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(54) SAFETY WAVEGUIDE SEGMENTS

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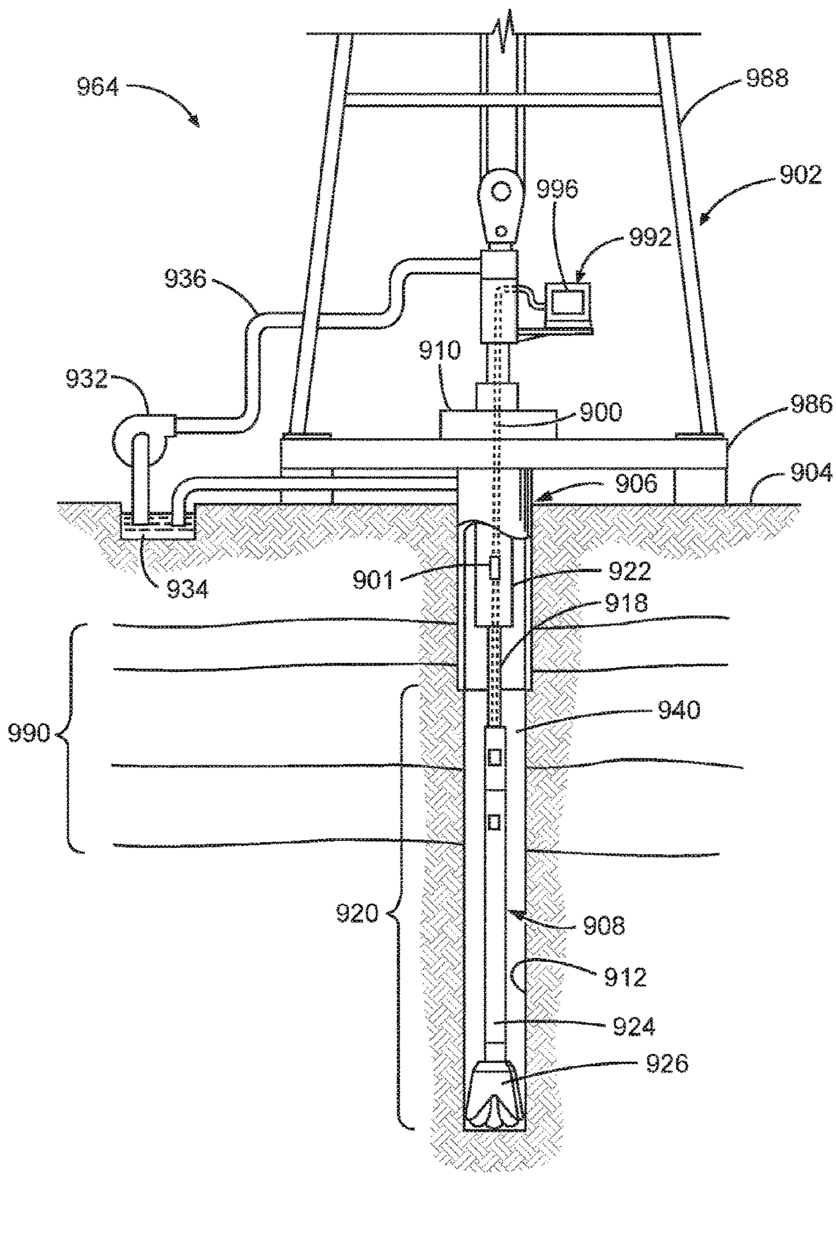
(57) ABSTRACT

A safety waveguide apparatus includes a waveguide segment body sealed by a respective dielectric plug on each end of the waveguide body. The waveguide segment body, or at least one of the dielectric plugs, are configured to divert an oil flow from within the waveguide segment body.



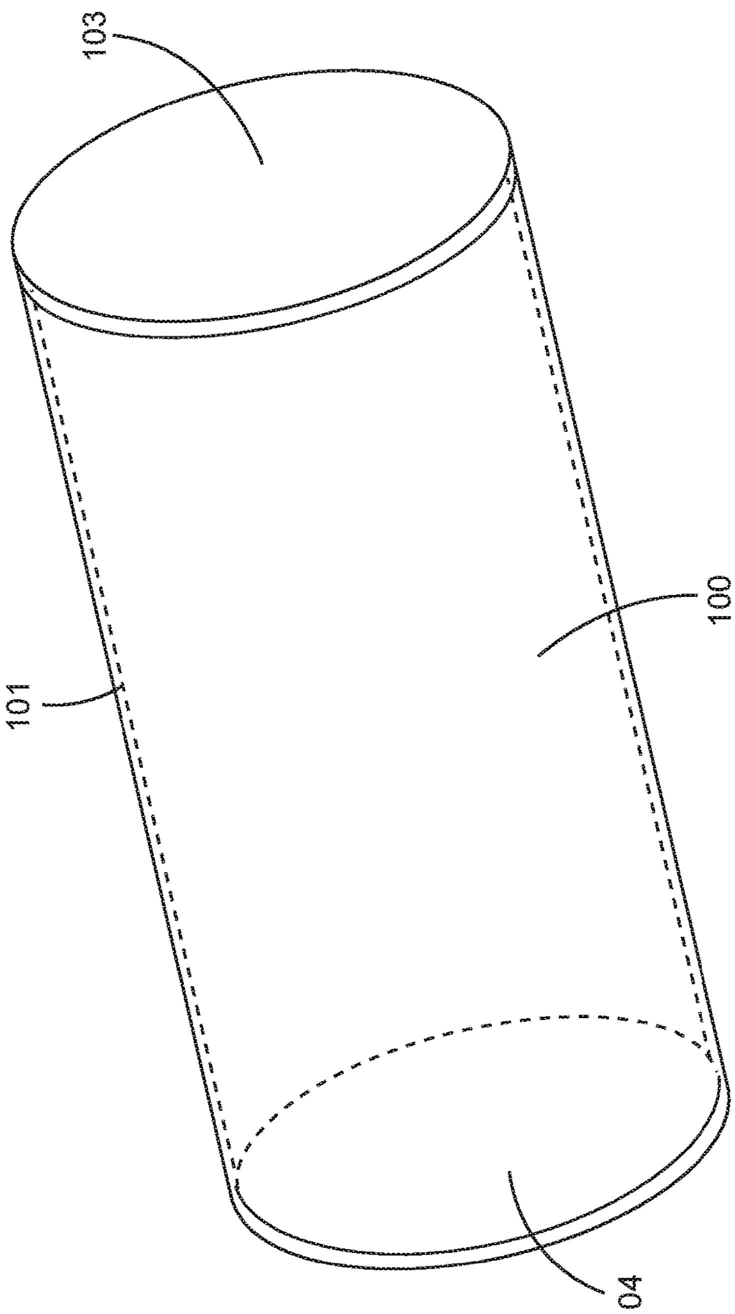


Fig. 1

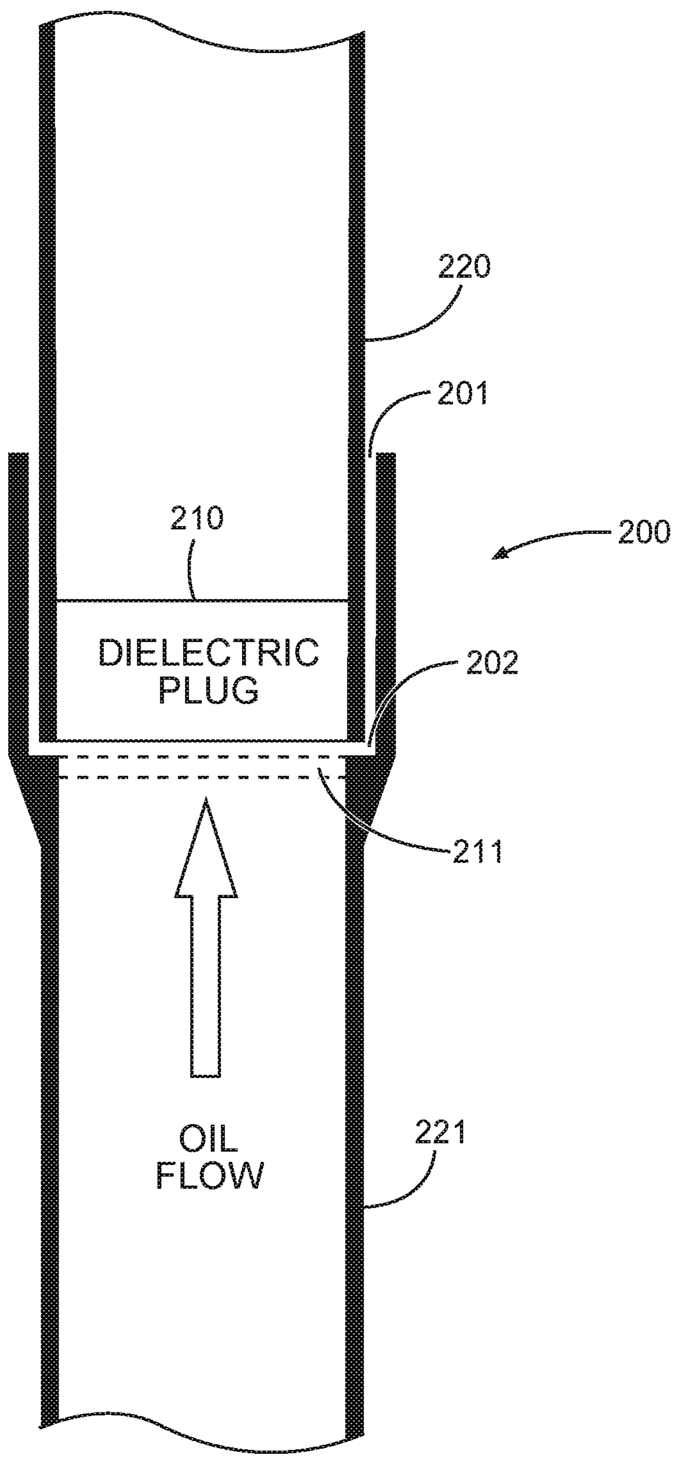


Fig. 2

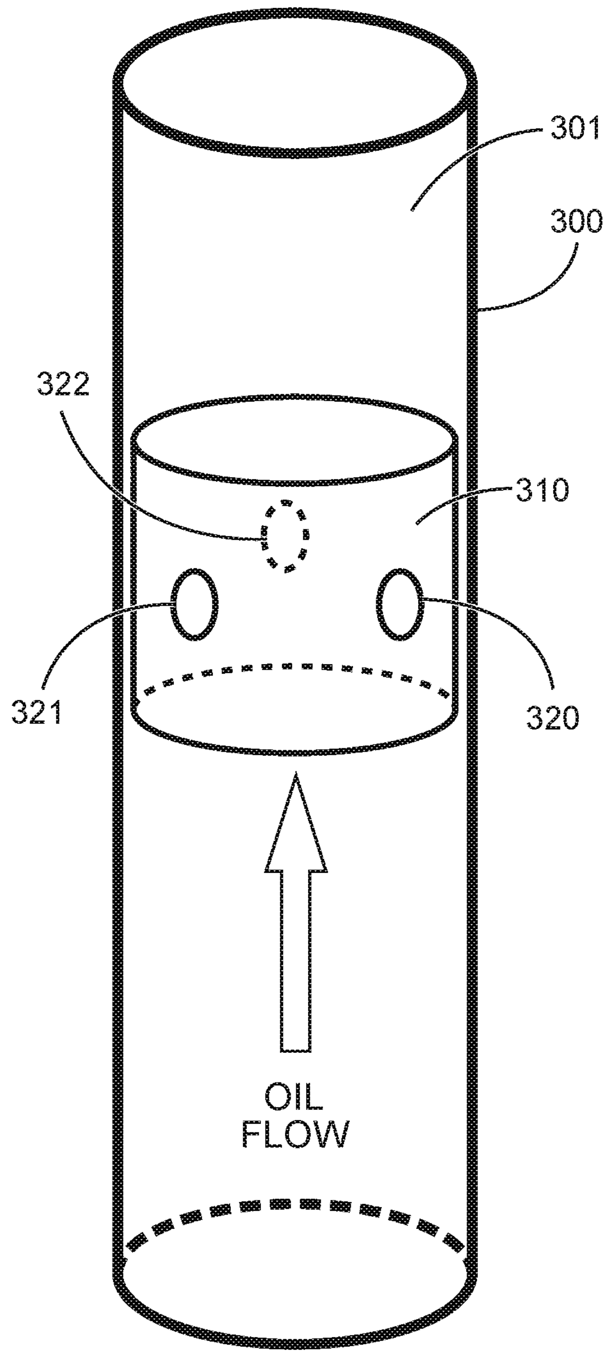


Fig. 3

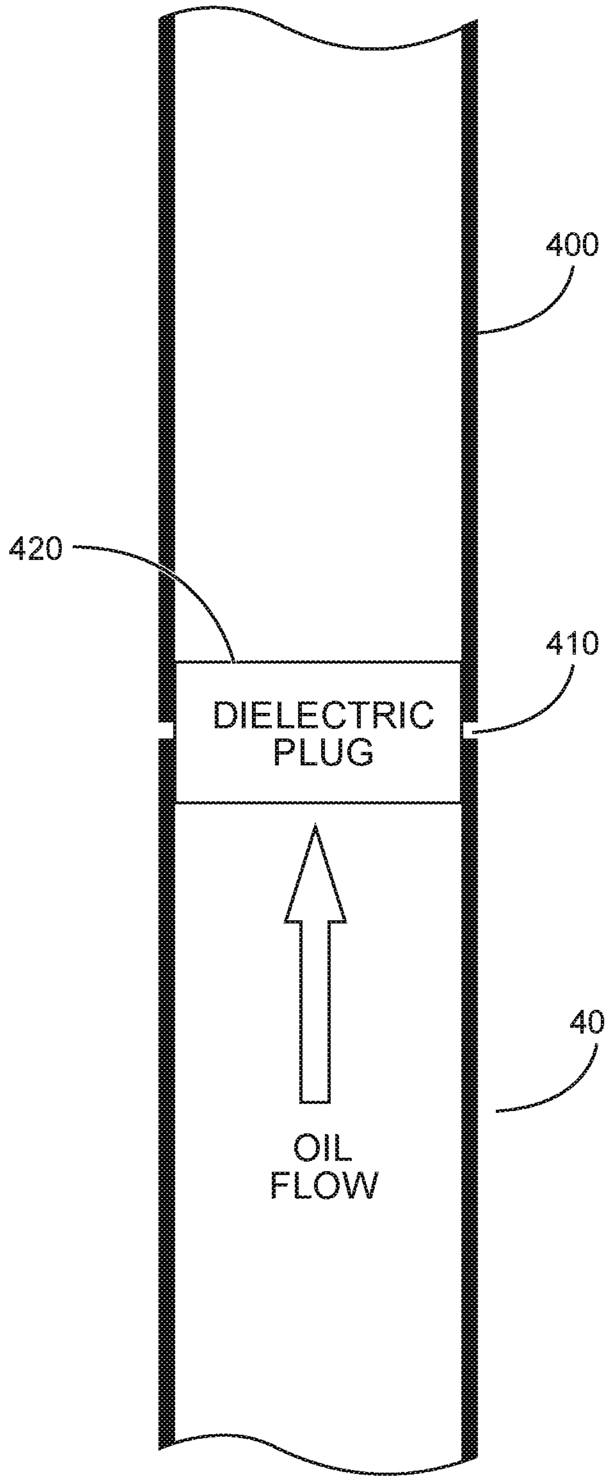


Fig. 4

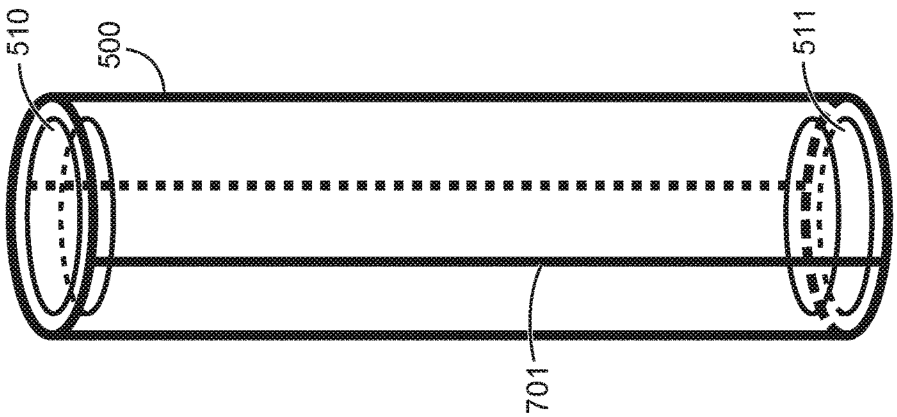


Fig. 7

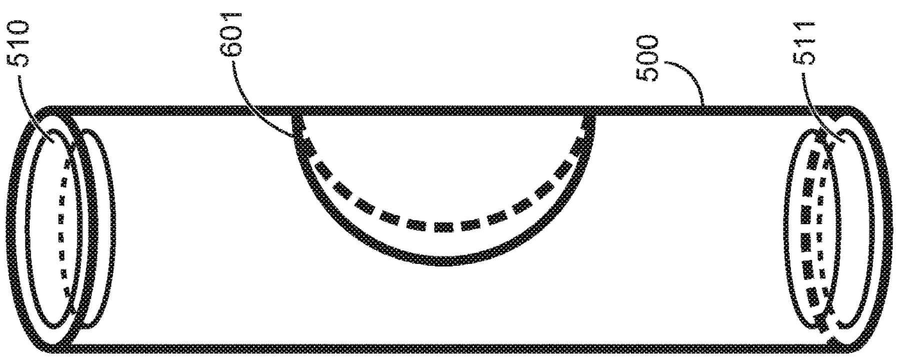


Fig. 6

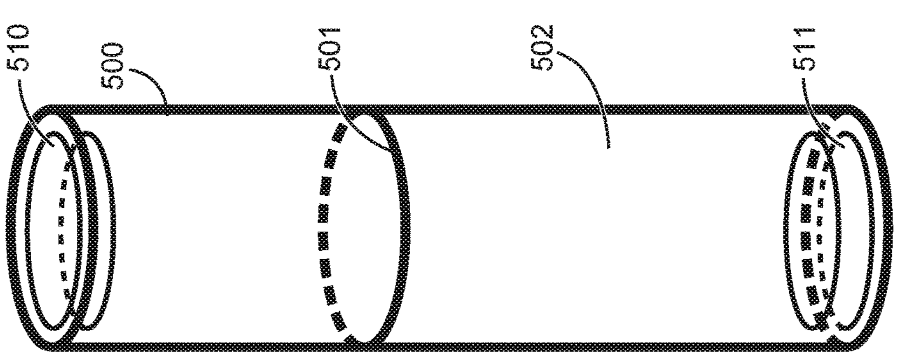


Fig. 5

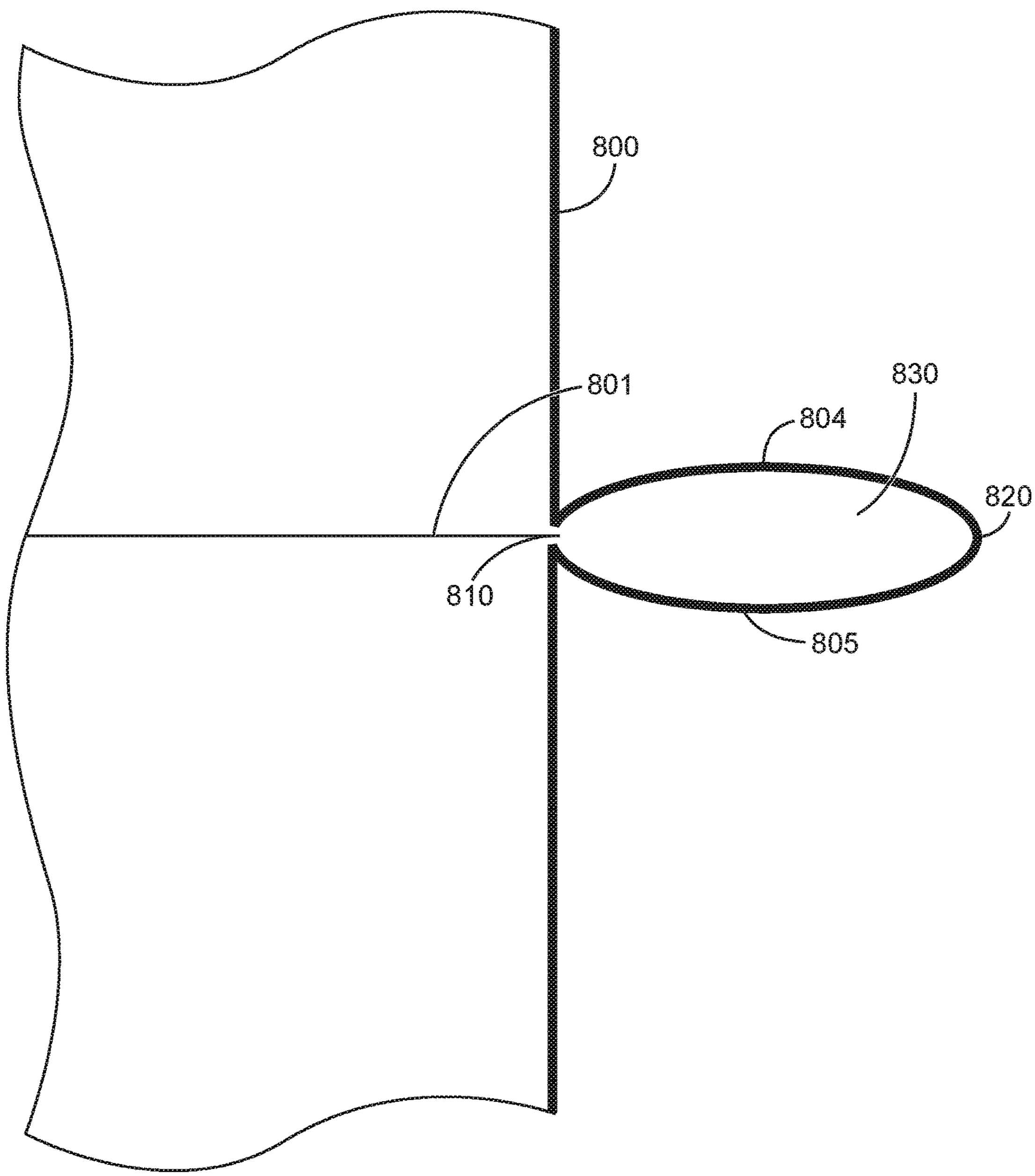


Fig. 8

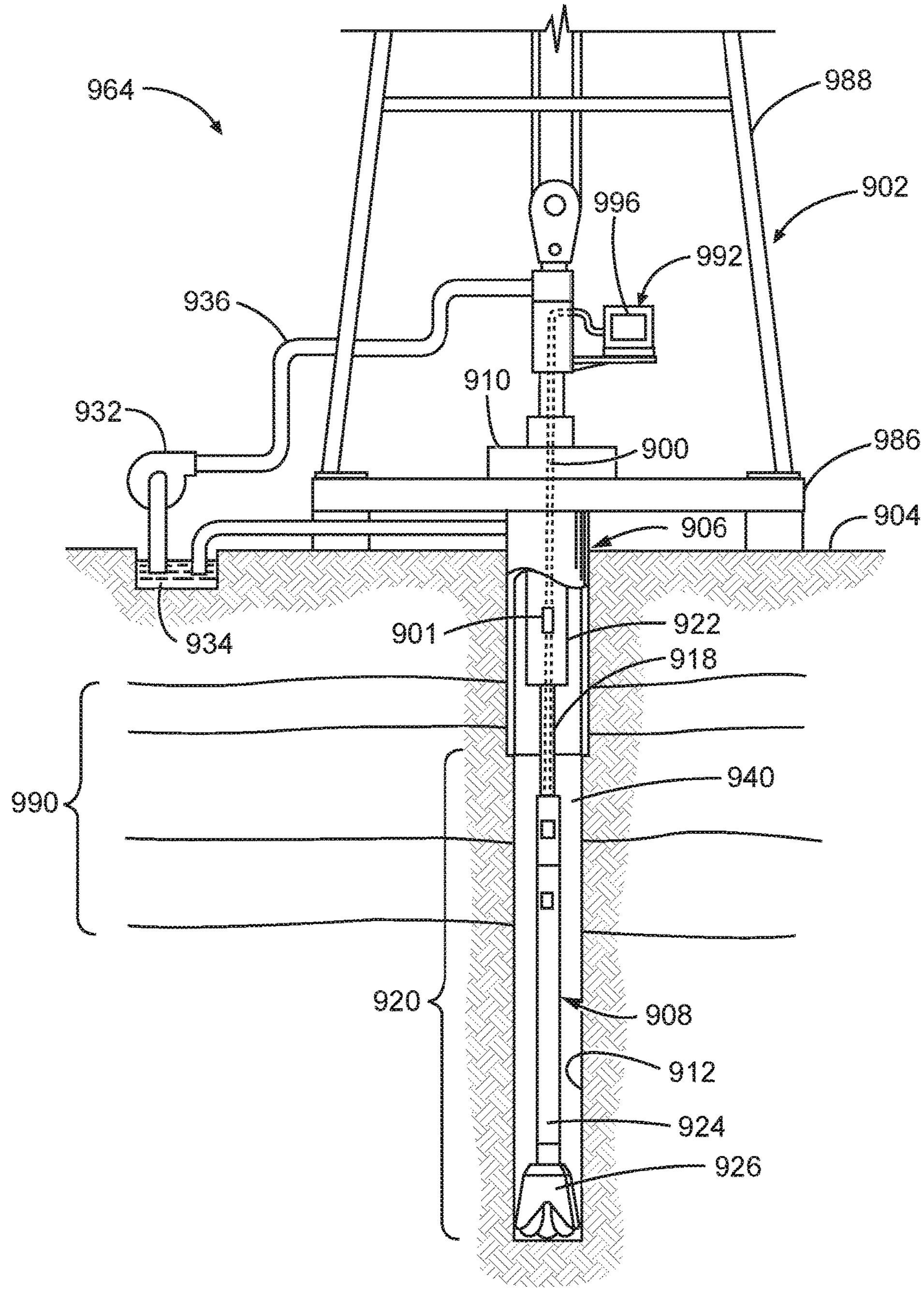


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Fig. 9

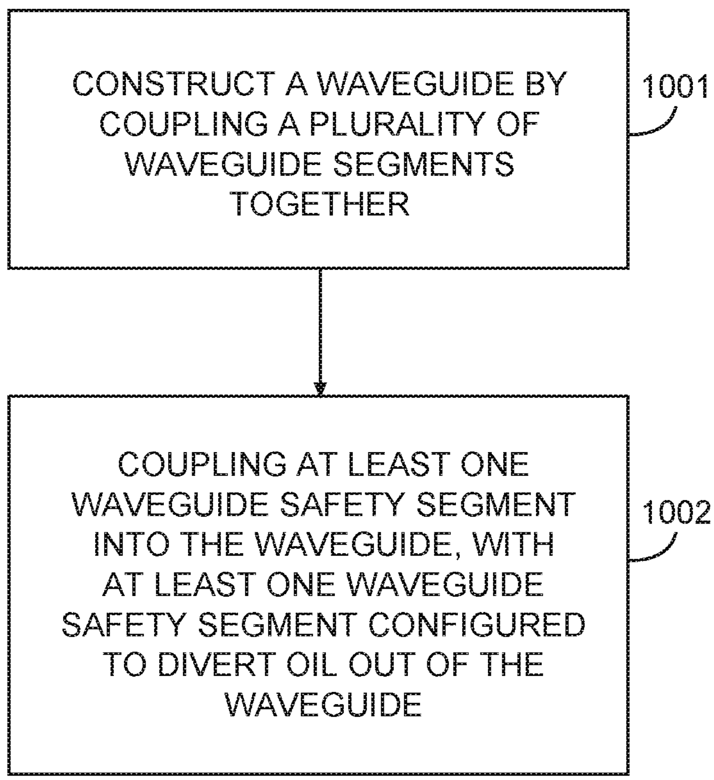
CONSTRUCT A WAVEGUIDE BY COUPLING A PLURALITY OF WAVEGUIDE SEGMENTS TOGETHER
1001
COUPLING AT LEAST ONE WAVEGUIDE SAFETY SEGMENT INTO THE WAVEGUIDE, WITH AT LEAST ONE WAVEGUIDE SAFETY SEGMENT CONFIGURED TO DIVERT OIL OUT OF THE WAVEGUIDE
1002

Fig. 10

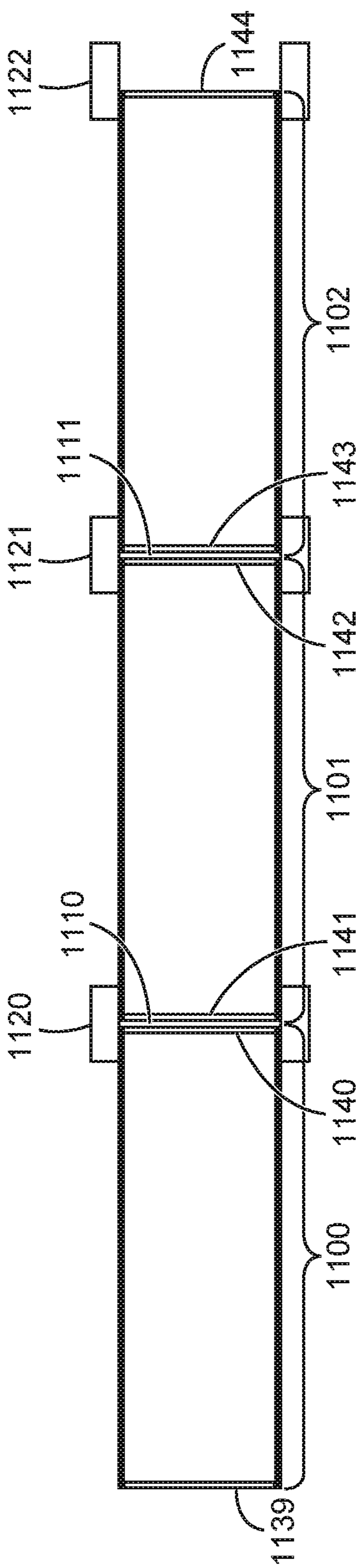
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Fig. 11

SAFETY WAVEGUIDE SEGMENTS

BACKGROUND

[0001] In drilling wells for oil and gas exploration, understanding the structure and properties of the associated geological formation provides information to aid such exploration. Measurements may be performed in a borehole to obtain this information. However, the environment in which the drilling tools operate and where measurements are made may be located at significant distances below the surface. It may be desirable to transmit downhole measurements to the surface for analysis and control purposes.

[0002] Electrical cables have been investigated for high speed communications to and from downhole tools. Use of electrical cables for such communication, however, has drawbacks due to limitations with information bandwidth. Optical fibers have also been investigated for high speed communications to and from downhole tools to overcome the information bandwidth limitations of electrical cables. Optical fibers have the drawback of typically needing near perfect optical alignment at their connections in order to achieve low signal loss.

[0003] Hollow waveguides may also be used to propagate signals between the downhole environment and the surface. However, if a hollow waveguide breaks, a path may be created through the waveguide for high pressure oil to flow to the surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** is a diagram showing a waveguide or waveguide segment apparatus, according to various embodiments.

[0005] FIG. **2** is a cross-sectional diagram showing a breakable waveguide connection, according to various embodiments.

[0006] FIG. **3** is a cross-sectional diagram showing vent holes covered by a dielectric plug in a waveguide or waveguide segment, according to various embodiments.

[0007] FIG. **4** is a cross-sectional diagram showing waveguide segments coupled by a breakable dielectric plug, according to various embodiments.

[0008] FIGS. **5-7** are cross-sectional diagrams showing multiple piece waveguide segments held together by external pressure, according to various embodiments.

[0009] FIG. **8** is a cross-sectional diagram showing external lips on a waveguide or waveguide segment, according to various embodiments.

[0010] FIG. **9** is a diagram showing a drilling system, according to various embodiments.

[0011] FIG. **10** is a flowchart of a method for constructing a waveguide, according to various embodiments.

[0012] FIG. **11** is a cross-sectional diagram showing a waveguide constructed of a plurality of waveguide segments, according to various embodiments.

DETAILED DESCRIPTION

[0013] Some of the challenges noted above, as well as others, may be addressed by using a waveguide incorporating breakable segments or connections that are configured to fail when relatively high pressure oil enters the waveguide. Similar to a fuse in an electrical circuit, when the safety waveguide segment experiences a particular internal pressure beyond that for which it is designed, the segment body or at least one of the dielectric plugs are configured to divert an oil flow from within the waveguide segment body.

[0014] FIG. **1** is a diagram showing a waveguide or waveguide segment apparatus, according to various embodiments. In an embodiment, a plurality of waveguide segments may be coupled together to form a waveguide. In another embodiment, the waveguide may be one continuous segment that includes one or more of the subsequently described embodiments of FIGS. **2-8**. The waveguide and waveguide segment apparatus are configured to internally propagate a signal.

[0015] The segment includes a substantially cylindrical body **101** that encloses a chamber **100**. The chamber is sealed from the ambient atmosphere by two dielectric plugs **103**, **104** (e.g., windows, dielectric windows) on either end of the substantially cylindrical body **101**.

[0016] The body **101** of the segment may comprise any material that enables the waveguide to propagate relatively high frequency signals. For example, the body **101** may comprise a metal pipe (e.g., copper). In another embodiment, the body **101** may be any material (e.g., steel or nonmetallic material) and the inner surface of the body **101** may be lined with a metal (e.g., gold).

[0017] The body **101** is shown and described as "cylindrical". The "cylindrical" description may include any shape that is approximately cylindrical such as, for example, oval, or any other shape that is configured to propagate signals.

[0018] The chamber **100** of the waveguide segment is sealed from the ambient atmosphere by the dielectric plugs **103**, **104** coupled to their respective ends of the axial length of the body **101**. The dielectric plugs **103**, **104** are made of a material that is transparent to any frequencies being propagated through the waveguide.

[0019] Moisture in the atmosphere is known to limit the propagation of some relatively high frequency signals. Thus, the chamber **100** of the waveguide may be at an approximate vacuum, a partial vacuum (e.g., less than 1 atmosphere) with a gas having a diffraction index of approximately 1, a gas atmosphere at approximately atmospheric pressure, or a combination of any of these. For example, the gas may be nitrogen, argon, and/or helium and the partial vacuum may include one or more of these gases. Subsequent reference to a vacuum is also defined to include a partial vacuum with one or more gases.

[0020] Since the waveguide or waveguide segments are constructed such that a vacuum or gas is sealed within the chamber, it is assumed that no oil is naturally present within the waveguide. Thus, the presence of an oil pressure is an indication that a portion of the waveguide downhole has been breached by oil and the oil has begun to flow upward (i.e., from downhole toward the surface) Each of the following described embodiments assumes that an upward oil flow occurs through the waveguide or the waveguide segment body **101** in order to trigger the safety waveguide segment.

[0021] FIG. **2** is a cross-sectional diagram showing a breakable waveguide connection, according to various embodiments. Only two waveguide segments **220**, **221** are illustrated in the figure. However, the concept can be used in one or more locations of an entire waveguide.

[0022] One of the segments **221** may comprise an end **200** having a recess **201** into which another adjacent waveguide segment **220** is insertable. The inserted segment **220** is then adjacent to or sits on a ledge **202** within the recess.

[0023] As described in the embodiment of FIG. **1**, the inserted segment **220** is sealed by a dielectric plug **210** that seals the bottom end of the inserted segment **220**. The force necessary to break the dielectric plug **210** is greater than the force necessary to push the inserted segment **220** out of the recess **201**. Thus, as the oil flow pressure builds up, the connection between the two segments **220**, **221** will break (i.e., segment **220** pushed out of the recess **201**) before the dielectric plug **210** breaks so that the oil is diverted out of the connection instead of up through the waveguide to the surface.

[0024] In an embodiment, an optional dielectric plug **211** seals the lower segment **221** to protect the inner chamber of that segment from dirt and moisture. This dielectric plug **211** may have a thinner composition than the dielectric plug **210** of the inserted segment **220** so that the lower dielectric plug **211** will break at approximately the same pressure or less as the pressure necessary to break the connection between the two segments **220**, **221**.

[0025] FIG. **3** is a cross-sectional diagram showing vent holes **320**-**322** covered by a dielectric plug **310** in a waveguide or waveguide segment **300**, according to various embodiments. This embodiment uses one or more vent holes **320**-**322** through the segment body **300** and into the inner chamber **301** (i.e., connecting the chamber **301** with the ambient atmosphere) to enable the oil flow through the chamber **301** to be diverted out of the segment body **300** through the vent holes **320**-**322**. The internal dielectric plug **310** seals the holes **320**-**322** from the ambient atmosphere when no oil is flowing through the segment body **300**.

[0026] The plug **310** may comprise a dielectric material and/or thickness that is transparent to certain frequencies of radiation. Thus, those frequencies being propagated through the waveguide are not impeded by the plug **310**.

[0027] The outside of the plug **310** that is visible through the holes **320**-**322** may be coated with the same material that makes up the waveguide body **300** or that is used to coat the inside surface of the waveguide body **300** or by some other conductive material. This enables the radiation to propagate through the waveguide **300** and not be affected by the holes. For example, the material may be a metal.

[0028] When oil is flowing through the waveguide **300**, the oil pressure pushes the plug **310** upwards to expose the holes **320**-**322**. Once the holes **320**-**322** are opened, the oil can be diverted out of the segment body **300** or drilling fluid can flow into the segment body **300** in order to prevent the pressurized oil from the bottom of the oil well from flowing to the surface through the waveguide pipe.

[0029] In another embodiment, the plug **310** may be made of a frangible material and/or extremely thin relative to the thickness of the segment body **300**. In such an embodiment, the oil pressure may break the plug **310** or both move and break the plug **310** to expose the vent holes **320**-**322**.

[0030] FIG. **4** is a cross-sectional diagram showing waveguide segments **400**, **401** coupled by a breakable dielectric plug **420**, according to various embodiments. The waveguide segments **400**, **401** are coupled by the plug **420** at a joint **410**.

[0031] The plug **420** may comprise a dielectric material and/or thickness that is transparent to certain frequencies of radiation. Thus, those frequencies being propagated through the waveguide are not impeded by the plug **420**.

[0032] The outside of the dielectric plug **420** may be metal coated, especially if there is a gap at the joint **410** between the waveguide segments **400**, **401**. The plug **420** may be glued or otherwise fastened to the waveguide segments **400**, **401**. The plug **420** may also be held into the waveguide segments by a vacuum in each of the waveguide segments **400**, **401**.

[0033] If oil flows through one waveguide segment **401**, the oil pressure either pushes the plug **420** up, breaks the plug **420**, or both pushes and breaks the plug **420**. When the plug **420** is removed from the joint **410** holding the two segments **400**, **401** together, the two segments **400**, **401** become disconnected. Thus, the flow of oil through the waveguide to the surface is diverted.

[0034] FIGS. **5**-**7** are cross-sectional diagrams showing multiple piece waveguide segments held together by external pressure, according to various embodiments. These embodiments are for purposes of illustration only as other similarly cut waveguide segments would operate as safety waveguide segments in a similar fashion.

[0035] Each of the illustrated waveguide segments **500** may be substantially the same as the apparatus illustrated in FIG. **1**. For example, the body **500** encloses a chamber **502** that is sealed by the dielectric plugs **510**, **511** at respective ends of the body **500**. The chamber **502** is filled with a vacuum or partial vacuum.

[0036] In the illustrated embodiments of FIGS. **5**-**7**, the body **500** of each individual segment may be cut **501**, **601**, **701** into two or more pieces that are held together by the pressure differential between the ambient pressure on the outside and the vacuum inside. The ability of a vacuum to keep such pieces together is well known (i.e., Otto von Guericke's Magdeburg hemispheres).

[0037] If there is a downhole breach of the waveguide and oil flows up, the oil pressure first breaks the dielectric plug **511** sealing the bottom of the waveguide segment **500** and flows into the segment **500**. This destroys the vacuum and increases the inside pressure of the segment. When pressure from oil flowing through the segment **500** is greater than the pressure on the outside of the body **500** (i.e., ambient pressure), each individual waveguide segment will fall apart at their respective cuts **501**, **601**, **701**. In this embodiment, the dielectric plug **511** on the end of the segment can be relatively thin since it only has to withstand atmospheric pressure so that the waveguide segment does not fall apart while it is installed into a waveguide.

[0038] In an embodiment, the cuts **501**, **601**, **701** may have a sealant lining the cut surface between the two pieces. Such a sealant may provide improved protection for the vacuum within the segment **500** so that foreign matter present on the cut surfaces does not provide microscopic pathways for the ambient pressure to enter the segment **500**. The sealant might also act as a glue holding the pieces together as long as this glue is weak enough to not prevent the pieces from being separated by the internal pressure of oil flowing through the waveguide. Thus the glue breaks in response to the internal flow of oil within the waveguide or safety waveguide segment body.

[0039] FIG. **8** is a cross-sectional diagram showing external lips **804**, **805** on a waveguide or waveguide segment **800**, according to various embodiments. The lips **804**, **805** provide additional surface area for the ambient pressure to push against in order to provide a stronger force for holding two pieces of a segment together.

[0040] The lips **804**, **805** are attached to the segment **800** such that a first lip **804** is attached to a first surface of the segment **800** on one side of the cut **801** while a second lip **805** is attached to a second surface of the segment **800** on an opposing side of the cut **801**. An opening **810** between the lips **804**, **805** and the interior vacuum of the segment **800** enables the vacuum to exist in a gap **830** between the lips **804**, **805**. An air tight seal **820** between outer edges of the lips **804**, **805** protects the vacuum in the gap **830** and is held in place by the ambient atmospheric pressure working on the surface area of the lips **804**, **805**.

[0041] The lips **804**, **805** are shown on a cut **801** through the body of the segment. For example, the lips **804**, **805** may be located on any one of the cuts of FIGS. **5-7**. In another embodiment, the lips **804**, **805** may be incorporated onto other embodiments as well.

[0042] The lips **804**, **805** may be made of the same material as the body of the segment (e.g., metal). In another embodiment, the lips **804**, **805** may be made of a different material than the body of the segment.

[0043] Yet another embodiment may construct the waveguide or waveguide segment body from a relatively thin plastic or other material. An inside surface of the body may then be coated with metal (e.g., approximately 1 μm thickness of coating layer). If the metal coating is thicker than the skin depth, such a waveguide will behave (with respect to electromagnetic transmission properties) like a normal metal waveguide.

[0044] The relatively thin plastic material cannot withstand high pressure inside relative to the ambient pressure. Thus if oil flows through the waveguide, the waveguide segment will burst and divert the flow of oil from the remainder of the waveguide.

[0045] In another embodiment, the relatively thin material waveguide segment may be disposed in a vacuum filled metal pipe with cuts, such as described in the embodiments of FIGS. **5-7**. In such a waveguide, a traveling radiation wave sees the smooth metal coating inside of the plastic pipe so that the inside material of the segment body or the cut in the segment body do not cause any measurable signal loss in a propagated signal.

[0046] The embodiment of inserting a plastic pipe (coated on its inner surface with a metal) into a strong metal pipe with bad inside surface properties may be useful as a dielectric lining even if the metal waveguide is a standard waveguide without any safety features. In such an embodiment, the flow of oil through the waveguide may not be preventable but the problems related to the smoothness and the electric and magnetic properties of the outside waveguide may be reduced or eliminated. If a dielectric lining is desired inside of the waveguide (for example to reduce mode conversion), the plastic pipe may be metal-coated on its outside so that the plastic acts as the dielectric lining.

[0047] The above-described embodiments may be incorporated in one location of a waveguide or in multiple locations. For example, in a waveguide measured in multiple kilometers, a plurality of the safety waveguide segments may be incorporated into the waveguide. The waveguide may also incorporate a combination of the various embodiments of the safety waveguide segment.

[0048] FIG. **9** is a diagram showing a drilling system, according to various embodiments. The system **964** includes a drilling rig **902** located at the surface **904** of a well **906**. The drilling rig **902** may provide support for a drillstring **908**. The drillstring **908** may operate to penetrate the rotary table **910** for drilling the borehole **912** through the subsurface formations **990**. The drillstring **908** may include a drill pipe **918** and the bottom hole assembly (BHA) **920** (e.g., drill string), perhaps located at the lower portion of the drill pipe **918**.

[0049] The waveguide **900** including one or more embodiments of the safety waveguide segment apparatus **901** described previously may be disposed in the drill string to the BHA. In another embodiment, the waveguide **900** may be external to the drill string **908**. Thus, the waveguide **900** enables the BHA to communicate with the surface workstation **992** through relatively high frequency telemetry.

[0050] The BHA **920** may include drill collars **922**, a down hole tool **924**, stabilizers, sensors, an RSS, a drill bit **926**, as well as other possible components. The drill bit **926** may operate to create the borehole **912** by penetrating the surface **904** and the subsurface formations **990**.

[0051] During drilling operations within the cased borehole **912**, the drillstring **908** (perhaps including the drill pipe **918** and the BHA **920**) may be rotated by the rotary table **910**. Although not shown, in addition to or alternatively, the BHA **920** may also be rotated by a motor (e.g., a mud motor) that is located down hole. The drill collars **922** may be used to add weight to the drill bit **926**. The drill collars **922** may also operate to stiffen the bottom hole assembly **920**, allowing the bottom hole assembly **920** to transfer the added weight to the drill bit **926**, and in turn, to assist the drill bit **926** in penetrating the surface **904** and subsurface formations **990**.

[0052] During drilling operations, a mud pump **932** may pump drilling fluid (sometimes known by those of ordinary skill in the art as "drilling mud") from a mud pit **934** through a hose **936** into the drill pipe **918** and down to the drill bit **926**. The drilling fluid can flow out from the drill bit **926** and be returned to the surface **904** through an annular area **940** between the drill pipe **918** and the sides of the borehole **912**. The drilling fluid may then be returned to the mud pit **934**, where such fluid is filtered. In some examples, the drilling fluid can be used to cool the drill bit **926**, as well as to provide lubrication for the drill bit **926** during drilling operations. Additionally, the drilling fluid may be used to remove subsurface formation cuttings created by operating the drill bit **926**.

[0053] A workstation **992** including a controller **996** may include modules comprising hardware circuitry, a processor, and/or memory circuits that may store software program modules and objects, and/or firmware, and combinations thereof. The workstation **992** may also include modulators and demodulators for modulating and demodulating data transmitted downhole through the waveguide **900** or received through the waveguide **900** from the downhole environment. The workstation **992** and controller **996** are shown near the rig **902** only for purposes of illustration as these components may be located at remote locations.

[0054] These implementations can include a machine-readable storage device having machine-executable instructions, such as a computer-readable storage device having computer-executable instructions. Further, a computer-readable storage device may be a physical device that stores data represented by a physical structure within the device. Such a physical device is a non-transitory device. Examples of a non-transitory computer-readable storage medium can include, but not be limited to, read only memory (ROM), random access memory (RAM), a magnetic disk storage device, an optical storage device, a flash memory, and other electronic, magnetic, and/or optical memory devices.

[0055] FIG. **10** is a flowchart of a method for constructing a waveguide, according to various embodiments. In block **1001**, a waveguide may be constructed by coupling a plurality of waveguide segments together. One embodiment of a resulting waveguide is illustrated in FIG. **11** and described subsequently. The waveguide is configured to propagate a signal between a surface controller and a bottom hole assembly.

[0056] In block **1002**, at least one of the safety waveguide segments are coupled into the waveguide. At least one safety waveguide segments is configured to divert oil out of the waveguide. In an embodiment, the safety waveguide segment may be coupled into the waveguide such that a dielectric plug that seals each waveguide segment is shared between adjacent waveguide segments, such as illustrated in FIG. **4**.

[0057] FIG. **11** is a cross-sectional diagram showing a waveguide constructed of a plurality of waveguide segments, according to various embodiments. This waveguide is made up of a plurality of waveguide segments **1100-1102**, such as illustrated in FIG. **1**.

[0058] Adjacent waveguide segments **1100**, **1101** or **1101**, **1102** of the waveguide are coupled together with sleeves **1120-1122** surrounding joints **1110**, **1111**. For example, the window **1140** of a first segment **1100** is immediately adjacent to the window **1141** of a second segment **1101** and the sleeve **1120** surrounds a joint **1110** formed between the adjacent waveguide segments **1100**, **1101**. Thus, the waveguide comprises a plurality of windows **1139-1144**, each window **1139-1144** may be coupled to a respective end of the waveguide such that the resulting chamber is substantially sealed from the ambient atmosphere.

[0059] One or more of the waveguide segments **1100-1102** may be a safety waveguide segment as described in any of the above embodiments. If more than one waveguide segment **1100-1102** is a safety waveguide segment, different embodiments of the safety waveguide segment may be combined into the waveguide.

[0060] Example 1 is a safety waveguide apparatus comprising: a waveguide segment body configured to internally propagate a signal and sealed by a plurality of dielectric plugs, each dielectric plug coupled to a respective end of the waveguide segment body, wherein the waveguide segment body or at least one of the dielectric plugs are configured to divert an oil flow from within the waveguide segment body.

[0061] In Example 2, the subject matter of Example 1 can further include wherein the waveguide segment body is insertable into a recess in a second waveguide segment such that the at least one of the dielectric plugs is disposed in the recess, the at least one dielectric plug is configured to be broken by a first pressure and the waveguide segment body is moveable from the recess by a second pressure.

[0062] In Example 3, the subject matter of Examples 1-2 can further include a vent hole through the waveguide segment body; and an internal dielectric plug disposed inside the waveguide segment body substantially adjacent to the vent hole such that the vent hole is sealed from an ambient atmosphere.

[0063] In Example 4, the subject matter of Examples 1-3 can further include wherein the internal dielectric plug comprises a thickness and/or a material that is transparent to the internally propagated signal.

[0064] In Example 5, the subject matter of Examples 1-4 can further include wherein the waveguide segment body comprises a metal or is internally coated by metal and the internal dielectric plug is coated with metal.

[0065] In Example 6, the subject matter of Examples 1-5 can further include wherein the internal dielectric plug comprises a frangible material.

[0066] In Example 7, the subject matter of Examples 1-6 can further include a vacuum or gas in the waveguide segment body, wherein the waveguide segment body is coupleable to a second waveguide segment, containing vacuum or gas, by the at least one dielectric plug, wherein the at least one dielectric plug is moveable or breakable by a pressure in the second waveguide segment.

[0067] In Example 8, the subject matter of Examples 1-7 can further include wherein the waveguide segment body comprises a plurality of pieces, wherein the plurality of pieces are held together by a pressure differential between a first pressure acting externally on the body and a second pressure sealed within the body.

[0068] In Example 9, the subject matter of Examples 1-8 can further include wherein the plurality of pieces are additionally held together by a glue that breaks in response to the oil flow within the waveguide segment body.

[0069] In Example 10, the subject matter of Examples 1-9 can further include a plurality of lips coupled to the waveguide segment body, wherein each lip of the plurality of lips is coupled to an opposing side of a cut that separates the plurality of pieces such that a gap between the plurality of lips is open to a vacuum in the waveguide segment body.

[0070] In Example 11, the subject matter of Examples 1-10 can further include wherein the dielectric plugs are transparent to a frequency of the signal.

[0071] Example 12 is a method comprising: constructing a waveguide by coupling a plurality of waveguide segments together; and coupling at least one safety waveguide segment into the waveguide, wherein the at least one safety waveguide segment is configured to divert, out of the waveguide, oil flowing through the waveguide.

[0072] In Example 13, the subject matter of Example 12 can further include wherein coupling the at least one safety waveguide segment into the waveguide comprises coupling the safety waveguide segment such that a dielectric plug is shared between adjacent waveguide segments.

[0073] In Example 14, the subject matter of Examples 12-13 can further include wherein a first end of the waveguide is configured to be located at a surface controller and a second end of the waveguide is configured to be located at a bottom hole assembly and further comprising the waveguide propagating a signal between the controller and the bottom hole assembly.

[0074] Example 15 is a system comprising: a waveguide configured to propagate radiation at a frequency between a surface controller and a downhole tool; and a safety waveguide segment disposed in the waveguide, the safety waveguide segment configured to propagate the radiation at the frequency and divert oil out of the waveguide.

[0075] In Example 16, the subject matter of Example 15 can further include wherein the waveguide comprises a plurality of waveguide segments and a plurality of the waveguide segments comprise the safety waveguide segment.

[0076] In Example 17, the subject matter of Examples 15-16 can further include wherein the plurality of waveguide segments comprise a cylindrical waveguide segment body sealed on each end by a respective dielectric plug such that an inner chamber of the waveguide segment comprises a vacuum or a partial vacuum.

[0077] In Example 18, the subject matter of Examples 15-17 can further include wherein the safety waveguide segment comprises a material, lined with a metal, that is configured to break in response to the oil in the safety waveguide segment.

[0078] In Example 19, the subject matter of Examples 15-18 can further include wherein each waveguide segment comprises a chamber sealed from ambient atmosphere.

[0079] In Example 20, the subject matter of Examples 15-19 can further include wherein the waveguide is disposed in a drill string.

[0080] Although specific examples have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement that is calculated to achieve the same purpose may be substituted for the specific examples shown. Various examples use permutations and/or combinations of examples described herein. It is to be understood that the above description is intended to be illustrative, and not restrictive, and that the phraseology or terminology employed herein is for the purpose of description. Combinations of the above examples and other examples will be apparent to those of skill in the art upon studying the above description.

What is claimed is:

1. A safety waveguide apparatus comprising:

a waveguide segment body configured to internally propagate a signal and sealed by a plurality of dielectric plugs, each dielectric plug coupled to a respective end of the waveguide segment body, wherein the waveguide segment body or at least one of the dielectric plugs are configured to divert an oil flow from within the waveguide segment body.

2. The apparatus of claim **1**, wherein the waveguide segment body is insertable into a recess in a second waveguide segment such that the at least one of the dielectric plugs is disposed in the recess, the at least one dielectric plug is configured to be broken by a first pressure and the waveguide segment body is moveable from the recess by a second pressure.

3. The apparatus of claim **1**, further comprising:

a vent hole through the waveguide segment body; and

an internal dielectric plug disposed inside the waveguide segment body substantially adjacent to the vent hole such that the vent hole is sealed from an ambient atmosphere.

4. The apparatus of claim. **3**, wherein the internal dielectric plug comprises a thickness and/or a material that is transparent to the internally propagated signal.

5. The apparatus of claim **3**, wherein the waveguide segment body comprises a metal or is internally coated by metal and the internal dielectric plug is coated with metal.

6. The apparatus of claim **3**, wherein the internal dielectric plug comprises a frangible material.

7. The apparatus of claim **1**, further comprising a vacuum or gas in the waveguide segment body, wherein the waveguide segment body is coupleable to a second waveguide segment, containing vacuum or gas, by the at least one dielectric plug, wherein the at least one dielectric plug is moveable or breakable by a pressure in the second waveguide segment.

8. The apparatus of claim **1**, wherein the waveguide segment body comprises a plurality of pieces, wherein the plurality of pieces are held together by a pressure differential between a first pressure acting externally on the body and a second pressure sealed within the body.

9. The apparatus of claim **8**, wherein the plurality of pieces are additionally held together by a glue that breaks in response to the oil flow within the waveguide segment body.

10. The apparatus of claim **8**, further comprising a plurality of lips coupled to the waveguide segment body, wherein each lip of the plurality of lips is coupled to an opposing side of a cut that separates the plurality of pieces such that a gap between the plurality of lips is open to a vacuum in the waveguide segment body.

11. The apparatus of claim **1**, wherein the dielectric plugs are transparent to frequency of the signal.

12. A method comprising:

constructing a waveguide by coupling a plurality of waveguide segments together; and

coupling at least one safety waveguide segment into the waveguide, wherein the at least one safety waveguide segment is configured to divert, out of the waveguide, oil flowing through the waveguide.

13. The method of claim **12**, wherein coupling the at least one safety waveguide segment into the waveguide comprises coupling the safety waveguide segment such that a dielectric plug is shared between adjacent waveguide segments.

14. The method of claim **12**, wherein a first end of the waveguide is configured to be located at a surface controller and a second end of the waveguide is configured to be located at a bottom hole assembly and further comprising the waveguide propagating a signal between the controller and the bottom hole assembly.

15. A system comprising:

a waveguide configured to propagate radiation at a frequency between a surface controller and a downhole tool; and

a safety waveguide segment disposed in the waveguide, the safety waveguide segment configured to propagate the radiation at the frequency and divert oil out of the waveguide.

16. The system of claim **15**, wherein the waveguide comprises a plurality of waveguide segments and a plurality of the waveguide segments comprise the safety waveguide segment.

17. The system of claim **16**, wherein the plurality of waveguide segments comprise a cylindrical waveguide segment body sealed on each end by a respective dielectric plug such that an inner chamber of the waveguide segment comprises a vacuum or a partial vacuum.

18. The system of claim **15**, wherein the safety waveguide segment comprises a material, lined with a metal, that is configured to break in response to the oil in the safety waveguide segment.

19. The system of claim **15**, wherein each waveguide segment comprises a chamber sealed from ambient atmosphere.

20. The system of claim **15**, wherein the waveguide is disposed in a drill string.

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