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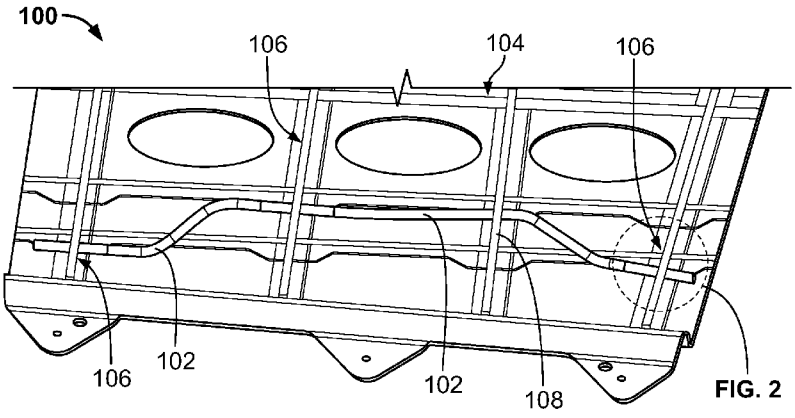


FIG. 2

FIG. 1

(57) Abstract: According to the embodiments provided herein, an insulated electrically conductive fluid seal (300, 400, 500) can include a non-conductive elastomer casing (302) and one or more electrically conductive plugs (304, 404, 504). The one or more electrically conductive plugs can be disposed radially in the casing (302). The one or more electrically conductive plugs (304, 404, 504) can be configured to dissipate and to transmit electrical charge between two mating conductive sealing surfaces.

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INSULATED ELECTRICALLY CONDUCTIVE FLUID SEAL

TECHNICAL FIELD

[0001] The present disclosure generally relates to fluid seals. Specifically, the present disclosure relates to insulated electrically conductive fluid seals that are configured to stretch during installation.

BACKGROUND ART

[0002] As fuel is pumped at typical high speeds, both the fuel and tubes or pipes of the delivery system become electrically charged. Thus, fuel delivery systems often incorporate mechanisms for dissipating and or transmitting the electrical charge to aircraft ground in order to prevent damage to the aircraft and to ensure passenger safety. Grounding lines or bonding wires are one common mechanism for dissipating and transmitting the charge from tubes of a fuel delivery system.

[0003] In an example flexible fuel delivery system **100** illustrated in **Fig. 1**, metal tubes are replaced with plastic or composite tubes **102** doped with electrically conductive elements or compounds. The plastic tubes **102** are interconnected to form a plumbing system within an aircraft wing **104**, for example. To provide support and structure to the flexible fuel delivery system **100**, the plastic tubes **102** are interconnected at connection points **106** and supported by tube support devices **108**. **Fig. 2** is a close-up view of a connection point **106** between two tubes **102**. Retention clips **202**, retention collars **204**, over-molded end fittings **206**, and bulkhead connectors **207** facilitate interconnections of tubes **102**. Ring-shaped elastomeric seals **208** are doped with electrically conductive polymers to facilitate the safe

transmission of the electric charge. The electrically conductive seals eliminates the need for bonding wires between the tubes and aircraft ground. The conductivity of the seal **208** may be adjusted by adjusting the geometry of the seal **208** and/or the level of conductive doping.

[0004] Doping an elastomeric seal **208** with a conductive materials, however, results in a stiff or rigid seal that lacks flexibility and is therefore difficult to install. Because of the stiffness, the seal **208** may crack or tear during installation into a gland or a groove since installation requires stretching the seal **208** sufficiently to clear walls of the gland. The cracks may not be easily detectable and therefore may cause future leaks. Moreover, it may be difficult and inefficient to modify the resistance of a seal **208** in or order to accommodate various seal **208** sizes and applications.

SUMMARY

[0005] In one embodiment, an insulated electrically conductive fluid seal can include a non-conductive elastomer casing and a plurality of electrically conductive plugs disposed radially in the casing. The one or more electrically conductive plugs can be configured to dissipate and to transmit electrical charge between two mating conductive sealing surfaces.

[0006] In another embodiment, an insulated electrically conductive fluid seal can include a seal casing and one or more conductive plugs. The seal casing can be formed from a non-conductive elastomer. The seal casing can include an inner contact surface and an outer contact surface. The one or more electrically conductive plugs can be disposed in the seal casing. The one or more electrically conductive plugs can extend between the inner contact surface and the outer contact surface. The

one or more electrically conductive plugs can be configured to dissipate and to transmit electrical charge between the inner contact surface and the outer contact surface of the seal casing.

[0007] In a further embodiment, an insulated electrically conductive fluid seal can include a seal casing and an electrically conductive plugs. The electrically conductive plug can be substantially ring shaped. The seal casing can be formed from a non-conductive elastomer. The seal casing can include an inner contact surface, an outer contact surface, a first axial surface and a second axial surface. The outer contact surface can be disposed radially outward of the inner contact surface. The first axial surface and the second axial surface can delimit the seal casing. The electrically conductive plug can be disposed in the seal casing. The conductive plugs can extend through the seal casing. The electrically conductive plug can be configured to dissipate and to transmit electrical charge between the inner contact surface and the outer contact surface.

[0008] According to any of the insulated electrically conductive fluid seals shown and described herein, the one or more electrically conductive plugs can be ring-shaped. Alternatively or additionally, the seal casing and the electrically conductive plug forms a laminar structure.

[0009] According to any of the insulated electrically conductive fluid seals shown and described herein, the one or more electrically conductive plugs can be cylindrical-shaped.

[0010] According to any of the insulated electrically conductive fluid seals shown and described herein, the one or more electrically conductive plugs can include an

elastomer doped with electrically conductive carbon. Alternatively or additionally, the electrically conductive carbon dopant can be in one or a combination of several forms such as, for example, powdered carbon, carbon nanotubes, milled carbon fiber, Grapheme, or any combination thereof.

[0011] According to any of the insulated electrically conductive fluid seals shown and described herein, the one or more electrically conductive plugs can form a parallel resistor network between two mating conductive sealing surfaces. Alternatively or additionally, the one or more electrically conductive plugs can be equally spaced around the seal casing.

[0012] According to any of the insulated electrically conductive fluid seals shown and described herein, adjusting the number of plugs disposed in the casing can determine the electrical measured resistance between two sealing surfaces. Alternatively or additionally, an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing can be dependent upon a number of the one or more electrically conductive plugs disposed in the seal casing.

[0013] According to any of the insulated electrically conductive fluid seals shown and described herein, adjusting the contact area of the plurality of plugs disposed in the casing can determine the electrical measured resistance between two sealing surfaces. Alternatively or additionally, an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing can be dependent upon a contact area of the one or more electrically conductive plugs disposed in the seal casing.

[0014] According to any of the insulated electrically conductive fluid seals shown and described herein, adjusting the lengths of the plurality of plugs disposed in the casing can determine the electrical measured resistance between two sealing surfaces. Alternatively or additionally, an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing can be dependent upon a length of the one or more electrically conductive plugs disposed in the seal casing.

[0015] According to any of the insulated electrically conductive fluid seals shown and described herein, adjusting the volumetric electrical resistance of elastomeric material of the plurality of plugs disposed in the casing determines the electrical measured resistance between two sealing surfaces. Alternatively or additionally, an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing can be dependent upon a volumetric resistance of the one or more electrically conductive plugs disposed in the seal casing.

[0016] According to any of the insulated electrically conductive fluid seals shown and described herein, the non-conductive elastomer can include one or more of fluorosilicone, ethylene propylene rubber, fluorocarbon, silicone, and nitrile.

[0017] According to any of the insulated electrically conductive fluid seals shown and described herein, the seal casing can have a rectangular cross-section with or without radiused corners.

[0018] According to any of the insulated electrically conductive fluid seals shown and described herein, the casing may be configured to be stretched about 50% and also configured to retract to within about 10% of original length within about five minutes of release after being stretched for about five minutes at about 50% stretch.

[0019] According to any of the insulated electrically conductive fluid seals shown and described herein, an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing can be less than about 500,000 ohms.

[0020] According to any of the insulated electrically conductive fluid seals shown and described herein, a volume ratio of the one or more electrically conductive plugs to the seal casing can be between about 15% and about 50%.

[0021] According to any of the insulated electrically conductive fluid seals shown and described herein, the one or more electrically conductive plugs can be molded radially into the seal casing.

[0022] According to any of the insulated electrically conductive fluid seals shown and described herein, the seal casing can enclose a central orifice. The inner contact surface can be disposed radially inward with respect to the central orifice compared to the outer contact surface.

[0023] According to any of the insulated electrically conductive fluid seals shown and described herein, the electrically conductive plug can include a rounded protuberance that extends beyond the outer contact surface of the seal casing.

[0024] According to any of the insulated electrically conductive fluid seals shown and described herein, the insulated electrically conductive fluid seal can include an isolation layer disposed between the electrically conductive plug and the seal casing. The isolation layer can have a higher conductivity than the electrically conductive plug

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] In the accompanying drawings, structures are illustrated that, together with the detailed description provided below, describe example embodiments of the claimed invention. Where appropriate, like elements are identified with the same or similar reference numerals. Elements shown as a single component may be replaced with multiple components. Elements shown as multiple components may be replaced with a single component. The drawings may not be to scale. The proportion of certain elements may be exaggerated for the purpose of illustration.

[0026] **Fig. 1** schematically depicts an example of a flexible fuel delivery system.

[0027] **Fig. 2** schematically depicts an example connection point of the fuel delivery system of **Fig. 1**.

[0028] **Fig. 3** schematically depicts an insulated electrically conductive fluid seal according to one or more embodiments shown and described herein.

[0029] **Fig. 4** schematically depicts an insulated electrically conductive fluid seal according to one or more embodiments shown and described herein.

[0030] **Fig. 5** schematically depicts an insulated electrically conductive fluid seal according to one or more embodiments shown and described herein.

[0031] **Fig. 6** schematically depicts a cross-sectional view of the insulated electrically conductive fluid seal of **Fig. 5** according to one or more embodiments shown and described herein.

DETAILED DESCRIPTION

[0032] The embodiments provided herein generally relate to insulated electrically conductive fluid seals that are flexible and easy to install. The insulated electrically

conductive fluid seals can be more reliable because the relatively high flexibility can reduce the likelihood of cracking or tearing during installation. Alternatively or additionally, the insulated electrically conductive fluid seal can provide multiple parallel bonding paths between two components that are be sealed and bonded by the insulated electrically conductive fluid seal. Moreover, the conductivity of the insulated electrically conductive fluid seals described herein can be efficiently modified in order to accommodate various seal applications. It should be understood that, while embodiments of the insulated electrically conductive fluid seal may be described herein with reference to an aircraft fuel delivery system, the insulated electrically conductive fluid seals may be used in any suitable fluid delivery system to provide for safe transmission of electrical charges.

[0033] Referring to **Fig. 3**, an embodiment of an insulated electrically conductive fluid seal **300** is schematically depicted. The seal **300** can comprise a seal casing **302** configured to form an enclosure around an interface between two components that substantially prevents leakage of fluid from the interface. For the purpose defining and describing the present disclosure, it is noted that the term "fluid," as used herein, can mean a substance, such as a liquid or a gas, that is capable of flowing and that changes its shape at a steady rate when acted upon by a force tending to change its shape. In some embodiments, the seal casing 302 can be formed from a flexible and non-conductive elastomer, i.e., the elastomer can be configured to substantially mitigate the flow of electrical current. In one example, the seal casing **302** can be made of Fluorosilicone such as, for example, Fluorosilicone Rubber per MIL-R-25988, Type I, Class I. In other examples, the seal casing **302** can be made of

ethylene propylene rubber, fluorocarbon, Fluorocarbon Elastomer (Viton), silicone, nitrile, or other suitable elastomers. The seal casing 302 can have a hardness of between about 50 Durometer and about 90 Durometer in one embodiment such as, for example, between about 65 Durometer to about 75 Durometer.

[0034] The elasticity and the resilience, or rebound, properties of the casing **302** enable the seal **300** to be stretched sufficiently to clear walls of a gland without damaging the seal **300** or negatively impacting the performance of the seal **300**. Accordingly, the seal **300** can be stretched during installation and substantially prevent leakage of fluid after installation. For example, the seal **300** may be comprised of an elastomer that will not break when stretched approximately 50%. In some embodiments, the seal **300** can be stretched approximately 50%, held for about five minutes at the stretch of approximately 50%, and then retract itself to within approximately 10% of original length within five minutes of release from the stretch of approximately 50% without breaking. Suitable elastomers are available from, for example: Parker Seals of Parker Hannifin Corporation of Cleveland, OH, USA; Greene-Tweed of Kulpsville, PA, USA; Minnesota Rubber & Plastics of Minneapolis, MN, USA; and other elastomer component manufactures.

[0035] In some embodiments, the seal casing **302** can be formed around a central orifice **306** that is configured to receive one or more components, such as, e.g., electrically conductive tubing. Accordingly, the seal casing **302** can be a body that encloses the central orifice **306**. Specifically, the seal casing **302** can comprise an inner contact surface **308** for contacting a sealing surface of one or more components at least partially positioned within the central orifice **306** and an outer contact surface

310 for contacting a sealing surface of one or more additional components. The inner contact surface **308** can be disposed radially inward with respect to the central orifice **306** compared to the outer contact surface **310**. Thus, the outer contact surface **310** can be disposed radially outward with respect to the central orifice **306** compared to the inner contact surface **308**.

[0036] Referring still to **Fig. 3**, the seal casing **302** can comprise a substantially a rectangular cross-section. Accordingly, the seal casing **302** can comprise a first axial surface **312** and a second axial surface **314** that delimit the seal casing **302** axially. In some embodiments, a transition **316** can be formed between the inner contact surface **308** and the first axial surface **312**, the inner contact surface **308** and the second axial surface **314**, or both. Likewise, the transition **316** can be formed between the outer contact surface **310** and the first axial surface **312**, the outer contact surface **310** and the second axial surface **314**, or both. In some embodiments, the substantially rectangular cross-section of the seal casing **302** can be formed with radiused corners, i.e., the transitions **316** can travel along a radius. Alternatively, the substantially rectangular cross-section of the seal casing **302** can be formed without radiused corners. It is noted that, while the seal casing **302** is depicted in **Figs. 3** and **4** as having a substantially rectangular cross-sectional body, the seal casing **302** may have any suitable cross-section for sealing and bonding multiple components.

[0037] The seal **300** can comprise one or more electrically conductive plugs **304** integrally molded radially into seal casing **302** such that the seal casing at least partially encloses the one or more electrically conductive plugs **304**. Thus, seal casing **302** can provide sealing functionality and a housing for the one or more

electrically conductive plugs **304**. As is noted above, the seal casing **302** can be formed from non-conductive material. Accordingly, the one or more electrically conductive plugs **304** can be more conductive than the seal casing **302**. In some embodiments, the one or more electrically conductive plugs **304** can be formed from an elastomer. In one example, the one or more electrically conductive plugs **304** are made of a carbon doped composite elastomer. It should be appreciated that the one or more electrically conductive plugs **304** may include or be doped with other materials suitable to conduct electricity, i.e., powdered silver, powdered aluminum or other powdered metals can be utilized in in non- aerospace fuel conveyance applications.

[0038] The one or more electrically conductive plugs **304** can form elongate bodies that extend throughout the seal casing **302**. Specifically, the one or more electrically conductive plugs **304** can be substantially cylindrical-shaped and extend through the seal casing **302** from the inner contact surface **308** to the outer contact surface **310**. It should be appreciated that the one or more electrically conductive plugs **304** may be shaped in other suitable forms, such as star-shaped, rectangular-shaped, elliptical-shaped, ring-shaped, spherically-shaped and so on. In further embodiments, the one or more plugs **304** can comprise a substantially spherical protuberance that protrudes beyond the inner contact surface **308**, the outer contact surface **310**, or both. It should be further appreciated that the one or more electrically conductive plugs **304** may be molded in other suitable orientations into seal casing **302** between any two surfaces of the seal casing **302**, for example, the one or more electrically conductive plugs **304** may extend axially from first axial surface **312** to the second axial surface **314**.

[0039] According to the embodiments described herein, the seal **300** can be configured to provide electrical bonding between conductive sealing surfaces in contact with the inner contact surface **308** and the outer contact surface **310** via the one or more electrically conductive plugs **304**. In some embodiments, the one or more electrically conductive plugs **304** can provide multiple parallel electrical current paths for both static electricity currents and lightning level currents to flow between two conductive sealing surfaces. In one embodiment, the one or more electrically conductive plugs **304** can be equally spaced around and within seal casing **302**. Thus, the one or more electrically conductive plugs **304** can create a parallel resistor network between a conductive sealing surface in contact with the inner contact surface **308** and a conductive sealing surface in contact with the inner contact surface **310**. Alternatively or additionally, the one or more electrically conductive plugs **304** can be centered with respect to the first axial surface **312** and the second axial surface **314**. Accordingly, the one or more electrically conductive plugs **304** can be configured to dissipate and to transmit electrical charge between two mating conductive sealing surfaces, either metallic, non-metallic, or a combination of both, such as, for example, tubes in a fuel delivery system. It should be appreciated that, while the seal **300** is depicted in **Fig. 3** as comprising eight of the one or more electrically conductive plugs **304**, the seal **300** may include any number of electrically conductive plugs **304** to achieve a desired effective resistance.

[0040] The effective resistance of the seal **300** can be adjusted by altering the number of the one or more electrically conductive plugs **304**, while maintaining a substantially constant formulation of the one or more electrically conductive plugs

304. Accordingly, the effective resistance of the seal **300** can be dependent upon the number of electrically conductive plugs **304** disposed in the seal casing **302**, i.e., the electrical measured resistance between a conductive sealing surface in contact with the inner contact surface **308** and a conductive sealing surface in contact with the outer contact surface **310** can be correlated to the number of electrically conductive plugs **304** disposed in the seal casing **302**. Thus, the electrical conductivity of a seal **300** may be easily adjusted by including more or less electrically conductive plugs **304** in the seal casing **302**. In some embodiments, the electrical conductivity of a seal **300** can be dependent upon a volume ratio of conductive plugs **304** to seal casing **302**. In one example, the volume ratio of conductive plugs **304** to seal casing **302** can range from about 15% to about 50% to achieve a desired effective resistance such as, for example, from about 15% to about 25% in another embodiment.

[0041] Referring collectively to **Figs. 3** and **4**, the electrical conductivity can be adjusted by modifying the geometry of the one or more electrically conductive plugs **304**. Specifically, an embodiment of an insulated electrically conductive fluid seal **400** can have a different electrical conductivity than the seal **300** due modification of the diameter or shape of the one or more electrically conductive plugs **304**. For example, the seal **400** can comprise one or more electrically conductive plugs **404** disposed within the seal casing **302**. The one or more electrically conductive plugs **404** can be configured to have a greater contact area compared to the one or more electrically conductive plugs **304** of the seal **300**, i.e., the cross sectional area can be increased at the inner contact surface **308**, the outer contact surface **310**, between the inner contact surface **308** and the outer contact surface **310**, or combinations thereof.

The increase in contact area can increase the electrical conductivity of a seal **400** compared to the seal **300**. Likewise, the one or more electrically conductive plugs **304** can have a smaller contact area (diameter) than the one or more electrically conductive plugs **404**, which may decrease the electrical conductivity of a seal **300** compared to the seal **400**. Accordingly, the effective resistance of the seal **300** can be dependent upon the contact area of the one or more electrically conductive plugs **304** disposed in the seal casing **302**. It should be appreciated that the one or more electrically conductive plugs **304** disposed in the seal casing **302** may all be of the same diameter. Alternatively, the one or more electrically conductive plugs **304** disposed in the seal casing **302** may vary in diameter. Likewise, the one or more electrically conductive plugs **404** disposed in the seal casing **302** may all be of the same diameter or may vary in diameter.

[0042] Referring collectively to **Figs. 4-6**, the electrical conductivity can be adjusted by modifying the geometry of the one or more electrically conductive plugs **404**. Specifically, an embodiment of an insulated electrically conductive fluid seal **500** can have a different electrical conductivity than the seal **400** due modification of the contact area of the one or more electrically conductive plugs **404**. For example, the seal **500** can comprise an electrically conductive plug **504** disposed within the seal casing **302**. Specifically, the electrically conductive plug **504** can be substantially ring shaped and positioned between first axial surface **312** and the second axial surface **314** of the seal casing **302**. Additionally, the electrically conductive plug **504** can extend through the seal casing **302** between the inner contact surface **308** and the outer contact surface **310**. In some embodiments, the electrically conductive plug **504**

can comprise a rounded protuberance that extends beyond the outer contact surface **310** of the seal casing **302**, which can decrease the effective resistance by promoting surface contact.

[0043] The seal **500** can have a substantially laminar structure with a layer of the seal casing **302** formed between the electrically conductive plug **504** and the inner contact surface **308** and a layer of the seal casing **302** formed between the electrically conductive plug **504** and the inner outer contact surface **310**. Alternatively or additionally, isolation layers can be disposed between the electrically conductive plug **504** and seal casing **302**. The isolation layers can have a higher conductivity than the electrically conductive plug **504**, which can decrease the effective resistance of the seal **500**. In some embodiments, the layers of the seal casing **302** and the electrically conductive plug **504** can be chemically and mechanically bonded to form the laminar structure.

[0044] The electrically conductive plug **504** can be configured to have a greater contact area compared to the one or more electrically conductive plugs **404** of the seal **400**. The increase in contact area can increase the electrical conductivity of the seal **500** compared to the seal **400**. Accordingly, the effective resistance of the seal **500** can be dependent upon the contact area of the electrically conductive plug **504** disposed in the seal casing **302**. Specifically, when the size of the seal **500** is kept constant, the width of the electrically conductive plug **504** can be increased to lower the effective resistance, i.e., the layer of the seal casing **302** formed between the electrically conductive plug **504** and the inner contact surface **308** and the layer of the seal casing **302** formed between the electrically conductive plug **504** and the inner

outer contact surface **310** can be decreased. Likewise, the width of the electrically conductive plug **504** can be decreased to raise the effective resistance.

[0045] Referring again to **Figs. 3** and **4**, the effective resistance of the seal **300** can be adjusted by modifying the length, i.e., distance between the inner contact surface **308** and the outer contact surface **310**, of the one or more electrically conductive plugs **304**, while maintaining a substantially constant formulation of the one or more electrically conductive plugs **304**. Accordingly, the effective resistance of the seal **300** can be dependent upon the length of the one or more electrically conductive plugs **304** disposed in the seal casing **302**. For example, an increase in length of the one or more electrically conductive plugs **304**, while maintaining formulation and cross sectional area, can increase in the effective resistance of the seal **300**.

[0046] Referring again to **Figs. 3-5**, the electrical conductivity of the seal **300** may be adjusted by modifying the volumetric resistance of the elastomeric material of the one or more electrically conductive plugs **304**. Specifically, an increase of the volumetric resistance of the elastomeric material of the one or more electrically conductive plugs **304**, while maintaining a substantially constant geometry, can increase in the effective resistance of the seal **300**. In some embodiments, the volumetric resistance of the elastomeric material can be adjusted by changing the form of, the amount of, the type of, the particle size distribution, particle sizing (if necessary) of carbon used as the conductive filler. Milled carbon, carbon nanotubes, carbon Grapheme, carbon powder and various combination of these forms of carbon can be used to obtain a desired effective resistance. Accordingly, the resistance of the

one or more electrically conductive plugs **304,** the one or more electrically conductive plugs **404**, the electrically conductive plug **504**, and therefore the electrical conductivity of the seal **300**, the seal **400** and the seal **500**, may be efficiently adjusted according to particular application needs and seal sizes. Thus, the effective resistance of the seal **300** can be dependent upon of the volumetric resistance of the elastomeric material of the one or more electrically conductive plugs **304** disposed in the seal casing **302**.

[0047] According to the embodiments described herein, the effective resistance of the seal **300**, the seal **400** and the seal **500** can be configured to dissipate and to transmit electrical charge between a conductive sealing surface in contact with the inner contact surface **308** of the seal casing **302** and a conductive sealing surface in contact with the outer contact surface **310** of the seal casing **302**. For example, the inner contact surface **308** of the seal casing **302** can be placed in close contact with an outer diameter of a conductive tube and the outer contact surface **310** of the seal casing **302** can be placed in close contact with inner diameter of a conductive cylindrical chamber such that the effective resistance of the seal **300** can be determined. In some embodiments, the effective resistance can be less than about 500,000 ohms when measured at an applied electrical voltage of 100 VDC such as, for example, less than about 50,000 ohms, in one embodiment, less than about 1,000 ohms, in another embodiment, when measured at an applied electrical voltage of 100 VDC, between about 1,000 ohms and about 50,000 ohms, in another embodiment, when measured at an applied electrical voltage of 100 VDC or between about 1,000

ohms and about 500,000 ohms, in another embodiment, when measured at an applied electrical voltage of 100 VDC.

[0048] It should now be understood that the embodiments described herein can be utilized to form electrically conductive O-rings and electrically conductive custom shaped elastomeric seals suitable to pass higher voltage and current pulse levels and longer duration lightning wave forms, than previous designs. Specifically, embodiments of the present disclosure having effective resistance values between about 2,500 ohms and about 1,000,000 ohms were tested. It was discovered that embodiments having an effective resistance greater than about 0 ohms and less than about 500,000 ohms successfully passed static electricity testing. It was further discovered that embodiments having an effective resistance between about 1,000 ohms and about 50,000 ohms successfully passed both static electricity testing and lightning current testing. In testing, the embodiments described herein passed lightning voltage testing with a voltage level of about 2,500 volts at wave form "B." Thus, the embodiments described herein can be used at any and all locations on aircraft. Moreover, the use of non-conductive seal casings mitigate failure modes of previous designs. Specifically, the non-conductive seal casing can reduce arcing between the two highly conductive tubular members that are sealed by an insulated electrically conductive fluid seal. It is believed that the non-conductive seal casing can provide highly insulating surfaces that can channel lightning current flow (as well as static electrical current flow) through and around the one or more electrically conductive plugs.

[0049] It is noted that the terms "substantially" and "about" may be utilized herein to represent the inherent degree of uncertainty that may be attributed to any quantitative comparison, value, measurement, or other representation. These terms are also utilized herein to represent the degree by which a quantitative representation may vary from a stated reference without resulting in a change in the basic function of the subject matter at issue. Accordingly, a quantitative representation preceded by the term “about” should be understood to include the exact quantity in addition to a functionally equivalent range surrounding the exact quantity.

[0050] Every explicitly described quantitative range described hereinabove should be understood to include every narrower quantitative range that is bounded by the explicitly described quantitative range, as if each narrower quantitative range was expressly described. For example, an explicitly described range of “about 1,000 ohms to about 500,000 ohms” should be considered to include narrower range between (and inclusive of) the minimum value of 1,000 ohms and the maximum value of 500,000 ohms; i.e., all ranges beginning with a minimum value of 1,000 ohms or more and ending with a maximum value of 500,000 ohms; or less, e.g., about 5,000 ohms to about 450,000 ohms, about 10,000 ohms to about 400,000 ohms, about 3,000 ohms to about 490,000 ohms, etc.

[0051] Furthermore, it is noted that directional references such as, for example, inward, outward, radial, axial and the like have been provided for clarity and without limitation. Thus, the directions may be reversed or oriented in any direction by making corresponding changes to the depicted structure to extend the examples described herein.

[0052] While particular embodiments have been illustrated and described herein, it should be understood that various other changes and modifications may be made without departing from the spirit and scope of the claimed subject matter. Moreover, although various aspects of the claimed subject matter have been described herein, such aspects need not be utilized in combination. It is therefore intended that the appended claims cover all such changes and modifications that are within the scope of the claimed subject matter.

CLAIMS

1. An insulated electrically conductive fluid seal, comprising:

a seal casing formed from a non-conductive elastomer, wherein the seal casing comprises an inner contact surface and an outer contact surface; and

one or more electrically conductive plugs disposed in the seal casing, wherein the one or more electrically conductive plugs extend between inner contact surface and the outer contact surface, and wherein the one or more electrically conductive plugs are configured to dissipate and to transmit electrical charge between the inner contact surface and the outer contact surface of the seal casing.

2. The insulated electrically conductive fluid seal of claim 1, wherein the one or more electrically conductive plugs are substantially ring shaped.

3. The insulated electrically conductive fluid seal of claim 2, wherein the one or more electrically conductive plugs consists of one electrically conductive plug.

4. The insulated electrically conductive fluid seal of claim 1, wherein the one or more electrically conductive plugs comprise an elastomer doped with electrically conductive carbon.

5. The insulated electrically conductive fluid seal of claim 1, wherein an effective resistance measured between the inner contact surface and the outer contact

surface of the seal casing is dependent upon a number of the one or more electrically conductive plugs disposed in the seal casing.

6. The insulated electrically conductive fluid seal of claim 1, wherein an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing is dependent upon a contact area of the one or more electrically conductive plugs disposed in the seal casing.

7. The insulated electrically conductive fluid seal of claim 1, wherein an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing is dependent upon a length of the one or more electrically conductive plugs disposed in the seal casing.

8. The insulated electrically conductive fluid seal of claim 1, wherein an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing is dependent upon a volumetric resistance of the one or more electrically conductive plugs disposed in the seal casing.

9. The insulated electrically conductive fluid seal of claim 1, wherein the non-conductive elastomer comprises fluorosilicone, ethylene propylene rubber, fluorocarbon, silicone, or nitrile.

10. The insulated electrically conductive fluid seal of claim 1, wherein the seal casing comprises a rectangular cross-section.

11. The insulated electrically conductive fluid seal of claim 1, wherein the casing is configured to be stretched about 50% from an original size for about five minutes, released and then retract to within about 10% of the original size within about five minutes of release.

12. The insulated electrically conductive fluid seal of claim 1, wherein an effective resistance measured between the inner contact surface and the outer contact surface of the seal casing is less than about 500,000 ohms

13. The insulated electrically conductive fluid seal of claim 1, wherein a volume ratio of the one or more electrically conductive plugs to the seal casing is between about 15% and about 50%.

14. The insulated electrically conductive fluid seal of claim 1, wherein the one or more electrically conductive plugs are molded radially into the seal casing.

15. The insulated electrically conductive fluid seal of claim 1, wherein the seal casing encloses a central orifice, and wherein the inner contact surface is disposed radially inward with respect to the central orifice compared to the outer contact surface.

16. An insulated electrically conductive fluid seal, comprising:

a seal casing formed from a non-conductive elastomer, wherein the seal casing comprises an inner contact surface, an outer contact surface disposed radially outward of the inner contact surface, a first axial surface and

a second axial surface such that the first axial surface and the second axial surface delimit the seal casing; and

an electrically conductive plug disposed in the seal casing, wherein the conductive plug is substantially ring shaped and extends through the seal casing and wherein the electrically conductive plug is configured to dissipate and to transmit electrical charge between the inner contact surface and the outer contact surface.

17. The insulated electrically conductive fluid seal of claim 16, wherein the electrically conductive plug comprises an elastomer doped with electrically conductive carbon.

18. The insulated electrically conductive fluid seal of claim 16, wherein the electrically conductive plug comprises a rounded protuberance that extends beyond the outer contact surface of the seal casing.

19. The insulated electrically conductive fluid seal of claim 16, wherein an effective resistance measured between the inner contact surface and the outer contact surface is less than about 500,000 ohms.

20. The insulated electrically conductive fluid seal of claim 16, further comprising an isolation layer disposed between the electrically conductive plug and the seal casing, wherein the isolation layer has a higher conductivity than the electrically conductive plug.

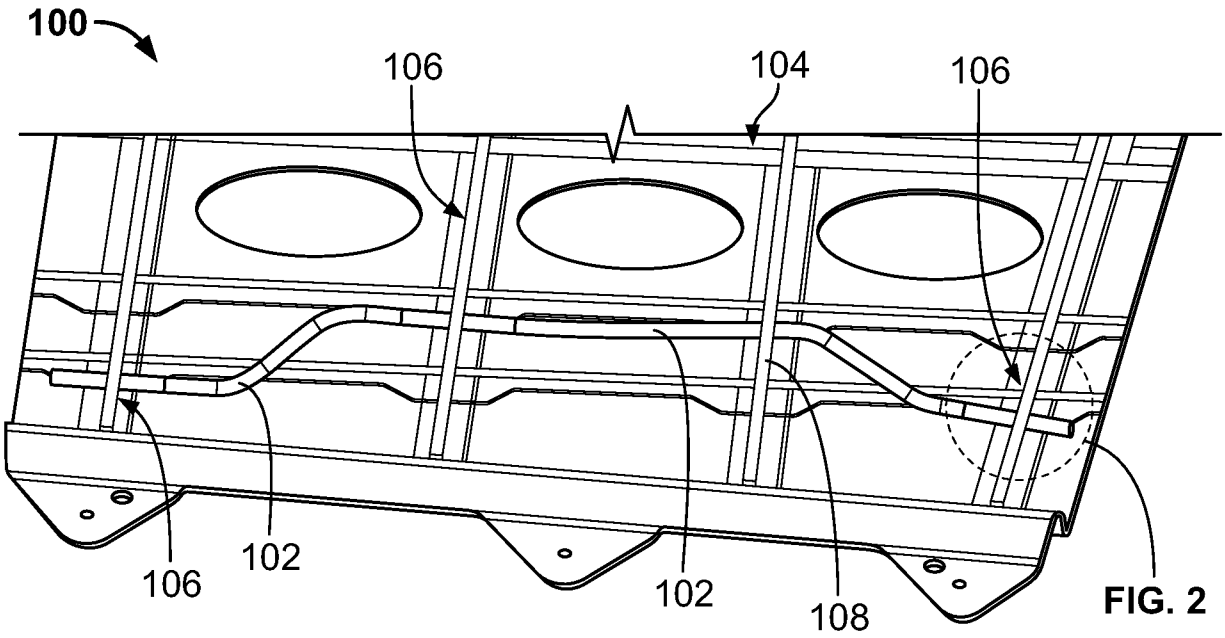


FIG. 1

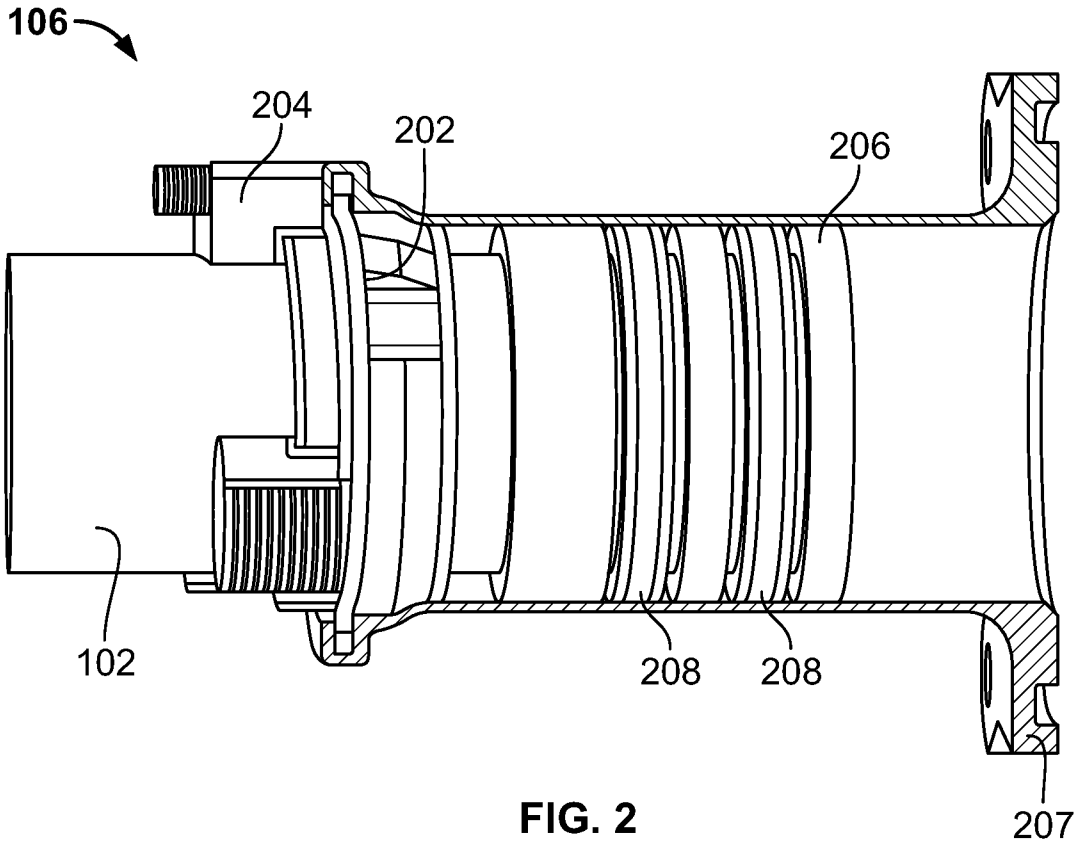


FIG. 2

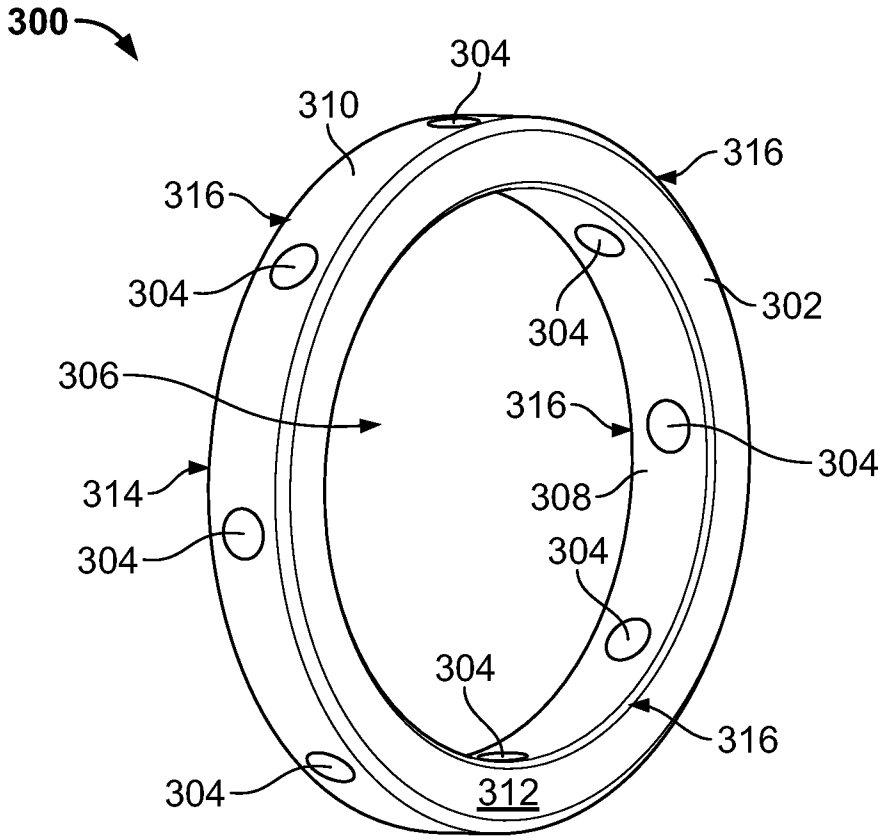

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FIG. 3

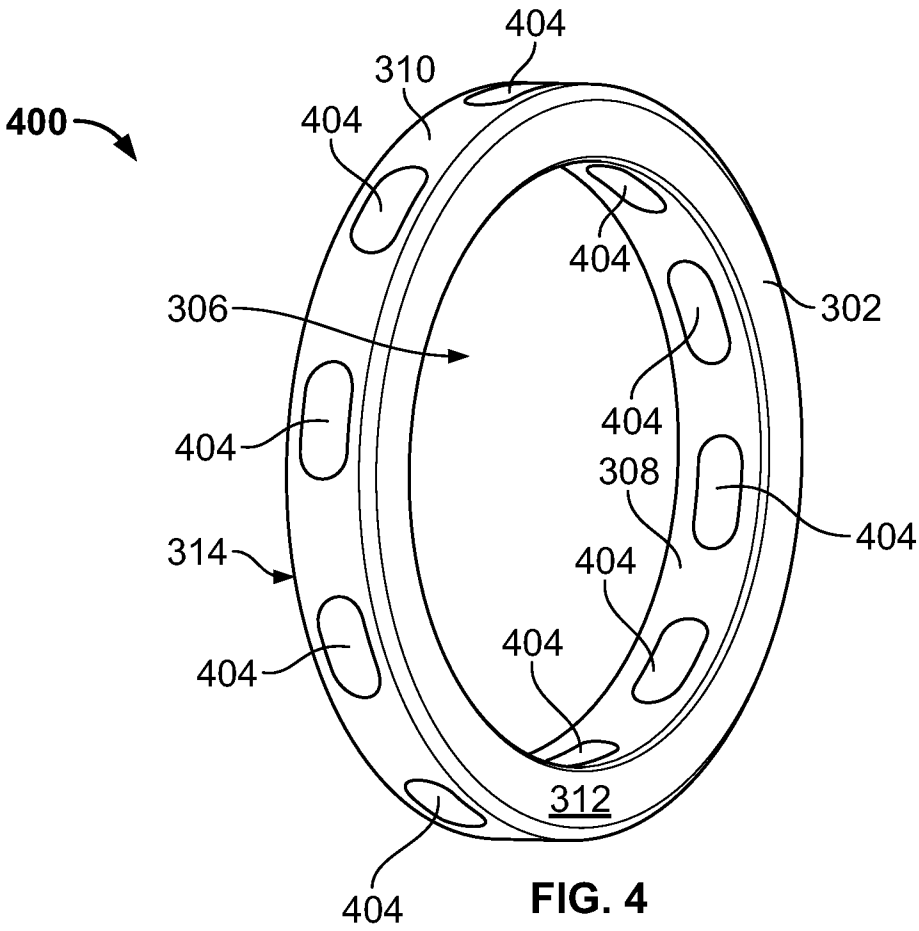

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FIG. 4

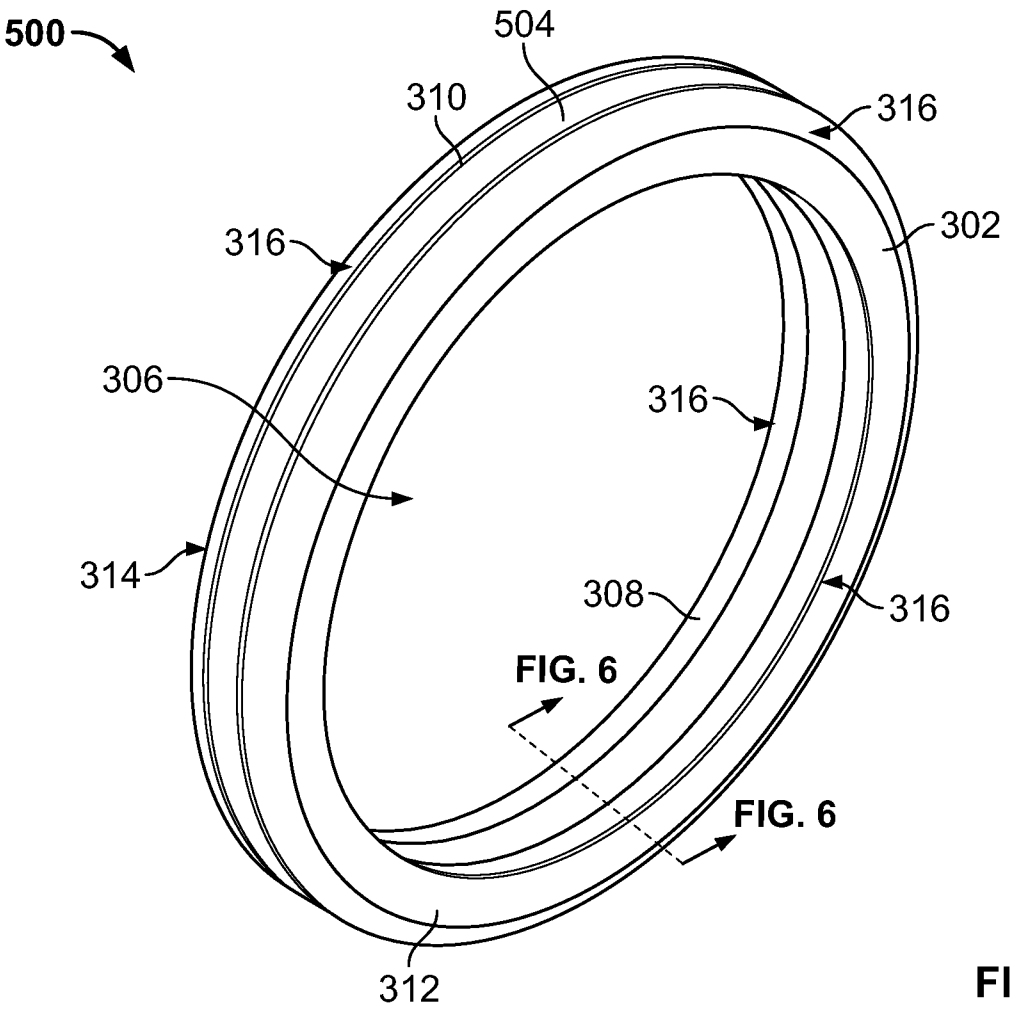

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FIG. 6
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FIG. 5

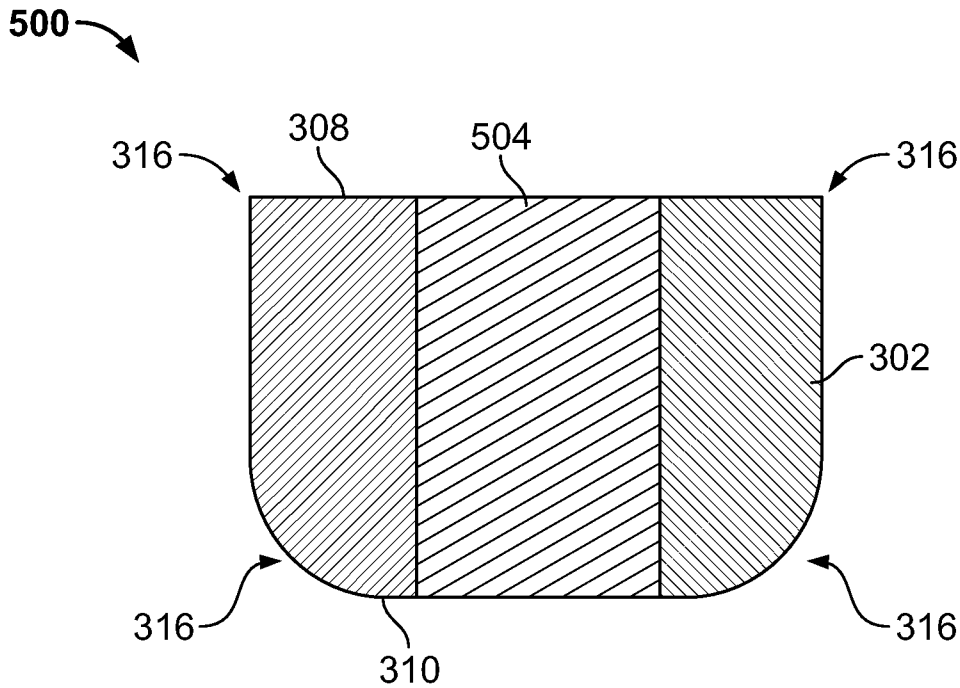

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FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/039478

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16J15/06 F16L25/01
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16J F16L B64D

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 264 339 A1 (NEOTECHA GMBH [AT]) 22 December 2010 (2010-12-22) paragraphs [0014] - [0016], [0019], [0027] claims 6,8 figure	1,4-13
X	US 2 966 539 A (SEARS EDWARD C ET AL) 27 December 1960 (1960-12-27) column 1, lines 36-42 column 3, lines 23-29, 48-64 column 3, line 75 - column 4, line 15 figures 1-8	1,5-15

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 September 2015	21/09/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Van Wel, Oscar

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/039478

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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