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Regan

(54) **METHODS AND SYSTEMS FOR CHANNELING AIRCRAFT HYDRAULIC FLUID**

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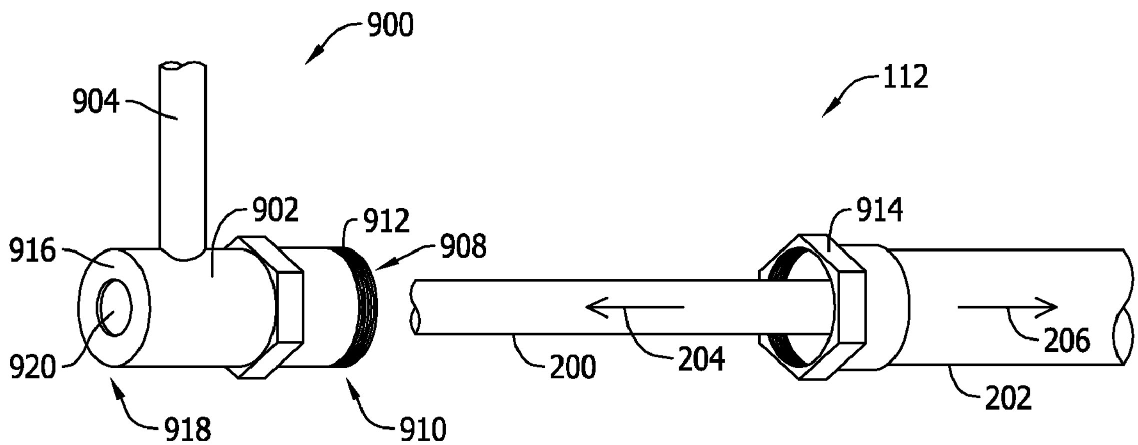
B64C 13/36	(2006.01)

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

CPC ***F16L 39/005*** (2013.01); ***B64C 13/36*** (2013.01); ***F15B 13/0807*** (2013.01)

(57) **ABSTRACT**

Methods and a fluid separation fitting for channeling hydraulic fluid in an aircraft are provided herein. The fluid separation fitting includes a first tube section and a second tube section. The first tube section includes a first end and a second end, and is configured to receive a first distribution line therethrough. The first distribution line is configured to channel fluid therethrough in a first direction. The first tube section is configured to be coupled to a second distribution line configured to channel fluid therethrough in an opposite second direction. The second distribution line circumscribes at least a portion of the first distribution line. The second tube section extends from the first tube section to channel fluid into or from the second distribution line via the first tube section.



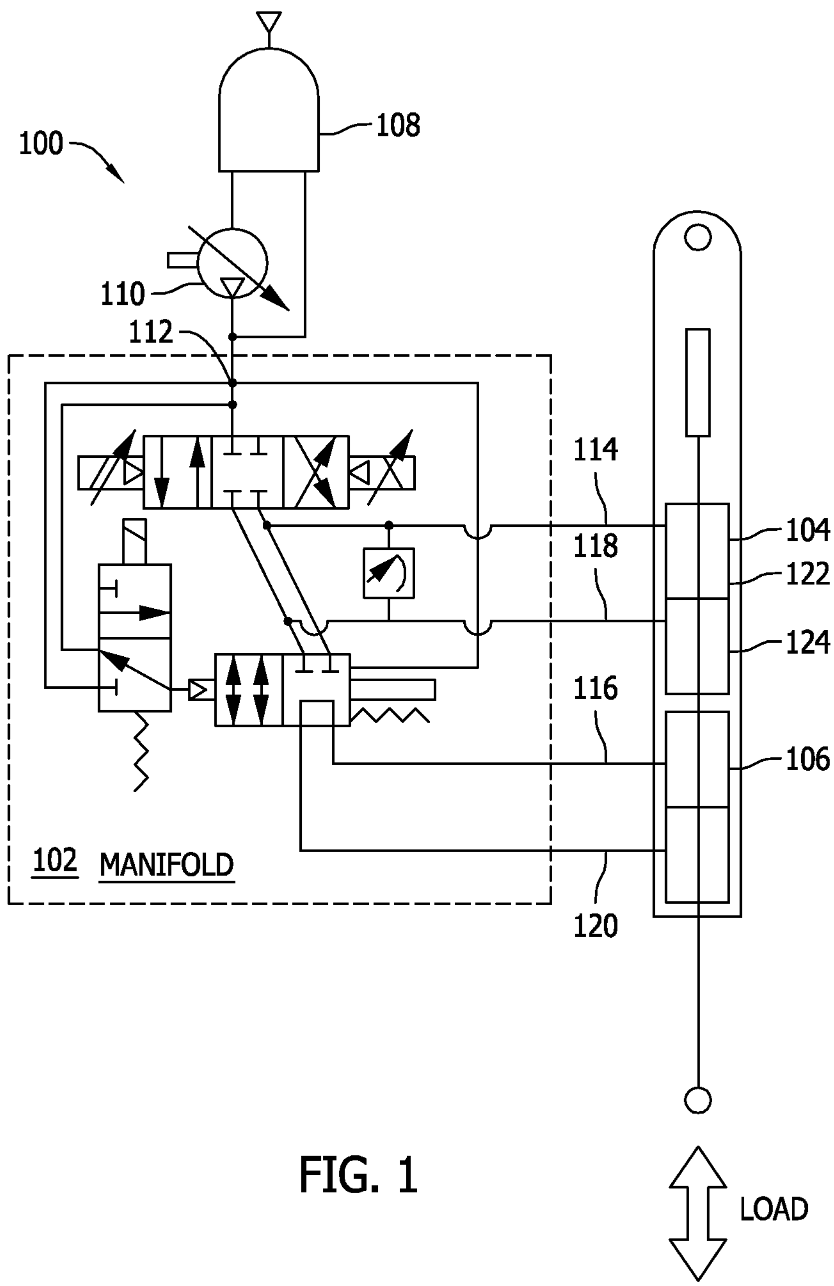

100
108
110
112
114
118
116
120
104
122
124
106
102 MANIFOLD
LOAD

FIG. 1

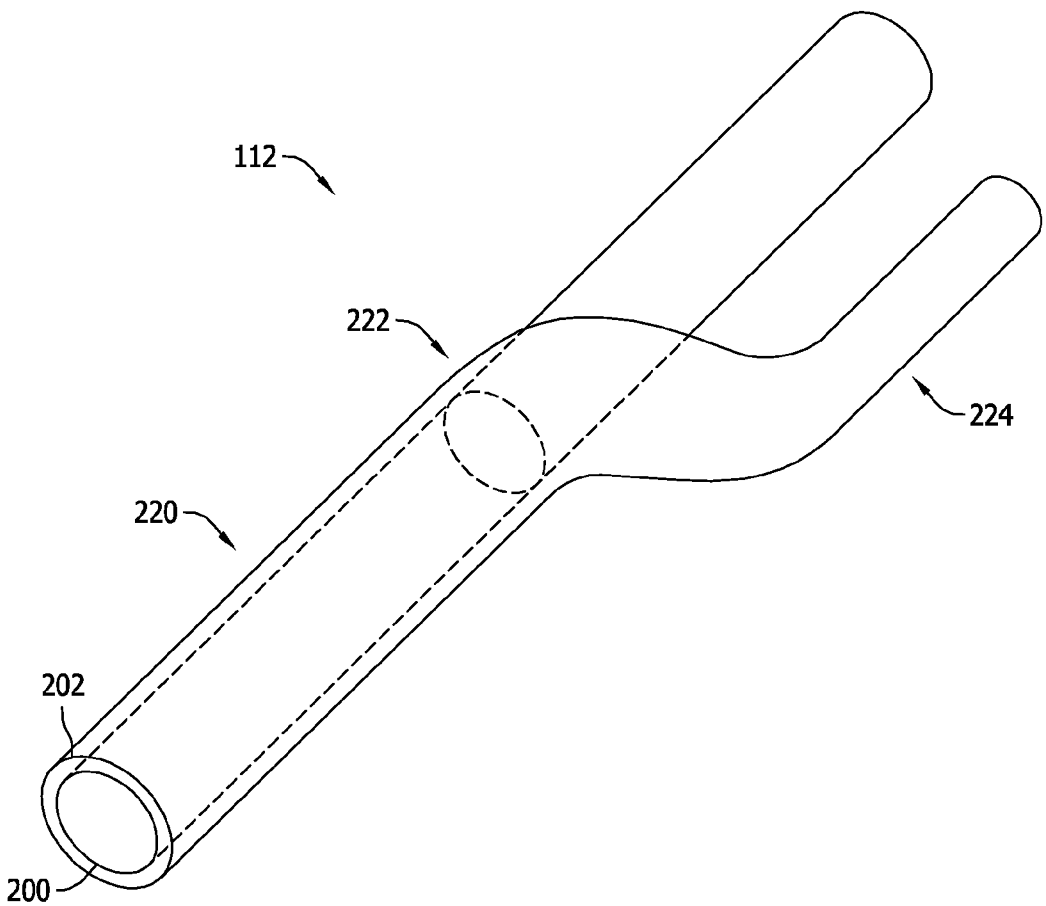


FIG. 2

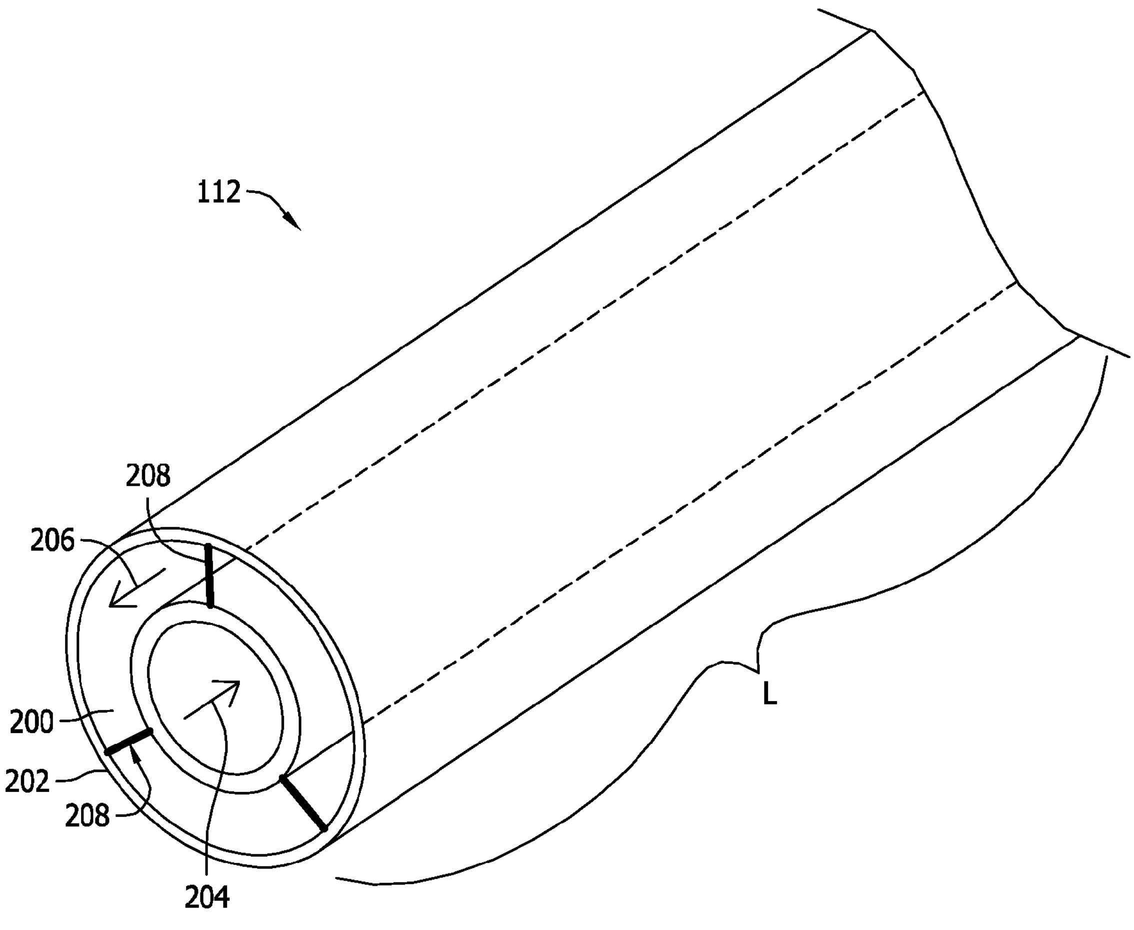


FIG. 3

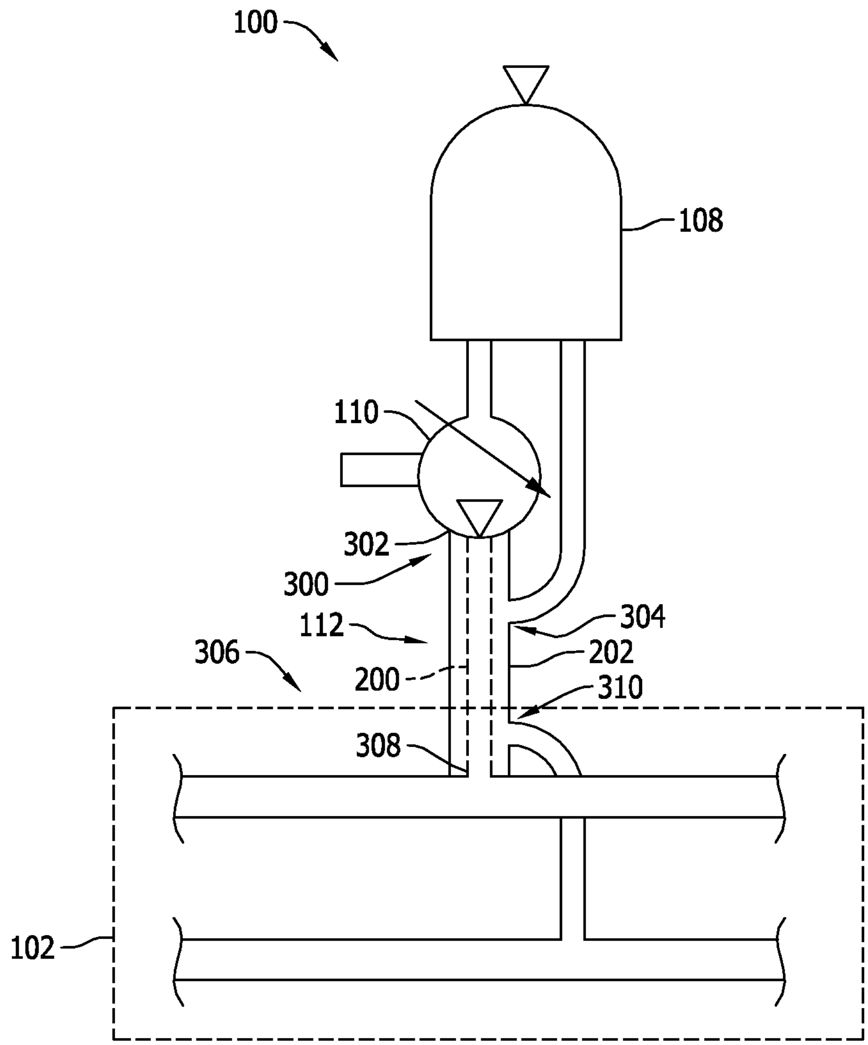


FIG. 4

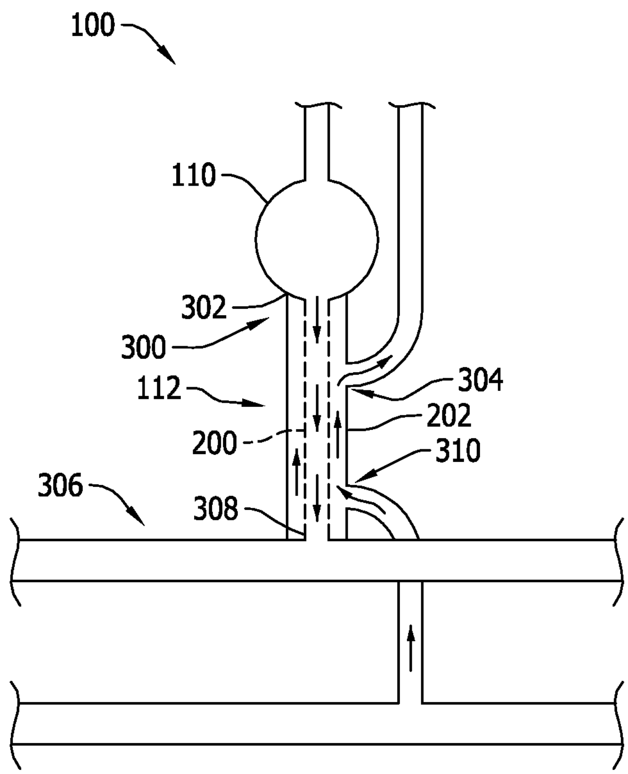


FIG. 5

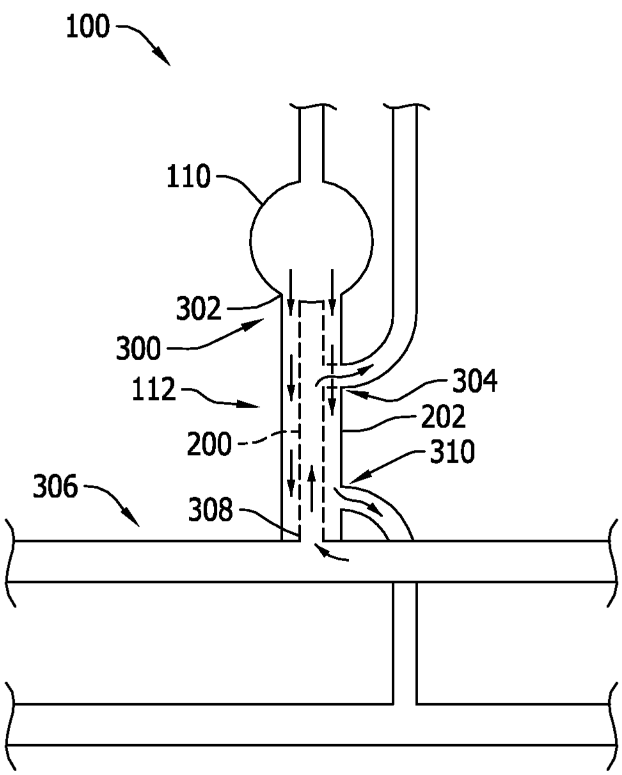


FIG. 6

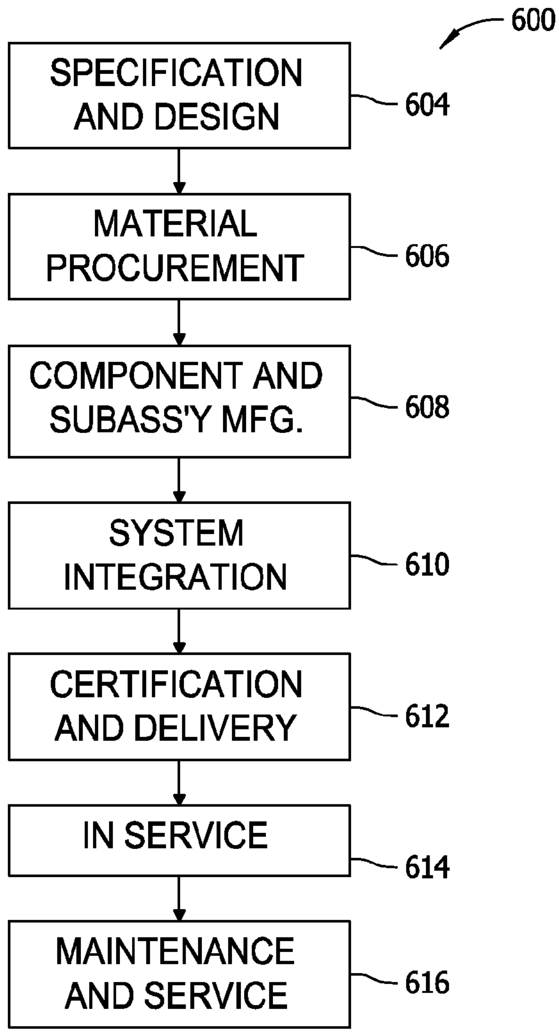

600
SPECIFICATION AND DESIGN
604
MATERIAL PROCUREMENT
606
COMPONENT AND SUBASS'Y MFG.
608
SYSTEM INTEGRATION
610
CERTIFICATION AND DELIVERY
612
IN SERVICE
614
MAINTENANCE AND SERVICE
616

FIG. 7

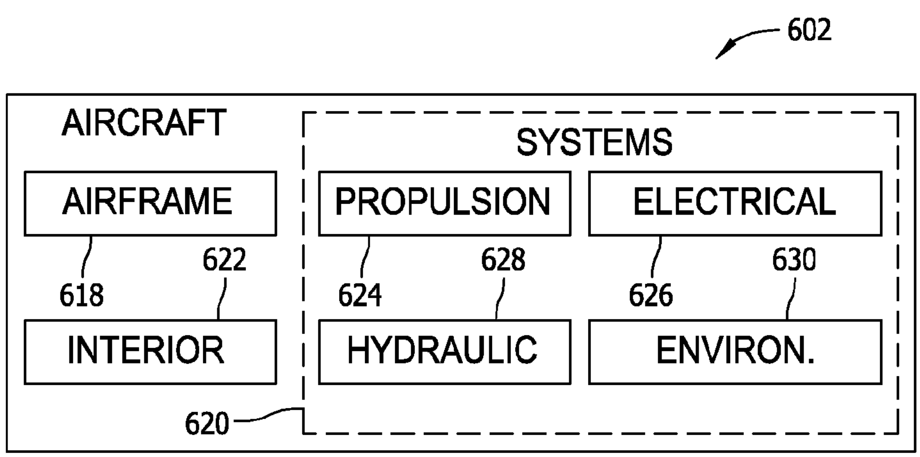

602
AIRCRAFT
SYSTEMS
AIRFRAME
PROPULSION
ELECTRICAL
618
622
624
628
626
630
INTERIOR
HYDRAULIC
ENVIRON.
620

FIG. 8

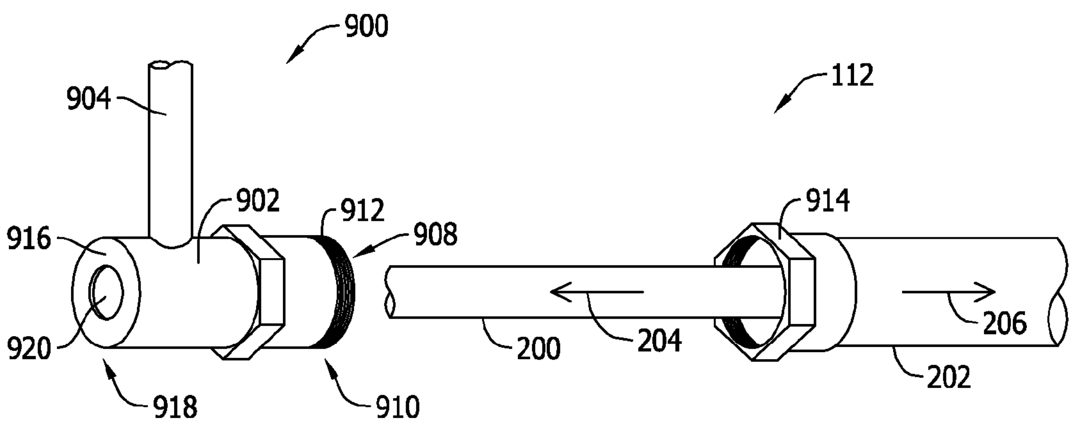


FIG. 9

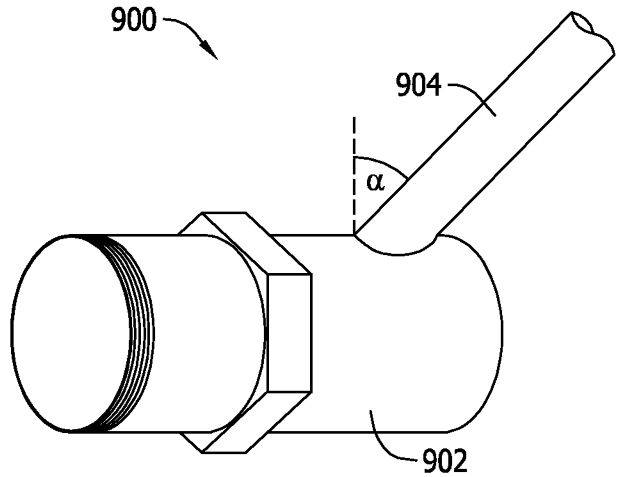


FIG. 10

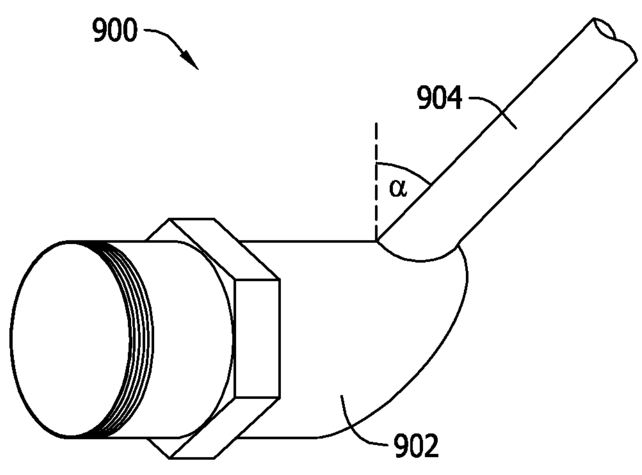


FIG. 11

METHODS AND SYSTEMS FOR CHANNELING AIRCRAFT HYDRAULIC FLUID

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation-in-part of U.S. application Ser. No. 13/922,748, filed Jun. 20, 2013, the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] The present disclosure relates generally to hydraulic systems and, more particularly, to aircraft hydraulic fluid distribution lines.

[0003] Known aircraft hydraulic systems use a pressurized supply line to transport hydraulic fluid to a load, and a separate return line for returning the hydraulic fluid from the load back to a storage tank or reservoir. Known pressurized supply lines and return lines are fabricated with a wall thickness that is sufficient to withstand pressure differentials that may exist within the hydraulic system. Separate pressure and return lines may require extra space and hardware. In an aircraft, space is limited, and the additional hardware increases weight, part cost, and installation time. Additionally, pressure lines are generally unprotected and thus, may be susceptible to damage during handling and installation and may be thicker and heavier than necessary.

BRIEF SUMMARY

[0004] In one aspect, a fluid separation fitting is provided that includes a first tube section and a second tube section. The first tube section includes a first end and a second end, and is configured to receive a first distribution line therethrough. The first distribution line is configured to channel fluid therethrough in a first direction. The first tube section is configured to be coupled to a second distribution line configured to channel fluid therethrough in an opposite second direction. The second distribution line circumscribes at least a portion of the first distribution line. The second tube section extends from the first tube section to channel fluid into or from the second distribution line via the first tube section.

[0005] In another aspect, a method of manufacturing a fluid separation fitting is provided. The method includes providing a first tube section having a first end and a second end, the first tube section configured to receive a first distribution line therethrough. The first distribution line is configured to channel fluid therethrough in a first direction. The first tube section is configured to be coupled to a second distribution line configured to channel fluid therethrough in an opposite second direction. The second distribution line circumscribes at least a portion of the first distribution line. The method also includes coupling a second tube section extending from the first tube section for channeling fluid into or from the second distribution line.

[0006] In yet another aspect, a hydraulic system is provided that includes a pump for pressurizing fluid, a manifold for distributing the pressurized fluid to at least one load, and a fluid distribution line fluidly coupled to the pump and the manifold. The fluid distribution line includes a first distribution line configured to channel the fluid in a first direction, a second distribution line configured to channel the fluid in an opposite second direction, said second distribution line concentrically aligned with and circumscribing said first distribution line, and a fluid separation fitting. The fluid separation fitting includes a first tube section and a second tube section. The first tube section includes a first end and a second end, and is configured to receive a first distribution line therethrough. The first distribution line is configured to channel fluid therethrough in a first direction. The first tube section is configured to be coupled to a second distribution line configured to channel fluid therethrough in an opposite second direction. The second distribution line circumscribes at least a portion of the first distribution line. The second tube section extends from the first tube section to channel fluid into or from the second distribution line via the first tube section.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a block diagram of an exemplary hydraulic system that may be used in an aircraft.

[0008] FIG. **2** is a perspective view of an exemplary fluid distribution system that may be used in the aircraft hydraulic system shown in FIG. **1**.

[0009] FIG. **3** is an enlarged perspective view of the fluid distribution system shown in FIG. **2**.

[0010] FIG. **4** is a perspective view of the fluid distribution system shown in FIG. **2** and coupled within the hydraulic system shown in FIG. **1**.

[0011] FIG. **5** is an enlarged view showing connections of the fluid distribution system to the aircraft hydraulic system shown in FIG. **4**.

[0012] FIG. **6** is a perspective view of an alternative fluid distribution system shown in FIG. **2** and coupled within the hydraulic system shown in FIG. **1**.

[0013] FIG. **7** is a flow diagram of an exemplary aircraft production and service methodology.

[0014] FIG. **8** is a block diagram of an exemplary aircraft that may be fabricated using the system shown in FIG. **1**.

[0015] FIG. **9** is a perspective view of an exemplary fluid separation fitting that may be used with the fluid distribution system shown in FIGS. **2** and **3**.

[0016] FIG. **10** is a perspective view of an alternative second tube section of the fluid separation fitting shown in FIG. **9**.

[0017] FIG. **11** is a perspective view of an alternative first tube section that may be used with the second tube section shown in FIG. **9**.

DETAILED DESCRIPTION

[0018] FIG. **1** is a block diagram of an exemplary hydraulic system **100** that may be used in an aircraft. Hydraulic system **100** includes a manifold **102**, a first actuator **104**, and a second actuator **106**. Manifold **102** is in flow communication to a pressure source (not shown) that includes a fluid reservoir **108** and a pump **110** that supply manifold **102** with a pressurized working fluid via a fluid distribution system **112**. Pump **110** may include any type of pump, such as, but not limited to, hydraulic pumps, engine driven pumps, electrically driven pumps, air or wind driven pumps, and/or ram air turbine (RAT) pumps. The working fluid is returned back to fluid reservoir **108** at the reservoir pressure via fluid distribution system **112**. From the reservoir **108**, the working fluid is then re-supplied to pump **110** via fluid distribution system **112**. Accordingly, hydraulic system **100** constitutes a closed fluid system.

[0019] First and second actuators **104** and **106**, respectively, may include any actuators used in known hydraulic systems. Each actuator **104** and **106**, respectively, includes a piston (not shown) movable within an actuator barrel (not shown). Each actuator **104** and **106**, respectively, also includes a shaft or rod (not shown). One end of the shaft engages the piston, while the other end of the shaft engages with the flight control surface. The actuator barrel is in flow communication to fluid reservoir **108** and to pump **110** via an extended fluid conduit **114** or **116** and a retracted fluid conduit **118** or **120**. Each actuator barrel is sized to enable the piston to move within the barrel when the barrel receives a supply of pressurized working fluid from reservoir **108** and pump **110** via fluid distribution system **112**.

[0020] Each actuator **104** and **106** is in flow communication to manifold **102** via a respective extended fluid conduit or line **114** or **116**, respectively, and via a retracted fluid conduit **118** or **120**. When provided with pressurized working fluid, the flow direction of the pressurized working fluid determines whether actuators **104** and **106** extend or retract, and thus operate to retract or extend the flight control surface. For example, first actuator's **104** piston extends when the pressurized working fluid enters an extend side **122** of first actuator **104** via extended fluid conduit **114**. Working fluid is discharged from a retract side **124** of first actuator **104** via retracted fluid conduit **118** and is returned to reservoir **108** via fluid distribution system **112**. Conversely, first actuator's **104** piston retracts when the pressurized working fluid is provided to retract side **124** via retracted fluid conduit **118**. In such a condition, the working fluid is discharged from extend side **122** of first actuator **104** via extended fluid conduit **114** and returned to reservoir **108** via fluid distribution system **112**.

[0021] FIG. **2** is a perspective view of an exemplary fluid distribution system **112**, and FIG. **3** is an enlarged perspective view of fluid distribution system **112** that may be used in aircraft hydraulic system **100** (shown in FIG. **1**). In the exemplary implementation, fluid distribution system **112** includes a first, inner line **200** and a second, outer line **202**. Outer line **202** includes a first portion **220**, a second portion **224**, and an interface portion **222** located therebetween. Inner line **200** extends in a substantially linear direction and is sized for insertion into outer line **202** at interface region **222**. More specifically, inner line **200** is insertable into outer line **202** with an interference fit at interface region **222**, and is substantially concentric with first portion **220**. Second portion **224** then extends transversely from interface region **222** to couple in flow communication with fluid reservoir **108** (shown in FIG. **1**).

[0022] Inner line **200** is concentrically positioned within outer line **202** along a full length L of fluid distribution system **112**. More specifically, outer line **202** is radially outward from inner line **200**. Fluid distribution system **112** is configured to channel a fluid in a first direction **204** via inner line **200** and channel fluid in a second direction **206** that is opposite first direction **204** via outer line **202**.

[0023] In the exemplary implementation, inner line **200** is a pressure supply line **200** that delivers pressurized working fluid to manifold **102** (shown in FIG. **1**). Further, in the exemplary implementation, outer line **202** is a return line **202** that returns the working fluid to fluid reservoir **108** (shown in FIG. **1**). Because return line **202** circumferentially surrounds pressure supply line **200**, at least a portion of hoop stresses induced to pressure supply line **200** are reduced, thus enabling pressure supply line **200** to be fabricated with a thinner wall thickness than other known pressure supply lines. In some implementations, one or more internal support members **208** extend between pressure supply line **200** and return line **202** to provide enhanced structural support and to facilitate preventing bending and/or disfigurement of fluid distribution system **112**. In an alternative implementation, return line **202** may be concentrically positioned within pressure supply line **200**.

[0024] In the exemplary embodiment, fluid distribution system **112** is fabricated using an additive manufacturing process. Specifically, an additive manufacturing process known as direct metal laser sintering (DMLS) or direct metal laser melting (DMLM) is used to manufacture fluid distribution system **112**. Although the fabrication process is described herein as DMLS, one having ordinary skill in the art would understand that DMLM could also be used. Alternatively, the additive manufacturing method is not limited to the DMLS or DMLM process, but may be any known additive manufacturing process that enables fluid distribution system **112** to function as described herein. This fabrication process eliminates complex joints and structures that would typically be defined between separate components that require welding or brazing. Rather, DMLS is an additive layer process that produces a metal component directly from a CAD model using a laser and a fine metal powder. The result is a monolithic distribution system having concentric first and second distribution lines connected by support members. The distribution system may further include ducts that extend from the first and second distribution lines that are configured to couple with separate fluid sources. In a further implementation, the ducts may also be manufactured in-situ with the distribution system using a DMLS, DMLM, or other additive manufacturing process to form a monolithic distribution system. In the exemplary implementation, aluminum-based alloy powders, corrosion resistant steel-based alloy powders, titanium-based alloy powders, and synthetic rubber compound powders are used to fabricate the fluid distribution line disclosed herein, but other powders that enable the fluid distribution line to function as described herein may be used.

[0025] FIG. **4** is a perspective view of a fluid distribution system **112** (shown in FIG. **2**) that is coupled within hydraulic system **100** (shown in FIG. **1**). FIG. **5** is an enlarged view showing connection of fluid distribution system **112** to aircraft hydraulic system **100**. In the exemplary implementation, at a first end **300**, pressure supply line **200** is in flow communication to pump **110** (shown in FIG. **1**). Return line **202** extends about pressure supply line **200** and is coupled to an end plate **302** of pump **110**. Return line **202** includes an outlet **304** that is coupled in flow communication to reservoir **108** to channel fluid returning from manifold **102** back into reservoir **108**.

[0026] In the exemplary implementation, at a second end **306**, pressure supply line **200** is coupled in flow communication to an inlet **308** of manifold **102** to enable fluid flow of pressurized fluid from pump **110** into manifold **102**. Further, fluid distribution system **112** includes a return line inlet **310** that channels fluid flowing from manifold **102** back towards reservoir **108**. In alternative implementations, fluid distribution system **112** may be coupled within system **100** using a separate connection device than the device that couples fluid distribution system **112** to system **100**.

[0027] FIG. **6** is a perspective view of an alternative fluid distribution system shown in FIG. **2** and coupled within the hydraulic system shown in FIG. **1**. The distribution system may include ducts that extend from the first and second distribution lines that are configured to connect with separate fluid sources. The system may be structured such that a duct that is coupled in flow communication with the first distribution line extends through a wall of the second distribution line to couple in flow communication with fluid reservoir **108** (shown in FIG. **1**). Further, the wall of the second distribution line and the duct may be manufactured in-situ with the distribution system using a DMLS, DMLM, or other additive manufacturing process to form a monolithic distribution system.

[0028] The methods and systems described herein are in the context of aircraft manufacturing and service method **600** (shown in FIG. **7**) and an aircraft **602** (shown in FIG. **8**). Alternatively, the methods and systems described herein may be implemented in any context and/or in any environment involving a fluid distribution system. During pre-production, method **600** may utilize specification and design **604** of the aircraft **602** and/or material procurement **606**. During production, component and subassembly manufacturing **608** and system integration **610** of the aircraft **602** occurs. Thereafter, aircraft **602** may go through certification and delivery **612** prior to being placed in service **614**. While in service by a customer, aircraft **602** is scheduled for routine maintenance and service **616** (including, for example, modification, reconfiguration, and/or refurbishment).

[0029] Each of the processes of method **600** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of venders, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

[0030] As shown in FIG. **8**, an aircraft **602** produced using method **600** may include an airframe **618** having a plurality of systems **620** and an interior **622**. Examples of high-level systems **620** may include one or more of a propulsion system **624**, an electrical system **626**, a hydraulic system **626**, and/or an environmental system **630**. Any number of other systems may be included. Although an aerospace example is shown, the principles of the invention may be applied to other industries, such as the automotive industry, machinery, and heavy equipment.

[0031] Apparatus and methods embodied herein may be employed during any one or more of the stages of the production and service method **600**. For example, components or subassemblies corresponding to production process **608** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **602** is in service. Also, one or more apparatus implementations, method implementations, or a combination thereof may be utilized during the production stages **608** and **610**, for example, by substantially expediting assembly of or reducing the cost of an aircraft **602**. Similarly, one or more of apparatus implementations, method implementations, or a combination thereof may be utilized while the aircraft **602** is in service, for example and without limitation, to maintenance and service **616**.

[0032] FIG. **9** is a perspective view of an exemplary fluid separation fitting **900** that may be used with fluid distribution system **112** (shown in FIGS. **2** and **3**). In the exemplary implementation, fluid separation fitting **900** is configured to separate inner line **200** (shown in FIG. **2**) from outer line **202** (shown in FIG. **2**). Fluid separation fitting **900** is manufactured using a subtractive manufacturing process or any other manufacturing process that enables fluid separation fitting to function as described herein. Fluid separation fitting **900** includes a first tube section **902** and a second tube section **904**.

[0033] In the exemplary implementation, first tube section **902** is configured to receive inner line **200** therethrough. Inner line **200** is configured to channel fluid therethrough in a first direction **204** (shown in FIG. **2**). First tube section **902** is configured to be coupled to outer line **202** configured to channel fluid therethrough in an opposite second direction **206** (shown in FIG. **2**). Outer line **202** circumscribes at least a portion of inner line **200**. First tube section **902** includes a connection device **908** positioned at a first end **910** of first tube section **902** for coupling fluid separation fitting **900** to outer line **202**. In the exemplary implementation, connection device **908** is a threaded male portion **912** configured to couple to a threaded female portion **914** on outer line **202**. Alternatively, connection device **908** may be any type of connection device that enables fluid separation fitting **900** to function as described herein. First tube section **902** also includes a flange **916** positioned at a second end **918** of first tube section **902**. Flange **916** defines an aperture **920** configured to receive inner line **200** therethrough.

[0034] In the exemplary implementation, second tube section **904** extends radially outward from first tube section **902**. Second tube section **904** is in flow communication with first tube section **902** and is configured to channel fluid into or from outer line **202** via first tube section **902**. In the exemplary implementation, second tube section **904** extends from first tube section **902** at a substantially perpendicular angle. In another implementation, as shown in FIG. **10**, second tube section **904** extends from first tube section **902** at an angle a to facilitate improving fluid flow from second tube section **904** into outer line **202**. In another implementation, as shown in FIG. **11**, second end **918** of first tube section **902** extends at the same angle a at which second tube section **904** extends from first tube section **902**.

[0035] Referring back to FIG. **9**, in the exemplary implementation, first tube section **902** is concentrically aligned with and circumscribes at least a portion of inner line **200** over a length L1 of first tube section **902**. Beyond length L1, inner line **200** extends longitudinally from first tube section **902** in first direction **204** and is no longer circumscribed by first tube section **902**.

[0036] The embodiments described herein facilitate reducing the size and space required for installation of fluid distribution lines in an aircraft. More specifically, the above-described systems integrate a pressure supply line within a return line, rather than having separate lines that require more space. The return line reduces stresses on and protects the pressure supply line during installation and operation, enabling a reduction in thickness of the pressure supply line. Further, the above-described fluid distribution line reduces weight, installation time, and costs.

[0037] A technical effect of the systems and methods described herein includes at least one of: (a) providing a first tube section having a first end and a second end, the first tube section configured to receive a first distribution line therethrough, wherein the first distribution line is configured to channel fluid therethrough in a first direction, the first tube section configured to be coupled to a second distribution line configured to channel fluid therethrough in an opposite second direction, wherein the second distribution line circumscribes at least a portion of the first distribution line; and (b) coupling a second tube section extending from the first tube section for channeling fluid into or from the second distribution line.

[0038] The implementations described herein relate generally to hydraulic systems and, more particularly, to methods and systems for channeling a fluid using aircraft hydraulic fluid distribution lines. Exemplary implementations of methods and systems for channeling a fluid using aircraft hydraulic fluid distribution lines are described above in detail. The methods and systems are not limited to the specific implementations described herein, but rather, components of systems and/or steps of the method may be utilized independently and separately from other components and/or steps described herein. Each method step and each component may also be used in combination with other method steps and/or components. Although specific features of various implementations may be shown in some drawings and not in others, this is for convenience only. Any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

[0039] An element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural elements or steps unless such exclusion is explicitly recited. Moreover, references to "one implementation" of the present invention and/or the "exemplary implementation" are not intended to be interpreted as excluding the existence of additional implementations that also incorporate the recited features.

[0040] This written description uses examples to disclose the implementations, including the best mode, and also to enable any person skilled in the art to practice the implementations, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and 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 language of the claims.

What is claimed is:

1. A fluid separation fitting comprising:

a first tube section comprising a first end and a second end, said first tube section configured to receive a first distribution line therethrough, wherein the first distribution line is configured to channel fluid therethrough in a first direction, said first tube section configured to be coupled to a second distribution line configured to channel fluid therethrough in an opposite second direction, wherein the second distribution line circumscribes at least a portion of the first distribution line; and

a second tube section extending from said first tube section for channeling fluid into or from the second distribution line.

2. A fluid separation fitting in accordance with claim **1**, wherein said first tube section further comprises a connection device positioned at said first end for coupling said fluid separation fitting to the second distribution line.

3. A fluid separation fitting in accordance with claim **1**, wherein said first tube section further comprises a flange coupled to said second end of said first tube section, said flange defining an aperture configured to receive the first distribution line therethrough.

4. A fluid separation fitting in accordance with claim **1**, wherein said second tube section extends from said first tube section at an angle to increase fluid flow from said second tube section into the second distribution line.

5. A fluid separation fitting in accordance with claim **4**, wherein said second end of said first tube section extends at the same angle at which said second tube section extends from said first tube section.

6. A fluid separation fitting in accordance with claim **1**, wherein said fluid separation fitting is manufactured using a subtractive manufacturing process.

7. A fluid separation fitting in accordance with claim **1**, wherein said first tube section is concentrically aligned with the first distribution line over a distance.

8. A fluid separation fitting in accordance with claim **1**, wherein said first tube section circumscribes at least a portion of the first distribution line over a distance.

9. A fluid separation fitting in accordance with claim **8**, wherein the first distribution line extends longitudinally from said first tube section in the first direction beyond the distance, and is no longer circumscribed by said first tube section.

10. A method of manufacturing a fluid separation fitting, said method comprising:

providing a first tube section having a first end and a second end, the first tube section configured to receive a first distribution line therethrough, wherein the first distribution line is configured to channel fluid therethrough in a first direction, the first tube section configured to be coupled to a second distribution line configured to channel fluid therethrough in an opposite second direction, wherein the second distribution line circumscribes at least a portion of the first distribution line; and

coupling a second tube section extending from the first tube section for channeling fluid into or from the second distribution line.

11. A method in accordance with claim **10**, further comprising forming a connection device at the first end of the first tube section for coupling the fluid separation fitting to the second distribution line.

12. A method in accordance with claim **10**, further comprising forming a flange at the second end of the first tube section, wherein the flange defines an aperture configured to receive the first distribution line therethrough.

13. A method in accordance with claim **10**, further comprising extending the second tube section at an angle from the first tube section to increase fluid flow from the second tube section into the second distribution line.

14. A method in accordance with claim **13**, further comprising extending the second end of the first tube section at the same angle at which the second tube section extends from the first tube section.

15. A method in accordance with claim **10**, wherein the fluid separation fitting is manufactured using a subtractive manufacturing process.

16. A hydraulic system comprising:

a pump for pressurizing fluid;

a manifold for distributing the pressurized fluid to at least one load; and

a fluid distribution line fluidly coupled to said pump and said manifold, said hydraulic fluid distribution line comprising:
- a first distribution line configured to channel the fluid in a first direction;
- a second distribution line configured to channel the fluid in an opposite second direction, said second distribution line concentrically aligned with and circumscribing said first distribution line; and
- a fluid separation fitting comprising:
  - a first tube section having a first end and a second end, the first tube section configured to receive said first distribution line therethrough, said first tube section configured to be coupled to said second distribution line; and
  - a second tube section extending from said first tube section for channeling fluid into or from said second distribution line.

17. A system in accordance with claim **16**, wherein said first tube section further comprises a connection device positioned at said first end for coupling said fluid separation fitting to the second distribution line.

18. A system in accordance with claim **16**, wherein said first tube section further comprises a flange coupled to said second end of said first tube section, said flange defining an aperture configured to receive the first distribution line therethrough.

19. A system in accordance with claim **16**, wherein said second tube section extends from said first tube section at an angle to increase fluid flow from said second tube section into the second distribution line.

20. A system in accordance with claim **19**, wherein said second end of said first tube section extends at the same angle at which said second tube section extends from said first tube section.

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