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(54) **CABLE SEALS AND METHODS OF ASSEMBLY**

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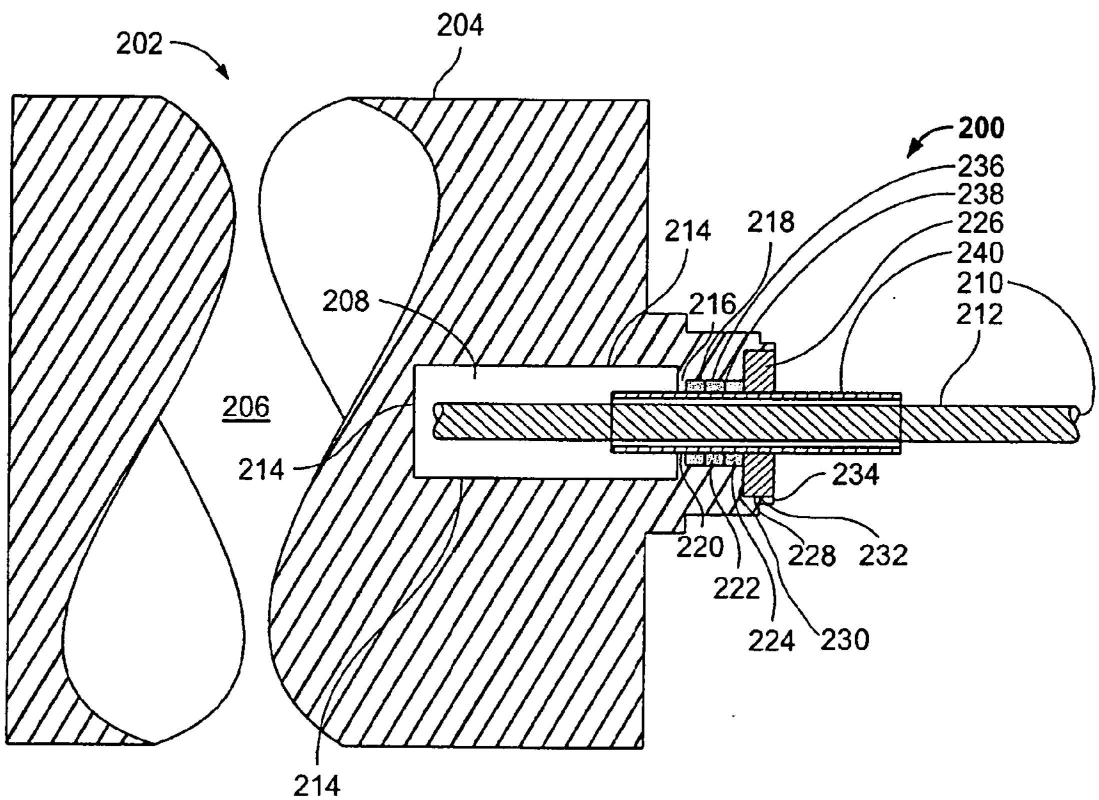
(57) **ABSTRACT**

A method of sealing a cable penetration includes assembling a cable seal and inserting the cable seal into a cable penetration. Assembling the cable seal includes adhering at least a portion of a heat-shrinkable tubing to at least a portion of a cable outer jacket, and positioning a secondary elastic seal over the heat-shrinkable tubing. An example of a secondary elastic seal could be O-rings. A cap or other means provides the outer sealing surface.



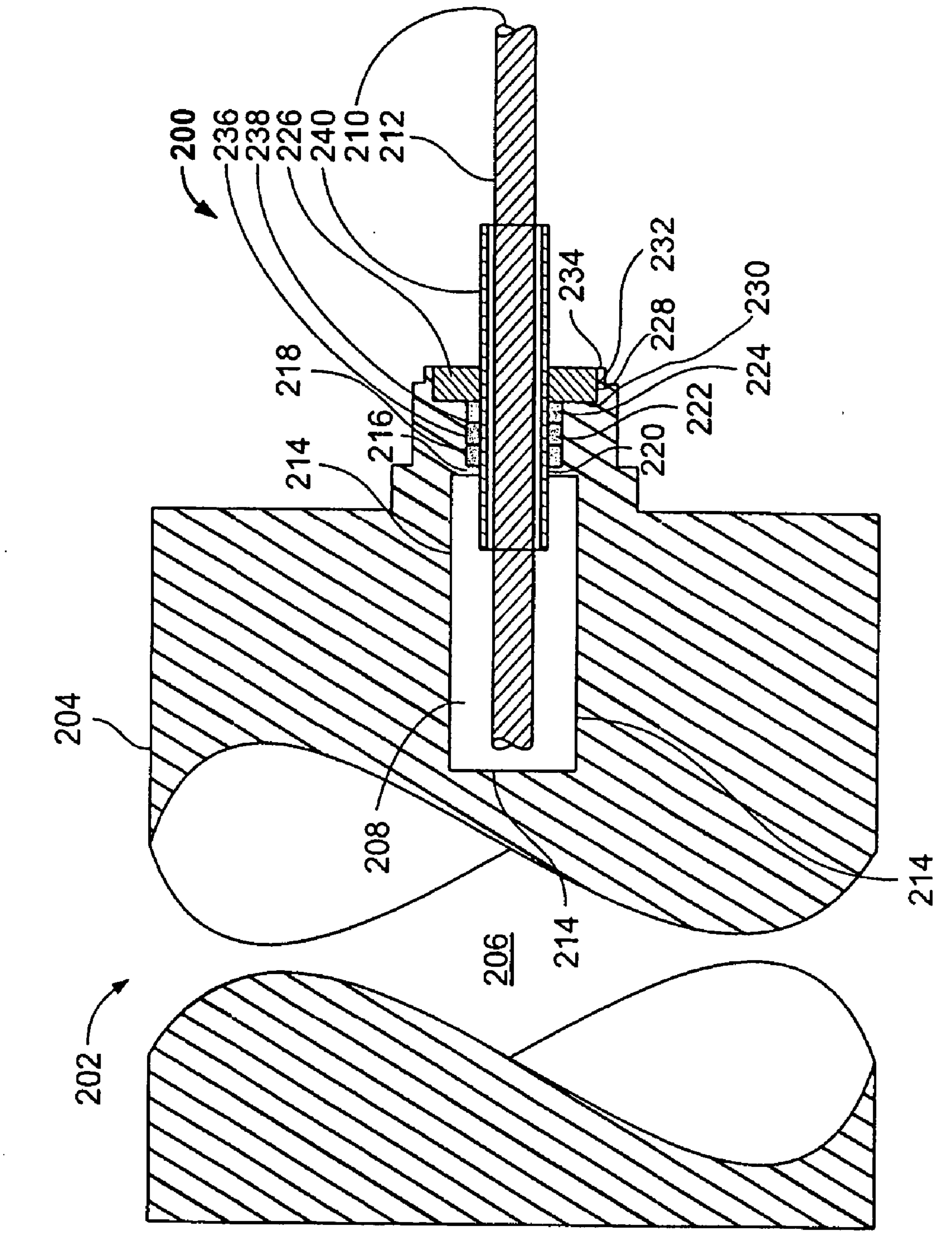

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FIG. 1

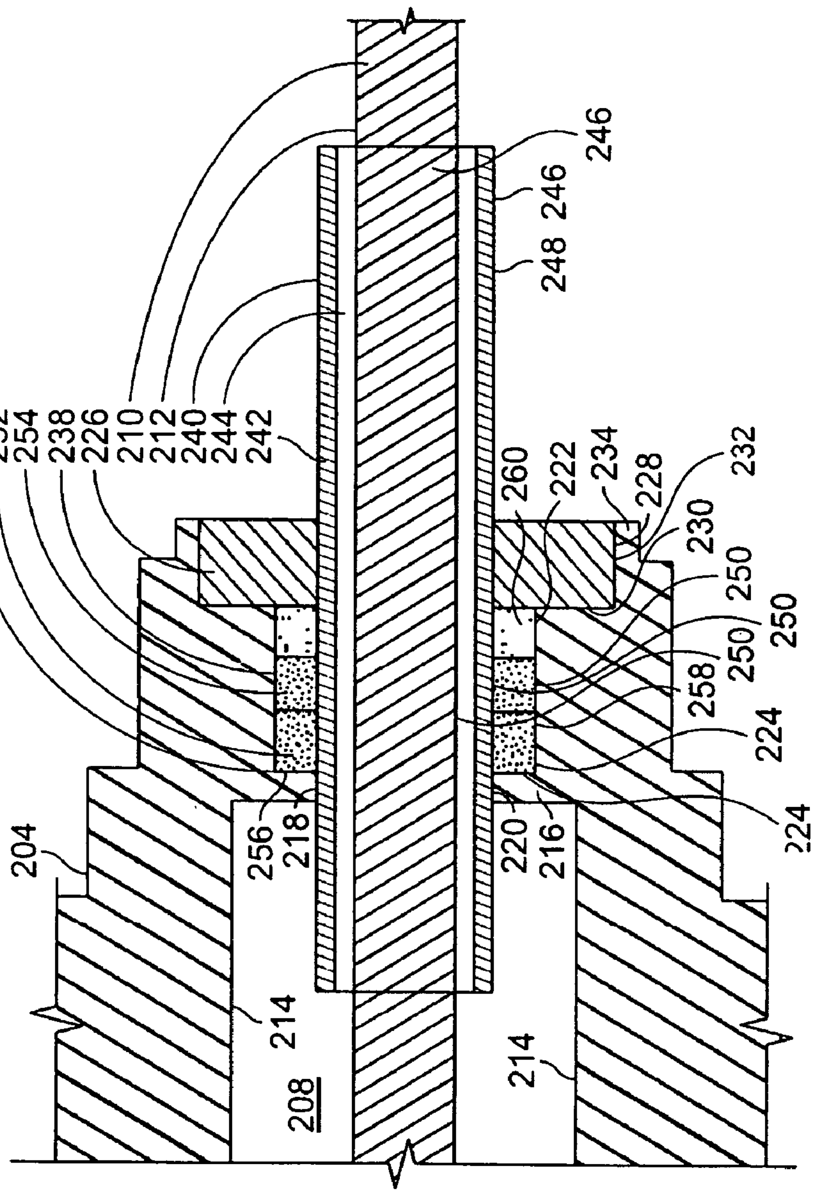
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FIG. 2

CABLE SEALS AND METHODS OF ASSEMBLY

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to methods and apparatus for assembling cable seals.

[0002] Many known industrial facilities have a variety of cable systems used to conduct electrical and electronic signals between field apparatus and non-field apparatus. Some examples of field apparatus are pressure data transmitters and valve position drive motors. Some examples of non-field apparatus include power sources and control system cabinets located in areas such as control rooms and offices. Some examples of cable uses are to transmit data to and from a variety of field apparatus and non-field apparatus, transmit electronic directives to field apparatus from non-field apparatus and to provide electrical power to apparatus regardless of location.

[0003] Many known cable systems include data and power cables that are typically routed through open passages of apparatus, the open passages often referred to as cable penetrations. The cable penetrations typically have seals to maintain the integrity of the cable jackets and to mitigate the potential for vapor ingression into the associated instrumentation/electronics region of the apparatus. The aforementioned seals may also be used in circumstances where separating differing environmental conditions between an electronic device and the cable penetration is not as important as simply providing for a cable support mechanism for facilitating cable routing, for example, cable tray ingress and egress, building wall penetrations and cable vault risers.

[0004] Many facilities have operating environments that include humidity levels that may exceed 50% relative humidity and temperature levels that may exceed 66° Celsius (C.) (150° Fahrenheit (F.)) for extended periods of time. Some facilities may also have apparatus positioned such that a potential for exposure to steam or other vapors may be present. In the aforementioned environmental circumstances, the outer jackets of the cables may experience cold flow, i.e., a time dependent strain (or deformation) of the cable jacket resulting from stress, and allow a subsequent vapor ingression into the associated instrumentation/electronics region of the apparatus.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In one aspect, a method of sealing a cable penetration is provided. The method includes assembling a cable seal and inserting the cable seal into a cable penetration. Assembling the cable seal includes adhering at least a portion of a heat-shrinkable tubing to at least a portion of a cable outer jacket, and positioning a secondary elastic seal over the heat-shrinkable tubing. An example of a secondary elastic seal could be O-rings. A cap or other means provides the outer sealing surface.

[0006] In another aspect, a cable seal is provided. The cable seal includes at least one cable having an FEP outer jacket. The seal also includes at least a portion of a predetermined length of a heat-shrinkable tubing that is inserted over at least a portion of the cable outer jacket. The seal further includes a cap having at least one sealing surface. The cap is inserted over at least a portion of the heat-shrinkable tubing. The seal also includes at least one elastic member. The member includes at least one sealing surface and is inserted over at least a portion of the heat-shrinkable tubing.

[0007] In a further aspect, a cable penetration sealing system is provided. The system includes a cable seal for a cable and at least one apparatus. The seal includes a predetermined length of a heat-shrinkable tubing, a cap, and at least one elastic member. The cable includes an FEP outer jacket. The tubing is inserted over at least a portion of the cable outer jacket. The cap includes at least one sealing surface and the cap is inserted over at least a portion of the heat-shrinkable tubing. The elastic member includes at least one sealing surface and is inserted over at least a portion of the heat-shrinkable tubing. The apparatus includes at least one cable penetration and the cable penetration is configured to receive the seal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a fragmentary illustration of an exemplary cable seal; and

[0009] FIG. **2** is an enlarged view of the cable seal shown in FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

[0010] FIG. **1** is a fragmentary illustration of an exemplary cable seal **200**. Seal **200** is integral to an apparatus **202**. In the exemplary embodiment, apparatus **202** is a proximity probe (sometimes referred to as an eddy current probe and/or a displacement transducer). Alternatively, apparatus **202** may be, but not be limited to, an electrical current transducer, a resistance temperature detector (RTD), or any other industrial field instrument. Also alternatively, apparatus **202** may be any object having a cable penetration, including a wall, cable tray side member, and a bracket assembly. Apparatus **202** is often used to measure bearing (not shown in FIG. **1**) vibration on large machines, such as turbines, as a function of the relative movement between the bearing and the journal. As the relative position between the bearing and journal varies, an electrical signal is induced within apparatus **202**. Apparatus **202** may be used with large machines including, but not limited to steam turbines, and may therefore be exposed to an environment that includes steam exiting a turbine bearing housing. The steam will normally increase the relative humidity and temperature levels within the vicinity of the bearing, and therefore, apparatus **202**.

[0011] Apparatus **202** has a housing **204** that is normally cast from a material that can withstand environments that include extended high temperatures, vibration, humidity, and exposure to steam. In the exemplary embodiment, housing **204** is cast from stainless steel. Alternatively, other materials including, but not limited to, titanium alloys may be used. Housing **204** has a plurality of cavities formed during the casting process. Alternatively, at least some of these cavities may be formed using standard machining techniques subsequent to the casting process. Apparatus **202** also has an instrumentation/electronics cavity **206** that is formed by a plurality of interior walls (not shown in FIG. **1**) of housing **204** to a set of predetermined dimensions to house the electronics and instrumentation (not shown in FIG. **1**) used to measure the relative movement within the associated component, for example, a journal bearing, and subsequently transform an induced electronic signal into a signal that is transmitted to computer **102**. Cavity **206** typically houses electrical power and electronic interconnections (not shown in FIG. **1**). Therefore, cavity **206** is normally the largest cavity within housing **204** and houses the components that may be sensitive to vapor ingression.

[**0012**] Housing **204** also has a cable cavity **208** that is positioned and dimensioned within housing **204** to facilitate pulling a cable **210** into housing **204**. Cable **210** has an outer jacket **212** that surrounds at least one electrical conductor (not shown in FIG. **1**). Cavity **206** and cavity **208** may be formed integrally or as separate cavities. Substantially annular cavity **208** is formed by a substantially annular cable cavity interior wall **214** and a cable cavity housing neck **216**. Neck **216** extends radially inward from the aforementioned housing inner wall and forms a substantially circular cable cavity open passage **218** and a cable cavity open passage sealing surface **220**. Neck **216** and passage **218** are discussed further below.

[**0013**] Housing **204** further has a substantially annular open passage **222** that is formed by a substantially annular housing open passage interior wall **224** and neck **216**. Furthermore, housing **204** has an annular housing opening **228** that is a widened portion of open passage **222** that is defined by an annular housing open passage vertical sealing surface **230** and an annular housing open passage horizontal sealing surface **232**. Sealing surface **230** protrudes axially inward from a housing outermost surface **234** and sealing surface **232** extends substantially radially perpendicular to surface **230**. Cavity **208**, open passage **218**, open passage **222** and housing opening **228** define a cable penetration.

[**0014**] Seal **200** includes a plurality of elastic media. In the exemplary embodiment the elastic media is a plurality of O-rings **236** and **238**. Alternatively, elastic media such as tapes, foams, putties, or other materials that meet or exceed the predetermined characteristics of O-rings **236** and **238** may be used. Seal **200** also has a heat-shrinkable tubing **240** and a housing cap **226**. Housing cap **226** is inserted over cable **210** and inserted into an annular housing opening **228**. Alternative, other media and materials that meet or exceed the predetermined characteristics of cap **226** may be used, for example, tapes, foams and putties. O-rings **236**, **238** and tubing **240** are discussed further below.

[**0015**] FIG. **2** is an enlarged view of exemplary cable seal **200**. FIG. **2** illustrates many of seal **200** components illustrated in FIG. **1** and discussed above.

[**0016**] In the exemplary embodiment, heat-shrinkable tubing **240** has two layers, tubing outer layer **242** and tubing inner layer **244**. Outer layer **242** is formed with polytetrafluoroethylene (PTFE). As a stand-alone material, PTFE heat-shrinkable tubing generally has a shrink ratio in the 2:1 to 4:1 range, i.e., the inner diameter of a section of PTFE tubing will be reduced by approximately 50% to 75% subsequent to heat application at a temperature range of approximately 325° C. to 340° C. (617° F. to 644° F.). PTFE typically has a continuous temperature rating of approximately 250° C. (482° F.) that is usually sufficient to protect an underlying cable from a nearby steam source that may have a temperature of approximately 100° C. (212° F.) at substantially atmospheric pressures. PTFE also is substantially non-porous and normally exhibits chemical resistance properties that are sufficient for many industrial applications. Furthermore, PTFE typically exhibits a smooth outer surface that facilitates a resistance to strain as discussed further below.

[**0017**] Inner layer **244** is formed with fluorinated ethylene-propylene (FEP). As a stand-alone material, FEP heat-shrinkable tubing generally has a shrink ratio in the 1.3:1 to 1.6:1 range, i.e., the inner diameter of a section of PTFE tubing will be reduced by approximately 23% to 37.5% subsequent to heat application at a temperature range of approximately 190° C. to 210° C. (374° F. to 410° F.). FEP typically has a continuous temperature rating of approximately 204° C. (400° F.) that is usually sufficient to protect an underlying cable from a nearby steam source that may have a temperature of approximately 100° C. (212° F.) at substantially atmospheric pressures. FEP, similar to PTFE, also is substantially non-porous and normally exhibits chemical resistance properties that are sufficient for many industrial applications. However, FEP typically does not exhibit as smooth an outer surface as PTFE.

[**0018**] In the exemplary embodiment, a section of tubing **240** is cut to a predetermined length. The length may be determined from the dimensions of the length of housing open passage **222** and the predetermined lengths of heat-shrinkable tubing that extend beyond passage **222** in either of the two axial directions along cable **210** The section of tubing **240** is inserted over cable **210**. Normally, it may be more convenient to slide tubing segment **240** over the end of cable **210**.

[**0019**] Heat is applied to dual-layer tubing **240** to form a tubing-enclosed cable portion **246** (illustrated as the section of cable **210** enclosed by tubing **240** in FIG. **2**). Inner FEP layer **244** melts and flows to encapsulate cable outer jacket **212**. Since outer jacket **212** is also formed from FEP, jacket **212** also melts slightly and a chemical bond between tubing inner layer **244** and jacket **212** is formed. Inner FEP layer **244** does not shrink as much as outer PTFE layer **242** does, therefore, layer **242** shrinks tightly over inner FEP layer **244** to form a tight, smooth seal in conjunction with inner layer **244** on cable outer jacket **212**. In the exemplary embodiment, tubing **240** has a continuous service temperature rating of approximately 200° C. (392° F.).

[**0020**] Alternatively, tubing **240** may have more than two layers, for example a neutral middle layer. Tubing **240** may also have one layer of a composite material that obtains substantially similar results as the exemplary embodiment.

[**0021**] Upon cooling of tubing-enclosed cable portion **246**, housing cap **226** is inserted over cable portion **246** in a manner substantially similar to that used to insert tubing **240** over cable **210** as described above. Cap **226** has an open passage (not shown in FIG. **2**) of sufficient diameter to facilitate insertion over cable portion **246** while having a clearance between an outermost surface **248** of cable portion **246** that is small enough to facilitate a mitigation of vapor ingression between cap **226** and cable portion **246** as well as provide additional structural support to cable portion **246** to mitigate strain of cable portion **246**. Cap **226** is positioned over cable portion **246** at approximately the midpoint of cable portion **246** so that sufficient length of cable portion **246** extends beyond passage **222** in either of the two axial directions along cable portion outermost surface **248** to facilitate sufficient strength in the layers of cable portion

246, to mitigate strain in cable portion 246, and to establish a small clearance between the outermost surface 248 of cable portion 246 and the cable cavity open passage sealing surface 220 as discussed below.

[0022] In the exemplary embodiment, two O-rings 236 and 238 are inserted over cable portion 246 to assemble a tubing/O-ring-enclosed cable portion 250. O-rings 236 and 238 are substantially circular and annular. O-rings 236 and 238 are inserted over cable portion 246 in a manner substantially similar to that used to insert tubing 240 over cable 210 as described above. O-ring 236 and O-ring 238 expand to mitigate a clearance between a surface 252 of O-ring 236 and a surface 254 of O-ring 238 and the radially outermost surface 248 of cable portion 246 to mitigate strain of cable portion 246 and facilitate a seal that tends to mitigate vapor ingression into cavity 208 along the outermost surface 248 of cable portion 246. The smooth outermost surface 248 of tubing-enclosed cable portion 246 formed by tubing outer layer 242 facilitates the sealing action between O-rings 236 and 238 and surface 248. O-ring 238 is a redundant backup for O-ring 236.

[0023] Tubing/O-ring-enclosed cable portion 250 is inserted into housing 204 through housing open passage 222 pulled into cavity 206 (shown in FIG. 1) for subsequent electrical connection to the appropriate terminals (not shown in FIGS. 1 and 2). Cable 210 is pulled through housing 204 until O-ring 236 contacts a housing open passage vertical O-ring sealing surface 256. The aforementioned expansion of O-ring 236 also tends to mitigate clearances between surface 252 of O-ring 236 and sealing surface 256 and a housing open passage horizontal O-ring sealing surface 258. O-ring 238 expands in a similar manner, however, instead of expanding against housing open passage vertical O-ring sealing surface 256, surface 254 of O-ring 238 expands against surface 252 of O-ring 236. The expansion of O-ring 236 against surfaces 256 and 258 and the expansion of O-ring 238 against surface 258 facilitate a seal that tends to mitigate vapor ingression into cavity 208. Housing open passage void 260 permits additional expansion of O-rings 236 and 238 in the axial direction.

[0024] Inserting Tubing/O-ring-enclosed cable portion 250 in housing 204 also tends to decrease a clearance between the outermost surface 248 of cable portion 246 and the cable cavity open passage sealing surface 220 to facilitate a mitigation of vapor ingression into cavity 208 and to mitigate strain of cable portion 246.

[0025] Assembly of seal 200 is completed by inserting cap 226 into housing opening 228 such that a substantial portion of cap 226 sealing surface is in contact with a substantial portion of surfaces 230 and 232 to facilitate a mitigation of vapor ingression into cavity 208 and to mitigate strain of cable portion 246. In the exemplary embodiment, cap 226 forms a friction seal with surface 232. Alternatively, an adhesive suitable for the associated environment may be used to affix cap 226 to surfaces 230 and 232. Also alternatively, at least one set screw may be inserted into a channel formed radially through housing 204 and cap 226.

[0026] The methods and apparatus for a cable seal described herein facilitate operation of a cable penetration sealing system. More specifically, designing and installing a cable seal as described above facilitates operation of a cable penetration sealing system by mitigating an cold flow of a cable jacket. As a result, degradation of cable jacket integrity, effectiveness and reliability, extended maintenance costs and associated system outages may be reduced or eliminated.

[0027] Although the methods and apparatus described and/or illustrated herein are described and/or illustrated with respect to methods and apparatus for a cable penetration sealing system, and more specifically, an apparatus cable seal, practice of the methods described and/or illustrated herein is not limited to apparatus cable seals nor to cable penetration sealing systems generally. Rather, the methods described and/or illustrated herein are applicable to designing, installing and operating any system.

[0028] Exemplary embodiments of cable seals as associated with cable penetration sealing systems are described above in detail. The methods, apparatus and systems are not limited to the specific embodiments described herein nor to the specific cable seals designed, installed and operated, but rather, the methods of designing, installing and operating cable seals may be utilized independently and separately from other methods, apparatus and systems described herein or to designing, installing and operating components not described herein. For example, other components can also be designed, installed and operated using the methods described herein.

[0029] While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

1. A method of sealing a cable penetration, said method comprising:

assembling a cable seal, said assembling comprising adhering at least a portion of a heat-shrinkable tubing to at least a portion of a cable outer jacket, positioning a cap over the heat-shrinkable tubing, and positioning at least one elastic member over at least a portion of the heat-shrinkable tubing; and

inserting the cable seal into a cable penetration.

2. A method in accordance with claim 1 wherein adhering at least a portion of a heat-shrinkable tubing to at least a portion of a cable outer jacket comprises positioning the heat-shrinkable tubing over the cable outer jacket by inserting at least one open end of a predetermined length of a multi-layered heat-shrinkable tubing over at least a portion of the cable outer jacket.

3. A method in accordance with claim 1 wherein adhering at least a portion of a heat-shrinkable tubing to at least a portion of a cable outer jacket further comprises melting a heat-shrinkable tubing inner layer such that it chemically bonds with the cable outer jacket, thereby increasing the strength of the cable outer jacket and mitigating a potential for cable outer jacket strain and cold flow of at least a portion of the cable outer jacket.

4. A method in accordance with claim 1 wherein positioning a cap over the heat-shrinkable tubing comprises inserting a cap open passage over the heat-shrinkable tubing outer surface, thereby mitigating a potential for cable outer jacket strain and cold flow of at least a portion of the cable outer jacket.

5. A method in accordance with claim 1 wherein positioning at least one O-ring over at least a portion of the

heat-shrinkable tubing comprises inserting at least one O-ring over a heat-shrinkable tubing outer surface, thereby facilitating a seal between at least a portion of an O-ring substantially annular inner surface and at least a portion of the heat-shrinkable tubing outer surface by expanding the O-ring, thereby mitigating a potential for cable outer jacket strain and cold flow of at least a portion of the cable outer jacket.

6. A method in accordance with claim 1 wherein inserting the cable seal into a cable penetration comprises inserting at least a portion of the cable seal through at least a portion of a cable penetration and compressing at least a portion of at least one O-ring against a sealing surface within the cable penetration, thereby mitigating stress within at least a portion of the cable outer jacket.

7. A method in accordance with claim 1 wherein inserting the cable seal into a cable penetration further comprises inserting the cap into the open passage such that a seal between the cable penetration and an external environment is facilitated.

8. A cable seal comprising:

at least one cable, said cable comprising an FEP outer jacket;

at least a portion of a predetermined length of a heat-shrinkable tubing, said tubing being inserted over at least a portion of said cable outer jacket, said tubing comprising an outer layer comprising a first material and an inner layer comprising a second material that is different from said first material, said first layer is chemically bonded to said cable outer jacket;

a cap, said cap comprising at least one sealing surface, said cap being inserted over at least a portion of said heat-shrinkable tubing; and

at least one elastic member, said member comprising at least one sealing surface, said member inserted over at least a portion of said heat-shrinkable tubing.

9. A cable seal in accordance with claim 8 wherein said inner layer comprises FEP, wherein said chemical bond between said inner layer and said outer jacket facilitates an increase of a strength of said cable outer jacket and facilitates mitigation of a potential for cable outer jacket strain and cold flow of at least a portion of said cable outer jacket.

10. A cable seal in accordance with claim 8 wherein said outer layer comprises PTFE and an outer surface, surface irregularities being mitigated on said outer surface, and said outer surface facilitates seal formation between said at least one elastic member and said cap and facilitates mitigation of a potential of cold flow of said cable outer jacket.

11. A cable seal in accordance with claim 8 wherein said cap sealing surface forms a substantially annular open passage, said open passage facilitates receipt of said cable.

12. A cable seal in accordance with claim 8 wherein said at least one elastic member further comprises a first O-ring and a second O-ring, said first and said second O-rings inserted over at least a portion of an outer surface of said heat-shrinkable tubing such that said first and said second O-rings facilitate mitigation of stress within said heat-shrinkable tubing and facilitate seal formation between said O-rings and an outer surface of said heat-shrinkable tubing.

13. A cable seal in accordance with claim 12 wherein said second O-ring comprises a redundant O-ring.

14. A cable penetration sealing system, said system comprising:

a cable seal for a cable, said cable seal comprising a predetermined length of a heat-shrinkable tubing, a cap, and at least one elastic member, said cable comprising an FEP outer jacket, said tubing being inserted over at least a portion of said cable outer jacket, said tubing comprising an outer layer comprising a first material and an inner layer comprising a second material that is different from said first material, said first layer is chemically bonded to said cable outer jacket, said cap comprising at least one sealing surface, said cap inserted over at least a portion of said heat-shrinkable tubing, said at least one elastic member comprising at least one sealing surface, said elastic member inserted over at least a portion of said heat-shrinkable tubing; and

at least one housing comprising at least one cable penetration, said cable penetration configured to receive said seal and comprises a substantially annular circumferential interior surface that comprises a protrusion.

15. A cable penetration sealing system in accordance with claim 14 wherein said substantially annular circumferential interior surface forms an instrumentation/electronics cavity.

16. A cable penetration sealing system in accordance with claim 14 wherein said protrusion extends radially and orthogonally inward from at least a portion of said circumferential interior surface, said protrusion comprises at least one annular radially innermost protrusion sealing surface and at least one protrusion sealing surface extending radially and orthogonally inward from at least a portion of said circumferential interior surface, said protrusion sealing surface comprising a predetermined axial length, said sealing surface facilitates a seal between said cable and said housing.

17. A cable penetration sealing system in accordance with claim 14 wherein at least a portion of said interior surface and at least a portion of said protrusion form a housing open passage, said open passage facilitates intrusion of said cable into said housing, said open passage comprising radial dimensions sized to facilitate receipt and compression of said at least one elastic member.

18. A cable penetration sealing system in accordance with claim 16 wherein said circumferential interior surface and said protrusion sealing surface extend radially and orthogonally inward from said circumferential interior surface to facilitate forming a seal between said cap and said housing.

19. A cable penetration sealing system in accordance with claim 14 wherein said inner layer comprises FEP and said outer layer comprises PTFE, said PTFE outer layer comprises an outer surface, said chemical bond between said FEP inner layer and said FEP outer jacket facilitates coupling of said tubing to said cable outer jacket to assemble a tubing-enclosed cable portion, said PTFE outer surface mitigates surface irregularities and facilitates mitigation of cold flow of said cable outer jacket.

20. A cable penetration sealing system in accordance with claim 14 wherein said at least one elastic member further comprises a first O-ring and a second O-ring, said first and said second O-rings inserted over at least a portion of an outer surface of said heat-shrinkable tubing such that said first and said second O-rings facilitate mitigation of stress within said heat-shrinkable tubing and facilitate seal formation between said O-rings and an outer surface of said heat-shrinkable tubing, said second O-ring being a redundant O-ring.

* * * * *