United States Patent Application Publication	20250264368
Kind Code	A1
Publication Date	August 21, 2025
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NON-INTRUSIVE MOUNTING OF AIRCRAFT FUEL PRESSURE SENSORS

Abstract

A system includes an aircraft fuel tank defining an interior configured to store fuel for flight. The interior is defined by a plurality of tank walls including a vertical wing spar of a wing. An opening is defined through the vertical wing spar. A guide tube has a first end sealingly engaged in the opening of the vertical wing spar to prevent leakage between the guide tube and the opening. An optic fiber extends through the guide tube, sealingly engaged to the first end of the guide tube to prevent leakage between the optic fiber and the first end of the guide tube. An optical pressure sensor is optically coupled to the optic fiber proximate a second end of the guide tube opposite the first end.

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Appl. No.: **18/444553**

Filed: **February 16, 2024**

Publication Classification

Int. Cl.: **G01L19/14** (20060101); **B64D37/04** (20060101); **B64D45/00** (20060101); **G01L11/02** (20060101); **G01L19/00** (20060101)

U.S. Cl.:

CPC **G01L19/142** (20130101); **B64D37/04** (20130101); **B64D45/00** (20130101); **G01L11/025** (20130101); **G01L19/0046** (20130101);

Background/Summary

BACKGROUND

1. Field

[0001] The present disclosure relates to pressure measurements, and more particularly to pressure and related measurements for fuel level determination in aircraft fuel tanks and the like.

2. Description of Related Art

[0002] Fuel quantity measurement techniques for aircraft fuel tanks are developing, and many of these utilize multiple pressure sensors throughout a fuel tank. Older fuel level probes have been relatively intrusive to maintain. If they ever need to be replaced or repaired, a technician must access the inside of fuel tank manually and/or with tools.

[0003] The conventional techniques have been considered satisfactory for their intended purpose. However, there is an ever present need for improved, less intrusive systems and methods for installing and maintaining fuel level sensors in aircraft fuel tanks and the like. This disclosure provides a solution for this need.

SUMMARY

[0004] A system includes an aircraft fuel tank defining an interior configured to store fuel for flight. The interior is defined by a plurality of tank walls including a vertical wing spar of a wing. An opening is defined through the vertical wing spar. A guide tube has a first end sealingly engaged in the opening of the vertical wing spar to prevent leakage between the guide tube and the opening. An optic fiber extends through the guide tube, sealingly engaged to the first end of the guide tube to prevent leakage between the optic fiber and the first end of the guide tube. An optical pressure sensor is optically coupled to the optic fiber proximate a second end of the guide tube opposite the first end.

[0005] At least one additional guide tube and optic fiber can extend from the vertical wing spar into the interior. The second end of the guide tube can terminate at terminal surface that defines an opening locally perpendicular to a longitudinal axis of the guide tube. The terminal surface can be devoid of any covering over the second end of the guide tube. The guide tube and optic fiber can be devoid of electrical circuitry within the interior. The guide tube can be a non-pressure transmitting tube. At least one drain hole can be defined laterally through the guide tube.

[0006] A retainer can be mounted inside the interior, wherein the second end of the guide tube engages the retainer. The retainer can include a pin or shoulder. At least one bracket or hose clamp can anchor the guide tube to the tank at a point along the guide tube between the first end and the second end. A sheath around the optic fiber can be configured to facilitate guiding the optic fiber along an inside surface of the guide tube. The first end of the guide tube can be mounted to the vertical spar proximate an access hatch or control surface of the wing. The guide tube can be polymeric. The pressure sensor can include a reflective pressure diaphragm extending in a direction parallel to a terminal surface of the guide tube.

[0007] A method includes during construction of an aircraft wing, installing a polymeric guide tube extending from a vertical wing spar at a first end of the guide tube into an interior of a fuel tank at a second end of the guide tube, engaging and the second end of the polymeric guide tube with a retainer in the interior of the fuel tank, affixing the guide tube along its length with one or more brackets or hose clamps, and mounting the first end of the guide tube to the vertical spar. The method can include advancing a sheathed optic fiber through an interior of the guide tube until a sealing fitting of the sheathed optic fiber engages a terminal at the first end of the guide tube, to position an optical probe at a tip of the optic fiber into a predetermined pressure-measurement position relative to the second end of the guide tube.

[0008] A method includes, e.g. after aircraft construction but during maintenance or the like, advancing a sheathed optic fiber through an interior of a guide tube in an aircraft fuel tank until a sealing fitting of the sheathed optic fiber engages a terminal at the first end of the guide tube, to position an optical probe at a tip of the optic fiber into a predetermined pressure-measurement position relative to a second end of the guide tube.

[0009] 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.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

[0011] FIG. **1** is a schematic perspective view of an embodiment of a system constructed in accordance with the present disclosure, showing a portion of an aircraft wing with a fuel tank level sensor array therein;

[0012] FIG. **2** is a schematic perspective view of a portion of the system of FIG. **1**, showing the wing with control surfaces removed, and showing attachment points for guide tubes and optic fiber sensors;

[0013] FIG. **3** is a schematic cross-sectional perspective view of the system of FIG. **1**, showing brackets along the length of the guide tubes, mounting the guide tubes to the internal structure of the fuel tank;

[0014] FIG. **4** is a schematic cross-sectional perspective view of the system of FIG. **1**, showing one of the retainers for positioning the sensor end of the guide tube inside the fuel tank;

[0015] FIG. **5** is a schematic cross-sectional side elevation view of a portion of the system of FIG. **1**, showing the predetermined position of the probe tip relative to the terminal surface of the guide tube at the second end of the guide tube; and

[0016] FIG. **6** is a schematic cross-sectional side elevation view of a portion of the system of FIG. **1**, showing connecting of the optic fiber to the first end of the guide tube at the vertical spar.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] 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 embodiment of a system in accordance with the disclosure is shown in FIG. **1** and is designated generally by reference character **100**. Other embodiments of systems 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 to provide for facilitated installation, removal, and maintenance of fuel pressure sensors and the like without having to access the interior of an aircraft fuel tank manually or with tools.

[0018] The system **100** includes an aircraft fuel tank **102** defining an interior **104** configured to store fuel for flight. The interior **104** is defined by a plurality of tank walls **106** including a vertical wing spar **108** of an aircraft wing **110**. FIG. **2** shows the wing **110** with the control surfaces **112** of FIG. **1** removed to show openings **114** that are defined through the vertical wing spar **108**. A guide tube **116**, two of which are labeled in FIG. **3**, has a first end **118** sealingly engaged, e.g. with a sealing fitting **120** labeled in FIG. **6**, in the opening **114** of the vertical wing spar **108** to prevent leakage between the guide tube **116** and the opening **114**. The first end **118** of the guide tube is mounted to the vertical spar **108** at the opening **114** proximate an access hatch or control surface **112** of the wing **110** for easy access for installation and removal of pressure sensors as further described below.

[0019] With reference now to FIG. **4**, the second end **122** of the guide tube **116** terminates at terminal surface **124** that defines an opening **126** (labeled in FIG. **5**) locally perpendicular to a longitudinal axis A (labeled in FIG. **5**) of the guide tube **116**. A retainer **128** is mounted inside the interior **104** to one of the tank walls **106**, wherein the second end **122** of the guide tube engages the retainer **128**. The retainer **128** includes a pin, shoulder, or the like, affixed in the interior **104** at a position where it is intended to take pressure measurements for the fuel tank **102**. At least one bracket or hose clamp **130** anchors the guide tube **116** to the tank **102** at one or more points along the guide tube **116** between the first end **118** and the second end **130**. Although FIG. **3** shows two guide tubes **116**, any suitable number of additional guide tubes (and associated optic fibers) can be used as needed extending from the vertical wing spar **108** into predetermined positions in the interior **104** to provide pressure measurements at all the intended positions within the tank **102**.

[0020] Referring now to FIG. **5**, the terminal surface **124** of the guide tube **116** defines the opening **126** which is devoid of any covering over the second end **122** of the guide tube **166**. The guide tube **122** is a non-pressure transmitting tube. At least one drain hole **132** (labeled in FIGS. **3-4**) is defined laterally through the guide tube **116** to allow the interior of the guide tube **116** to drain and prevent transmission of pressure along the guide tube **116**.

[0021] With continued reference to FIG. **5**, an optic fiber **134** (single fiber strand or bundle of fiber strands) extends through the guide tube **116**. An optical pressure sensor **136**, such as a Fabry-Pérot type, Bragg grating type, and/or the like type sensor, is mounted to and optically coupled to the optic fiber **134** proximate the second end **122** of the guide tube **116**. A sheath **138** around the optic fiber **134** is configured to facilitate guiding the optic fiber **134** along the inside surface **140** of the guide tube **116** as further described below. In a Fabry-Pérot type sensor **136**, the pressure sensor **136** includes a reflective pressure diaphragm **137** extending in a direction parallel to a terminal surface **124** of the guide tube **116**. The optic fiber **134** is sealingly engaged to the first end **118** of the guide tube **116**, e.g. with a sealing fitting **142** labeled in FIG. **6**, to prevent leakage between the optic fiber/sheath **134**, **128** and the first end **118** of the guide tube **116**. The sealing provided by the fittings **120** and **142** prevents fuel inside the tank **102** from leaking out through the opening **114**. The guide tube **118** can be made of a polymeric material, the optic fiber **134** and sensor **136** can be made of glass materials, and the sheath **138** can be made of a polymer or glass material, so the system **100** can be devoid of electrical circuitry within the interior **104** of the tank **102**.

[0022] With reference to FIG. **3**, during construction of the aircraft wing **110**, the guide tube **116** can be installed, extending from the vertical wing spar **108** at a first end **118** of the guide tube **116** into the interior **104** of the fuel tank **102** at the second end **122** of the guide tube **116** by inserting the second end **122** of the guide tube **116** through the opening **114** in the vertical wing spar **108** until the second end **122** of the polymeric guide tube **116** engages with the retainer **128** as shown in FIGS. **4** and **5**. The position of the retainer **128** and the length of the guide tube **116** are both known so as to have the first end **118** of the guide tube **116** seal to the opening **114** with the second end **122** engaging the retainer **128**, e.g. mounting the first end **118** of the guide tube **116** with the fitting **120** to the vertical spar **108** as shown in FIG. **6**. The guide tube **116** can be affixed along its length to the structures in the interior **104** of the fuel tank **102** with one or more brackets or hose clamps **130** (as shown in FIGS. **3-4**).

[0023] With reference now to FIG. **5**, with the guide tube **116** mounted in place, the optical probe tip or sensor **136** can be placed in the intended position in the tank **102** by advancing a sheathed optic fiber **134** through the interior of the guide tube **116** until a sealing fitting **142** of the sheathed optic fiber **134** engages a terminal, e.g. fitting **120** of the guide tube **116**, at the first end **118** of the guide tube **116** as indicated in FIG. **6** by the large arrows. This places the optical probe or sensor **136** at a tip of the optic fiber **134** into a predetermined pressure-measurement position relative to the second end **122** of the guide tube **118**. The sensor **136** can be precisely placed in the intended position, whether that is slightly inside the guide tube **116** as indicated by the span d in FIG. **5**, slightly outside the guide tube **116** as indicated by the span d′ in FIG. **5**, or exactly flush with the terminal surface **124** of the guide tube **124**. The spacer **146** proximate the sensor end of the optic fiber **134** spaces the sensor **136** and inner wall of the guide tube **116** apart to help ensure proper positioning of the sensor within the guide tube **116**. The end **144** of the optic fiber **134** not shown in FIG. **6** can be optically coupled to optical equipment such as an interferometer to make pressure measurements, as indicated in FIG. **6**.

[0024] With reference to FIG. **6**, after aircraft construction but during maintenance or the like, the optic fiber **134** and its sensor **126** can be removed by disengaging the fitting **142** from the opening **114** and pulling the optic fiber **134** out of the guide tube **134**. A refurbished, repaired, or new optic fiber **134** and sensor **136** can be replaced into the proper sensing position by advancing the sheathed optic fiber **136**, sensor end first, through an interior of the guide tube **116** (which would still be in place in an aircraft fuel tank **102**) until a sealing fitting **142** of the sheathed optic fiber **134** engages a terminal, e.g. fitting **120**, at the first end **118** of the guide tube **116**. This positions the optical probe at a tip of the optic fiber **134** into the predetermined pressure-measurement position relative to a second end **122** of the guide tube, as shown in FIG. **5**. There is no need to align the end of the optic fiber **134** with any keyways, splines, or the like in the second end **122** of the guide tube **116**—the end of the optic fiber **134** is inherently positioned in the correct place by having matched lengths of the optic fiber **134** and the guide tube **122**.

[0025] Systems and methods as disclosed herein provide potential benefits including the following. No internal access to the fuel tank is necessary after original manufacture with this approach, i.e. a technician's hands or tools need not ever enter the interior of the fuel tank. No other opening besides the opening **114** (labeled in FIG. **2**) need be used to access the sensor **134** (labeled in FIG. **5**). The sensors can be removed/replaced/maintained at any time with very minimal intrusion. Tubes, flanges and fittings can be made out of any suitable fuel-proof material, which is conducive to the trend to move away from having metallic materials in fuel level sensors inside the tank. Additionally, the guide tubes can have some drainage holes in them to allow for the free passage of fuel behind the sensor so it does not stagnate there, and so no fuel need be pulled out when a technician removes the sensor as described above. The openings **114** can be midway vertically on the vertical wing spar **108** (labeled in FIG. **2**) to provide structural strength around the openings **114**.

[0026] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for facilitated installation, removal, and maintenance of fuel pressure sensors and the like without having to access the interior of an aircraft fuel tank manually or with tools. While the apparatus and methods of the subject disclosure have been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the scope of the subject disclosure.

Claims

1. A system comprising: an aircraft fuel tank defining an interior configured to store fuel for flight, wherein the interior is defined by a plurality of tank walls including a vertical wing spar of a wing; an opening through the vertical wing spar; a guide tube with a first end sealingly engaged in the opening of the vertical wing spar to prevent leakage between the guide tube and the opening; an optic fiber extending through the guide tube, sealingly engaged to the first end of the guide tube to prevent leakage between the optic fiber and the first end of the guide tube; and an optical pressure sensor optically coupled to the optic fiber proximate a second end of the guide tube opposite the first end.

2. The system as recited in claim 1, further comprising at least one additional guide tube and optic fiber extending from the vertical wing spar into the interior.

3. The system as recited in claim 1, wherein the second end of the guide tube terminates at terminal surface that defines an opening locally perpendicular to a longitudinal axis of the guide tube.
4. The system as recited in claim 3, wherein the terminal surface is devoid of any covering over the second end of the guide tube.
5. The system as recited in claim 1, wherein the guide tube and optic fiber are devoid of electrical circuitry within the interior.
6. The system as recited in claim 1, wherein the guide tube is a non-pressure transmitting tube.
7. The system as recited in claim 6, wherein at least one drain hole is defined laterally through the guide tube.
8. The system as recited in claim 1, further comprising a retainer mounted inside the interior, wherein the second end of the guide tube engages the retainer.
9. The system as recited in claim 8, wherein the retainer includes a pin or shoulder.
10. The system as recited in claim 8, further comprising at least one bracket or hose clamp anchoring the guide tube to the tank at a point along the guide tube between the first end and the second end.
11. The system as recited in claim 1, further comprising a sheath around the optic fiber configured to facilitate guiding the optic fiber along an inside surface of the guide tube.
12. The system as recited in claim 1, wherein the first end of the guide tube is mounted to the vertical spar proximate an access hatch or control surface of the wing.
13. The system as recited in claim 1, wherein the guide tube is polymeric.
14. The system as recited in claim 1, wherein the pressure sensor includes a reflective pressure diaphragm extending in a direction parallel to a terminal surface of the guide tube.
15. A method comprising: during construction of an aircraft wing, installing a polymeric guide tube extending from a vertical wing spar at a first end of the guide tube into an interior of a fuel tank at a second end of the guide tube, engaging and the second end of the polymeric guide tube with a retainer in the interior of the fuel tank, affixing the guide tube along its length with one or more brackets or hose clamps, and mounting the first end of the guide tube to the vertical spar.
16. The method as recited in claim 15, further comprising advancing a sheathed optic fiber through an interior of the guide tube until a sealing fitting of the sheathed optic fiber engages a terminal at the first end of the guide tube, to position an optical probe at a tip of the optic fiber into a predetermined pressure-measurement position relative to the second end of the guide tube.
17. A method comprising: advancing a sheathed optic fiber through an interior of a guide tube in an aircraft fuel tank until a sealing fitting of the sheathed optic fiber engages a terminal at the first end of the guide tube, to position an optical probe at a tip of the optic fiber into a predetermined pressure-measurement position relative to a second end of the guide tube.
18. The method as recited in claim 17, wherein a terminal surface of the guide tube is devoid of any covering over the second end of the guide tube.
19. The method as recited in claim 17, wherein the guide tube and optic fiber are devoid of electrical circuitry within the interior.
20. The method as recited in claim 17, wherein the guide tube is a non-pressure transmitting tube.