments, the method includes wiring an AC power source to the pump. It is contemplated that the method can include installing a switch operatively connected to the pump, and wiring an AC power source to the switch, and/or the method can include securing the lubrication lines to the gearbox housing. The method can also include orienting the jet tubes to point at desired transmission components.

[0013] In another aspect, an emergency lubrication system for use with a gearbox assembly described above includes a plug having a jet tube extending therethrough. The plug is sized to seal either the breather or the visual inspection port. The emergency lubrication system includes a lubrication line connected to the jet tube, a switch and a pump. An emergency lubrication reservoir is in fluid communication with the jet tube through the lubrication line such that, when the pump is activated, lubrication flows from the emergency lubrication reservoir through the lubrication line and the jet tube. The system can include a reservoir mount connected to the emergency lubrication reservoir. The reservoir mount operatively connects the emergency lubrication reservoir an accessory module of the gearbox assembly.

[0014] 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

[0015] 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, embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

[0016] FIG. **1** is a perspective view of an exemplary embodiment of a rotorcraft constructed in accordance with the present disclosure, schematically showing a gearbox assembly;

[0017] FIG. **2** is a side elevation view of the gearbox assembly of FIG. **1**, schematically showing the breather port and the visual inspection ports;

[0018] FIG. **3** is a plan view of the gearbox assembly of FIG. **1**, showing an exemplary embodiment of jet tubes directed toward the main bevel gear mesh;

[0019] FIG. **4** is a cross-sectional side elevation view of a portion of the gearbox assembly of FIG. **1**, showing an exemplary embodiment of the jet tube of the breather directed toward the tail take-off gear mesh;

[0020] FIG. **5** is diagram of an embodiment of a method of retrofitting a gearbox assembly with an emergency lubrication system in accordance with an exemplary embodiment of the present disclosure; and

[0021] FIG. **6** is a schematic depiction of an embodiment of a field retrofit kit constructed in accordance with an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] 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 a gearbox assembly in accordance with the disclosure is shown in FIG. **1** and is designated generally by reference character **100**. Other embodiments of gearbox assemblies, emergency lubrication systems, and methods of retrofitting gearbox assemblies in accordance with the disclosure, or aspects thereof, are provided in FIGS. **2-6**, as will be described. The systems and methods described herein can be used in vehicular applications, such as in aircraft.

[0023] Referring now to FIG. **1**, an exemplary rotorcraft **10** is shown. Rotorcraft **10** includes a main rotor system **12** and an airframe **14**. Airframe **14** includes a longitudinally extending tail **16** with a tail rotor system **18**, at least one engine **20**, and a gearbox assembly **100**. Engines **20** are operatively connected to main rotor system **12** and tail rotor system **18** through gearbox assembly **100**, and are configured to supply rotational energy to both main rotor system **12** through a main rotor shaft **24** and tail rotor system **18** through gearbox assembly **100**. Although a particular rotorcraft configuration is illustrated and described in the disclosed embodiment, other configurations and/or machines, such as ground vehicles, jet aircraft, turbofan engines, high speed compound rotary wing aircraft with supplemental translational thrust systems, dual contra-rotating, coaxial rotor system aircraft, turbo-props, tilt-rotors and tilt-wing aircraft, will also benefit from the present invention.

[0024] As shown in FIGS. **2** and **3**, gearbox assembly **100** includes a regular operation lubrication system (not shown) which provides lubrication to the gearbox assembly **100** during normal operation, and an emergency lubrication system **101** which provides lubrication when the regular operation lubrication system breaks down or is unable to provide the needed lubrication. Gearbox assembly **100** has a housing **102** with an interior **104**. A lubricant sump **106** is disposed within a lower region of housing **102** relative to gravity when rotorcraft **10** (shown in FIG. **1**) is in level flight. A transmission **112** is disposed within interior **104** of housing **102** in fluid communication with lubricant sump **106**. Housing **102** includes a breather port **108** and two visual inspection ports **110**. Breather port **108** is a vent in gearbox housing **102** sized to relieve internal pressure and/or admit air. Visual inspection ports **110** are openings in the gearbox housing **102**, sealed with respective plugs, described below, which can be removed to for visual inspection of the gears and other internal components. Prior to installation of the emergency lubrication system **101**, breather port **108** existed in the housing **102** to allow insertion of a breather, and the visual inspection ports **110** existed in the housing **102** and provided visual access to the transmission **112** for use during inspection.

[0025] Some gearbox assemblies can leak lubricant from cracks that develop in the gearbox housing, holes resulting from ballistic impact, or maintenance incidents such as failure to properly reinstall the gearbox drain plug and/or other lubrication system components. These can result in lubricant loss while the gearbox is transmitting rotational energy. Some leaks can be relatively slow, leakage requiring between about ten and sixty minutes before lubricant flow from the primary lubricant flow path may be reduced. Other losses can be relatively rapid, such as pressure side leaks, leakage requiring less than ten minutes before lubricant flow from the primary lubricant flow path may be reduced. In these cases, an emergency lubrication system **101**, described below, can be switched on.

[0026] With reference now to FIG. **2**, an emergency lubricant reservoir **114** is in fluid communication with transmission gears **128**, **136** and **130** through modified breather port **108** and through visual inspection ports **110**. Gearbox assembly **100** includes three lubrication lines **116**. One lubrication line **116** connects the emergency lubrication reservoir **114** to breather port **108**. The other two lubrication lines **116** connect emergency lubrication reservoir **114** to respective visual inspection ports **110**. Gearbox assembly **100** includes a second emergency lubricant reservoir **118** having a pump **120**. Second emergency lubricant reservoir **118** is in fluid communication with the first emergency lubrication reservoir **114** so as to pump lubricant from the reservoirs **114**, **118**. Emergency lubrication reservoirs **114** and **118**, respectively, are mounted to an accessory module **117** through respective first and second reservoir mounts, **119** and **121**, respectively. While not required in all aspects, a switch controlled by a controller can control the pump to provide the lubricant. In other aspects, the controller could selectively control the pump **120** to regulate the flow of lubricant into the housing **102**, such as in pulses or in a constant stream to ensure lubrication reaches the transmission gears **128**, **136** and **130**.

[0027] As shown in FIG. **3**, visual inspection ports **110** include respective plugs **111** having jet tubes **122** therein. Jet tubes **122** direct lubricant from the emergency lubricant reservoir **114** to desired transmission components, for example, components highly sensitive to loss of lubricant.

Those skilled in the art will readily appreciate that jet tubes **122** can be longer than jet tubes **122** found in breather port **108** so that the lubricant can effectively reach the desired location. Gearbox assembly **100** includes a main bevel gear mesh **126**. Main bevel gear mesh **126** is at two locations on the underside of main bevel gear **128** where main bevel gear **128** meshes with respective main bevel pinions **130** which transmit torque from the input quills of respective engines. Outlets **132** of jet tubes **122** of visual inspection ports **110** are oriented toward the two locations of main bevel gear mesh **126** and their respective bearings. While described in terms of 30 minute operation and exemplary flow rates, it is understood that other flow rates and operation times can be implemented in other aspects of the invention.

[0028] With reference now to FIG. **4**, breather port **108** includes a jet tube **122**. Breather port **108** includes a modified breather **124** disposed therein. Modified breather **124** includes annular filter **126** surrounding jet tube **122**. Gearbox assembly **100** includes a tail take-off gear mesh **136** on the topside of main bevel gear **128**. Above main bevel gear **128** is a tail take-off gear **135** which meshes with tail take-off pinion **138** to form tail take-off gear mesh **136**. An outlet **134** of jet tube **122** of breather port **108** is oriented toward tail take-off gear mesh **136**. It is contemplated that both plugs **111** and modified breather **124** can include flanges to assist in fail-safe assembly of plugs **111** and modified breather **124** into their respective ports **110** and **108**, respectively. This helps to ensure that the jet tubes **122** are consistently aligned toward the desired transmission component.

[0029] Those skilled in the art will readily appreciate that by having jet tubes at these three locations, the two locations of main bevel mesh **126** and the tail take-off mesh **136**, emergency oil is provided to three critical areas that are most sensitive to loss of oil. In accordance with some embodiments, the oil flow rate is equivalent to the time required to operate without oil. For example, if the emergency lubrication reservoirs hold 1 gallon of oil, and the time required to operate is 30 minutes then the total flow rate to the critical areas must be 1 gallon/30 min or 0.033 gal./min. If there are three critical locations for emergency oil jets, then the flow rate for each of the jets is ⅓ the amount, or 0.011 gal./min.

[0030] As shown in FIG. **5**, a method **200** of retrofitting a gear box assembly, e.g. gear box assembly **100**, with an emergency lubrication system, e.g. emergency lubrication system **101**, includes removing plugs from visual inspection ports, e.g. visual inspection ports **110**, of a gearbox housing, e.g. a gearbox housing **102**, and removing a breather from a breather port, e.g. breather port **108**, of the gearbox housing, as indicated by box **202**. Method **200** includes installing jet plugs, e.g. plugs **111** and modified breather **124**, into the respective visual inspection ports and breather port, as indicated by box **204**. The jet plugs include jet tubes, e.g. jet tubes **122**. Method **200** includes orienting the jet tubes to point at desired transmission components, e.g. main bevel gear mesh **126** and/or tail take-off gear mesh **136**, as indicated by box **206**. While described in terms of specific ports, it is understood that other ports could have their plugs or breathers removed to the extent such other ports exist on a particular gear box assembly.

[0031] With continued reference to FIG. **5**, method **200** includes removing fasteners (such as nuts and washers from screws) of an accessory module, e.g. accessory module **117**, of the gear box assembly, and installing a first emergency lubrication reservoir, e.g. first emergency lubrication reservoir **114**, by mating the fasteners (e.g. screws) on the accessory module with holes on a first reservoir mount, e.g. first reservoir mount **119**, as indicated by box **208**. Method **200** includes installing a second emergency lubrication reservoir, e.g. second emergency lubrication reservoir **118**, by mating the fasteners (e.g. screws) on the accessory module with holes on a second reservoir mount, e.g. second reservoir mount **121**, as indicated by box **210**.

[0032] As shown in FIG. **5**, method **200** includes securing the first and second emergency lubrication reservoirs onto the accessory modules and installing lubrication lines, e.g. lubrication lines **116**, between the jet tubes of the breather port and inspection ports to at least one of the first and second emergency lubrication reservoirs, e.g. first and second emergency lubrication reservoirs **114**, **118**, as indicated by box **212**. Method **200** includes securing the lubrication lines to the gearbox housing, as indicated by box **214**. Method **200** includes providing power to a pump of the second emergency lubrication reservoir (e.g., wiring an AC power source to pump **120** of second emergency lubrication reservoir **118**, installing a switch operatively connected to pump **120**, and wiring an AC power source to the switch) as indicated by box **216**.

[0033] With reference now to FIG. **6**, the emergency lubrication system is designed to be a field retrofit kit so that existing gearbox assemblies can be upgraded to meet the new test requirements and last 30 minutes after loss of oil from a pressurized lubrication line. Retrofit kit **300** includes a breather **324** and two plugs **311**, each breather **324** and plug **311** includes a respective jet tube **322**. Kit **300** includes three lubrication lines **316**, a switch **315**, and two emergency lubrication reservoirs **314** and **318**. Emergency lubrication reservoir **318** includes a pump **320** built in. It is also contemplated that kit **300** includes first and second reservoir mounts, **319** and **321**.

[0034] Embodiments of the gearbox assemblies, emergency lubrication systems, and methods of retrofitting gearbox assemblies described herein can provide a supply of lubricant sufficient for gearbox operation for more than thirty (30) minutes under hover power conditions, and longer in certain embodiments, depending on the power requirements, extending the interval of time between when the primary lubrication flow may no longer be able to provide sufficient lubricant flow to when operation of the gearbox assembly may be affected, thereby providing compliance with the certification requirements described above irrespective of how fast lubricant is lost from the gearbox assembly.

[0035] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for transmissions with superior properties including improved reliability during operation in an oil-out condition. While described in the context of a rotary wing helicopter and FAA requirements, in is understood that aspects of the invention can be used which meet other requirements, and can be used in other types of machinery, including industrial machinery, automobiles, maritime machinery, locomotives, without restriction. 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.

What is claimed is:

1. A gearbox assembly with emergency lubrication system, comprising:

a housing with an interior including a lubricant sump, wherein the housing includes a breather port and a visual inspection port, wherein the breather port is sized for at least one of relieving internal pressure or admitting air, and wherein the visual inspection port is located to allow visual inspection of a component in an interior of the housing;

a transmission disposed within the interior of the housing in fluid communication with the lubricant sump; and

an emergency lubricant reservoir in fluid communication with the transmission through at least one of the breather port or the visual inspection port.

2. The gearbox assembly as recited in claim **1**, further comprising lubrication lines, wherein each lubrication line connects the emergency lubrication reservoir to at least one of the breather port or the visual inspection port.

3. The gearbox assembly as recited in claim **1**, further including a lubricant pump operatively connected to the emergency lubricant reservoir.

4. The gearbox assembly as recited in claim **1**, wherein the breather port and visual inspection port include respective jet tubes to direct lubricant to a desired transmission component.

5. The gearbox assembly as recited in claim **4**, wherein the breather port includes a breather disposed therein, and wherein the breather includes annular filter surrounding the jet tube.

6. The gearbox assembly as recited in claim **4**, wherein the transmission includes a main bevel gear mesh and a tail take-off gear mesh, wherein the housing includes a second visual inspection port having a further respective jet tube, wherein the emergency lubricant reservoir is in fluid communication with the transmission through the second visual inspection port and the further respective jet tube, and wherein outlets of the two jet tubes of the visual inspection ports are oriented toward the main bevel gear mesh and an outlet of the jet tube of the breather port is oriented toward the tail take-off gear mesh.

7. A method of retrofitting a gear box assembly with an emergency lubrication system, comprising:

removing plugs from visual inspection ports of a gearbox housing;

removing a breather from a breather port of the gearbox housing; and

installing jet plugs into the respective visual inspection ports and breather port, wherein each jet plug includes a respective jet tube.

8. The method as recited in claim **7**, further comprising:

removing nuts and washers from screws of an accessory module of a gear box assembly;

installing a first emergency lubrication reservoir by mating the screws on the accessory module with holes on a first reservoir mount;

installing a second emergency lubrication reservoir, wherein the second emergency lubrication reservoir includes a pump, by mating the screws on the accessory module with holes on a second reservoir mount;

securing the first and second emergency lubrication reservoirs onto the accessory module; and

installing lubrication lines between the jet tubes of the breather port and inspection ports to at least one of the first and second emergency lubrication reservoirs.

9. The method as recited in claim **8**, further comprising wiring an AC power source to the pump.

10. The method as recited in claim **8**, further comprising installing a switch operatively connected to the pump, and wiring an AC power source to the switch.

11. The method as recited in claim **8**, further comprising securing the lubrication lines to the gearbox housing.

12. The method as recited in claim **7**, further comprising orienting the jet tubes to point at desired transmission components.

13. An emergency lubrication system for use with a gearbox assembly having a housing with an interior including a lubricant sump, wherein the housing includes a breather port and two visual inspection ports, the breather port being sized for at least one of relieving internal pressure or admitting air, and the visual inspection port being located to allow visual inspection of a transmission in an interior of the housing, the emergency lubrication system comprising:

a plug having a jet tube extending therethrough, wherein the plug is sized to seal either the breather or the visual inspection port;

a lubrication line connected to the jet tube;

a pump; and

an emergency lubrication reservoir in fluid communication with the jet tube through the lubrication line such that, when the pump is activated, lubrication flows from the emergency lubrication reservoir through the lubrication line and the jet tube.

14. An emergency lubrication system as recited in claim **13**, further comprising a reservoir mount connected to the emergency lubrication reservoir, wherein the reservoir mount operatively connects the emergency lubrication reservoir an accessory module of the gearbox assembly.

* * * * *