

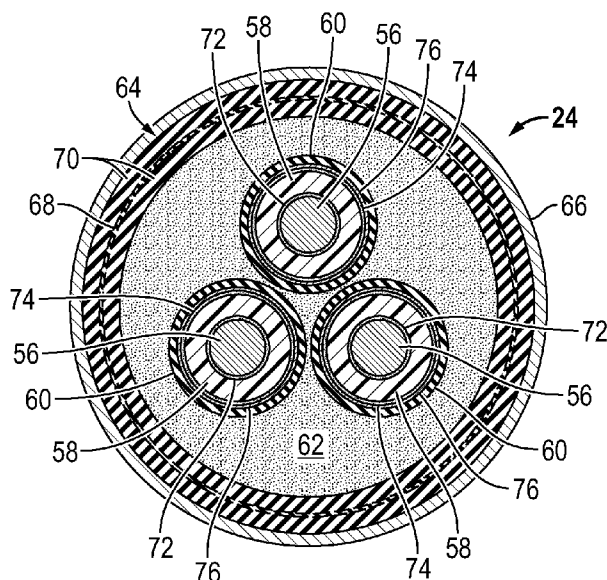


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[Continued on next page]

(54) **Title:** HIGH-TEMPERATURE POWER CABLE RESISTANT TO FLUID INCURSION

FIG. 5



(57) **Abstract:** A technique facilitates construction of an electrical cable, e.g. a power cable. The electrical cable comprises a conductor for conducting electricity and protective insulation layers which enable operation of the electrical cable in harsh environments and/or at higher voltages. The conductor is protected by an internal elastomeric jacket disposed around the conductor and comprising ethylene propylene diene monomer (EPDM). Additionally, the conductor is protected by an external elastomeric jacket disposed around the internal elastomeric jacket and comprising portions of nitrile rubber (e.g. NBR or HNBR) and EPDM bonded together.



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PATENT APPLICATION

HIGH-TEMPERATURE POWER CABLE RESISTANT TO FLUID INCURSION

DOCKET NO.: IS14.9695-WO-PCT

INVENTORS: Jason Holzmüller
Jinglei Xiang**BACKGROUND**

[0001] In many hydrocarbon well applications, power cables are employed to deliver electric power to various devices. For example, a power cable may be used to deliver electric power downhole to an electric submersible pumping system located in a subterranean environment. Existing power cables employ electrical conductors which are surrounded by layers of insulation material, but existing constructions can be susceptible to the high temperatures and high pressures as well as the deleterious fluids often present in downhole environments. For example, some of the insulation materials swell in the presence of hydrocarbon fluids and some of the insulation materials are susceptible to permeation by corrosive substances, such as hydrogen sulfide. Once hydrogen sulfide or other corrosive downhole gases have permeated a power cable, rapid changes in the well pressure can cause explosive decompression damage and render the power cable inoperable. Additionally, downhole power cables tend to be limited to a maximum voltage rating of 5 kV because the layers surrounding the conductors have insufficient electrical stress relief for applications utilizing voltages higher than 5 kV.

SUMMARY

[0002] In general, a methodology and system are provided which facilitate construction of an electrical cable, e.g. a power cable. The electrical cable comprises a conductor for conducting electricity and protective insulation layers which enable operation of the electrical cable in harsh environments and/or at higher voltages. The conductor is protected by an internal elastomeric jacket disposed around the conductor and comprising ethylene propylene diene monomer (EPDM). Additionally, the conductor is protected by an external elastomeric jacket disposed around the internal elastomeric jacket and comprising portions of nitrile rubber (e.g. NBR or HNBR) and EPDM bonded together. In some applications, the portions of nitrile rubber and EPDM may be formed as layers which are simultaneously extruded and cross-linked to securely bond the layers together. Depending on the application, some embodiments of the electrical cable may comprise additional features, such as additional insulation layers, armor layers, and/or ground plane layers.

[0003] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0005] Figure 1 is a schematic illustration of a well system comprising an example of an electrical power cable coupled with an electric submersible pumping system, according to an embodiment of the disclosure;

[0006] Figure 2 is a cross-sectional view of an example of the electrical power cable illustrated in Figure 1, according to an embodiment of the disclosure;

[0007] Figure 3 is a cross-sectional view of another example of the electrical power cable illustrated in Figure 1, according to an embodiment of the disclosure;

[0008] Figure 4 is a cross-sectional view of another example of the electrical power cable illustrated in Figure 1, according to an embodiment of the disclosure; and

[0009] Figure 5 is a cross-sectional view of another example of the electrical power cable illustrated in Figure 1, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0010] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0011] The present disclosure generally relates to a methodology and system which facilitate construction of an electrical cable, e.g. a power cable. The electrical cable comprises a conductor for conducting electricity and protective insulation layers which enable operation of the electrical cable in harsh environments and/or at higher voltages. In a variety of applications, the electrical cable comprises a plurality of conductors used to provide electric power in downhole applications. For example, the power cable may comprise three electrical conductors used to provide three-phase power

to an electric submersible pumping system employed downhole in a wellbore to pump well fluids.

[0012] The at least one conductor is protected by an internal elastomeric jacket disposed around the conductor and comprising ethylene propylene diene monomer (EPDM). Additionally, the conductor(s) is protected by an external elastomeric jacket disposed around the internal elastomeric jacket and comprising portions of nitrile rubber and EPDM bonded together. By way of example, the nitrile rubber may be in the form of NBR (acrylonitrile-butadiene rubber) or HNBR (hydrogenated nitrile butadiene rubber). In some applications, the portions of nitrile rubber and EPDM may be formed as layers which are simultaneously extruded and cross-linked to securely bond the layers together. Depending on the application, some embodiments of the electrical cable may comprise additional insulation layers, an armor layer, a ground plane layer, and/or other additional features.

[0013] According to an embodiment, a power cable is constructed for use with an electric submersible pumping system and utilizes an external elastomeric jacket formed with an EPDM jacket core simultaneously extruded with a nitrile rubber (NBR or HNBR) outer skin. The nitrile rubber outer skin provides a high strength, fluid and gas resistant barrier while maintaining a low cost and an effective temperature resistance via the EPDM based jacket core. The two layers are simultaneously applied by an extrusion process, e.g. co-extruded or tandem-extruded, and are chemically cross-linked together.

[0014] This power cable construction provides a highly reliable construction for use in high temperature applications in which the power cable is in contact with hydrocarbon fluids. For example, the power cable construction enables use in high temperature environments in which the power cable is disposed within a dielectric oil filling a tubing, e.g. coiled tubing, used to deploy an electric submersible pumping system. The power cable construction also enables downhole use with higher levels of voltage, e.g. voltages greater than 5 kV. The cable operates effectively in corrosive

oilfield environments in which the cable is exposed to hydrocarbons, high-pressure gases, and operating temperatures above 180°C.

[0015] Referring generally to Figure 1, an embodiment of a well system is illustrated as comprising a downhole, electrically powered system, e.g. an electric submersible pumping system. Electric power is provided to the electric submersible pumping system or other powered system via a power cable. The power cable, in turn, is coupled with the electrically powered system by an electrical connector, e.g. a pothead assembly. The illustrated electric submersible pumping system or other types of electrically powered systems may comprise many types of components and may be employed in many types of applications and environments, including cased wells and open-hole wells. The well system also may be utilized in vertical wells or deviated wells, e.g. horizontal wells.

[0016] Referring again to Figure 1, a well system 20 is illustrated as comprising an electrically powered system 22 which receives electric power via an electrical power cable 24. By way of example, the electrically powered system 22 may be in the form of an electric submersible pumping system 26, and the power cable 24 is designed to withstand high temperature, harsh environments. Although the electric submersible pumping system 26 may have a wide variety of components, examples of such components comprise a submersible pump 28, a submersible motor 30, and a motor protector 32.

[0017] In the example illustrated, electric submersible pumping system 26 is designed for deployment in a well 34 located within a geological formation 36 containing, for example, petroleum or other desirable production fluids. A wellbore 38 may be drilled and lined with a wellbore casing 40, although the electric submersible pumping system 26 (or other type of electrically powered system 22) may be used in open hole wellbores or in other environments exposed to hydrocarbons, high temperatures, and high-pressure deleterious gases. In the example illustrated, however, casing 40 may be perforated with a plurality of perforations 42 through which production

fluids flow from formation 36 into wellbore 38. The electric submersible pumping system 26 may be deployed into a wellbore 38 via a conveyance or other deployment system 44 which may comprise tubing 46, e.g. coiled tubing or production tubing. By way of example, the conveyance 44 may be coupled with the electrically powered system 22 via an appropriate tubing connector 48. In the illustrated embodiment, power cable 24 is routed along deployment system 44. However, the electric submersible pumping system 26 also can be suspended via the power cable 24 to form a cable deployed electric submersible pumping system 26. In this latter application, the power cable 24 is constructed as a robust cable able to support the weight of the electric submersible pumping system 26.

[0018] In the example illustrated, electric power is provided to submersible motor 30 by electrical power cable 24. The submersible motor 30, in turn, powers submersible pump 28 which draws in fluid, e.g. production fluid, into the pumping system through a pump intake 50. The fluid is produced or moved to the surface or other suitable location via tubing 46. However, the fluid may be pumped to other locations along other flow paths. In some applications, for example, the fluid may be pumped along an annulus surrounding conveyance 44. In other applications, the electric submersible pumping system 26 may be used to inject fluid into the subterranean formation or to move fluids to other subterranean locations.

[0019] As described in greater detail below, the electrical power cable 24 is constructed to consistently deliver electric power to the submersible pumping system 26 over long operational periods in environments subject to high temperatures, high pressures, deleterious fluids, high voltages, and/or other conditions which can be detrimental to conventional power cables. The power cable 24 is connected to the corresponding, electrically powered component, e.g. submersible motor 30, by an electrical connector 52, e.g. a suitable pothead assembly.

[0020] Depending on the application, the power cable 24 may comprise an individual electrical conductor protected by an insulation system or a plurality of

electrical conductors protected by the insulation system. In various submersible pumping applications, the electrical power cable 24 is in the form of a motor lead extension. In many of these applications, the motor lead extension 24 is designed to carry three-phase current, and submersible motor 30 comprises a three-phase motor powered by the three-phase current delivered through the three electrical conductors of motor lead extension 24.

[0021] Referring generally to Figure 2, an example of electrical power cable 24 is illustrated in cross-section. In this example, the electrical cable 24 is a power cable comprising a plurality of electrical conductors 56 although some power cables 24 may utilize other numbers of conductors or even a single conductor. By way of example, each conductor 56 may be surrounded by a primary insulation layer 58 and a fluid barrier layer 60 located around each primary insulation layer 58. The power cable 24 also may comprise an internal elastomeric jacket 62 disposed around the plurality of conductors 56 collectively. The internal elastomeric jacket 62 is located externally of the fluid barriers 60 and also may fill interstices between the fluid barrier layers 60. Additionally, the illustrated power cable 24 comprises an external elastomeric jacket 64 disposed around the internal elastomeric jacket 62. An armor layer 66 also may be positioned around the external elastomeric jacket 64 and may be formed of a metallic material, e.g. a galvanized steel or other steel material.

[0022] The external elastomeric jacket 64 is a composite structure and may be formed of a nitrile rubber portion 68 (e.g. NBR or HNBR) bonded with an ethylene propylene diene monomer (EPDM) portion 70. The nitrile rubber portion 68 and the EPDM portion 70 may be cross-linked to provide a uniform external elastomeric jacket 64 having the benefits of both nitrile rubber and EPDM. According to an embodiment, the nitrile rubber portion 68 and the EPDM portion 70 may be formed as layers with the nitrile rubber portion 68 being the external layer. In this embodiment, the layers 68, 70 may be simultaneously extruded, e.g. co-extruded or tandem-extruded, to form a co-extrusion which is cross-linked. Depending on the application, the nitrile rubber layer 68

and the EPDM layer 70 may be cross-linked while being simultaneously extruded to form the external elastomeric jacket 64 as a well bonded co-extrusion.

[0023] With respect to the portion/layer 68, the NBR or HNBR compound may be formed according to various techniques and with various materials. For example, the NBR or HNBR compound may be based on a typical carbon black or mineral (e.g. silica, clay, or other suitable mineral) filled composition. In this type of embodiment, the compound may comprise an acrylonitrile content (ACN%) which functions as a primary contributor to fluid, e.g. gas, resistance. In various applications, increasing ACN% can result in improved oil resistance and lower gas permeability.

[0024] In some embodiments, the compound, e.g. HNBR compound, forming portion/layer 68 may be formed to utilize high-aspect ratio fillers which provide the material with enhanced barrier properties for great resistance to permeation of fluid, e.g. gas. By way of example, the high-aspect ratio fillers may comprise platelet-like fillers which align during a high shear extrusion process. Because of the highly aligned sheets of impermeable filler, a tortuous path is created in the elastomer that greatly reduces the fluid, e.g. gas, permeation rate. Examples of suitable platelet-like fillers include exfoliated grapheme nanoplatelets, such as those available from XG Sciences, Inc. of Lansing Michigan. Other high-aspect ratio fillers also may be utilized and include graphite, talc, boron nitride, exfoliated nanoclays, carbon nanotubes, MXenesTM (as reported by Drexel Nanomaterials Group), and/or other fillers having a desirably high aspect ratio. To improve compatibility with the elastomer, at least some of these fillers may be surface modified by appropriate techniques, such as silanization or surface grafting of polymer groups.

[0025] The materials used to form the various components and features of electrical cable 24 may vary according to the parameters of a given application. By way of example, however, the electrical conductors 56 may be formed of copper, e.g. high purity copper, and may be solid, stranded, or compacted stranded. Stranded and compacted stranded conductors 56 may offer improved flexibility for some applications.

The conductors 56 also may be coated with a variety of coatings, such as corrosion resistant coatings which help prevent conductor degradation when exposed to hydrogen sulfide gas or other deleterious elements that can be present in downhole environments. Examples of such coatings include tin, lead, nickel, silver, or other corrosion resistant alloys metals.

[0026] Similarly, the primary insulation layer 58 also may have various configurations and be formed from various materials. For example, the primary insulation layer 58 around each conductor 56 may be formed of EPDM and/or polyetheretheretherketone (PEEK). If EPDM is selected, various compound formulations may be selected to enhance oil and decompression resistance. The primary insulation layer 58 may be thoroughly bonded, e.g. adhered, to the conductor 56 or to the layers applied to the exterior of the conductor 56. In some applications, PEEK provides improved mechanical properties which increase the protection against damage during power cable installation and operation. The much higher stiffness of PEEK also may allow for greater ease in sealing over power cable features at cable termination points, e.g. at a motor pothead, well connectors, feed-throughs, and/or other terminations. Appropriate selection of such materials can improve the reliability of the power cable 24 and the overall well system 20.

[0027] The fluid barrier layer 60 is formed of a material selected to protect the conductors 56 and the overall power cable 24 from corrosive downhole fluids, e.g. gases. The fluid barrier layer 60 may be constructed as a single layer or as a plurality of layers and may, for example, be in the form of an extruded and/or taped layer or layers. By way of example, the extruded and/or taped layers may be formed of fluoropolymers, lead, or other materials sufficient to provide protection against the deleterious well fluids. One type of suitable material is polytetrafluoroethylene (PTFE). Various combinations of layers, e.g. combinations of extruded and taped layers, also may be employed to establish the fluid barrier layer 60.

[0028] Referring generally to Figure 3, another embodiment of electrical cable 24 is illustrated. In this example, electrical cable 24 further comprises a conductor shield layer 72 disposed around each conductor 56. The conductor shield layer 72 may comprise a corrosion resistance layer as described above. In a variety of embodiments, however, the conductor shield layer 72 is in the form of a semi-conductive layer disposed around each conductor 56 to control electrical stress in the cable 24 and to minimize discharge. The conductor shield layer 72 may be particularly useful in power cables 24 rated above 5 kV.

[0029] Depending on the application and environment, the conductor shield layers 72 may vary in thickness and in some applications may be between 0.002 and 0.020 inches in thickness. Additionally, each conductor shield layer 72 may be bonded to the corresponding conductor 56 and also to the surrounding primary insulation layer 58 to block gas migration. In some applications, the conductor shield layers 72 may be stripable to provide easy access to the cable conductors 56. However, the conductor shield layer 72 may not be bonded in certain other applications.

[0030] By way of example, each conductor shield layer 72 may comprise a semi-conductive tape wrap or an extruded semi-conductive polymer. In some applications, each conductor shield layer 72 comprises an elastomer or thermoplastic and is co-extruded with the primary insulation layer 58 so as to allow the layers to be cross-linked together. The cross-linking reduces the potential for voids at the interface between the conductor shield layer 72 and the primary insulation layer 58. In some embodiments, the material selected for conductor shield layer 72 is an elastomer, e.g. EPDM, compound loaded with conductive fillers. However, a PEEK compound (or related high temperature polymer) containing conductive or semi-conductive fillers can be used to improve reliability in some high-temperature environments. In various embodiments, the semi-conductive nature of the material used for the conductor shield layer 72 is defined as having a resistivity less than 5000 ohm-cm.

[0031] Referring generally to Figure 4, another embodiment of electrical cable 24 is illustrated. In this embodiment, electrical cable 24 further comprises an insulation shield layer 74 in the form of a semi-conductive layer applied over the primary insulation layer 58 to minimize electrical stresses in the cable 24. The insulation shield layer 74 may be bonded to the primary insulation layer 58 or may be stripable. At least some adhesion between the insulation shield layer 74 and adjacent layers may be helpful in preventing voids or defects in the electrical cable 24.

[0032] Depending on the application, the insulation shield layer 74 may be a semi-conductive tape or a semi-conductive polymer. As with the conductor shield layer 72, the insulation shield layer 74 can be co-extruded with the primary insulation layer 58 to ensure contact throughout the interface between the surfaces. In various embodiments, the material used to form the insulation shield layer 74 may be semi-conductive and defined as having a resistivity less than 5000 ohm-cm. The same material may be used for the insulation shield layer 74 and the conductor shield layer 72, however different materials also may be used to enhance stripability, processing, and/or performance characteristics. Additionally, the insulation shield layer 74 may be continuous with the primary insulation layer 58, and the two layers may be fully bonded or partially bonded depending on the parameters of a given application.

[0033] Referring generally to Figure 5, another embodiment of electrical cable 24 is illustrated. In this embodiment, electrical cable 24 further comprises a ground plane 76 which may be in the form of a metallic shield layer. The ground plane/metallic shield layer 76 may be disposed externally of insulation shield layer 74 or at other suitable locations. In this example, the layers 76 serve to electrically isolate the phases of the power cable 24 from each other. The ground plane/metallic shield layer 76 may be formed from a variety of materials, including copper, aluminum, lead, conductive tapes, conductive braids, conductive paints, or extruded materials applied to provide a conductive layer. In some applications, the material is selected so that the shield layer 76 also serves as a barrier which protects the inner cable layers from deleterious fluids, e.g. deleterious gases. It should be noted that the various layers described, e.g. conductor

shield layer 72, insulation shield layer 74, ground plane 76, and/or other layers may be used individually or in various combinations according to the parameters of a given application.

[0034] In each of these embodiments, the internal elastomeric jacket 62 and the external elastomeric jacket 64 may be employed to protect the electrical cable 24 from damage in extreme environments, e.g. extreme downhole environments. The jackets 62, 64 may be formed from various combinations of EPDM and nitrile rubber as described above. However, the jackets 62, 64 may comprise additional or other materials in some embodiments, including fluoropolymers, chloroprene, or other materials resistant to extreme downhole environments. The construction of electrical cable 24 also may vary according to the parameters of a given application and the cable may be arranged in, for example, circular configurations or flat configurations. In some round cable embodiments, three conductors 56 may be twisted together and protected by fluid, temperature, and pressure resistant combinations of jackets 62, 64.

[0035] The enhanced protection also enables use of power cables rated at greater than 5 kV in many downhole applications. In various embodiments, the protective jackets 62, 64 provide a unique composite of nitrile rubber and EPDM materials to better utilize the properties of these materials. For example, the internal elastomeric jacket 62 may be formed from EPDM while the external elastomeric jacket 64 is formed as a composite layer combining portions of nitrile rubber and EPDM.

[0036] According to an example, the external elastomeric jacket 64 comprises the radially inner jacket layer 70 formed of EPDM. This radially inner jacket layer 70 is firmly and completely bonded to the radially outer jacket layer 68 formed of nitrile rubber, e.g. NBR or HNBR. Forming portion 70 of the external elastomeric jacket 64 with EPDM (as well as internal elastomeric jacket 62) provides a high level of temperature resistance at a hot location within the power cable 24 adjacent the layers surrounding the heat producing conductors 56. The EPDM also is a material with great dielectric properties having high-volume resistivity and dielectric strength provided at an

area between the phases. Additionally, the EPDM material is a low-cost material and thus can readily be used as the most common cable material by both weight and volume in a variety of cable embodiments.

[0037] By simultaneously extruding the layer 68 of nitrile rubber with the layer 70 of EPDM, a high level of protection is provided against hydrocarbon migration into the cable 24, thus greatly enhancing the life of the power cable 24. The radially outer layer 68 also provides a high-strength outer layer which maintains this high-strength even after contact with hydrocarbon fluids. The high strength of radially outer layer 68 also helps reduce the likelihood of gas decompression damage. In many applications, the nitrile rubber layer 68 is towards the outside of the power cable 24 and is thus exposed primarily to temperatures controlled by the well fluid temperature as opposed to the temperatures resulting from electrical current moving along conductors 56. By locating the nitrile rubber layer 60 at such a position, the potential for material hardening due to thermal aging is reduced.

[0038] In many applications, the nitrile rubber layer 68 and the EPDM layer 70 of the external elastomeric jacket 64 are thoroughly cross-linked and bonded together. This reduces or eliminates voids between the layers that could otherwise result in potential sites for gas buildup and subsequent mechanical failure during rapid gas decompression. Such voids can be reduced or removed by providing a thoroughly bonded interface of the two materials by, for example, simultaneously extruding the materials via a co-extrusion or tandem-extrusion technique. In many applications, the two materials of layers 68, 70 may be cross-linked simultaneously while being simultaneously extruded. To further ensure an inter-penetrating network of cross-linking at the interface between the materials, the materials of layers 68, 70 may be pressure extruded using compatible cross-linking systems. For example, peroxide-based cure systems may be used because such systems readily cross-link both EPDM and nitrile rubber materials.

[0039] For some applications, cross-linking at the desired material interface, e.g. the interface between layers 68 and 70, may be improved with the aid of additives mixed

into one or both compounds to improve compatibility at the material interface. By way of example, the additive system may comprise co-polymers of hydrophobic and hydrophilic monomers, e.g. low ACN% NBR rubber, maleic anhydride adducted polybutadiene, maleic anhydride modified ethylene propylene, chloroprene rubber, or similar. The additive system also may comprise other additives that increase cross-linking efficiency such as 1,2 vinyl polybutadiene, various methacrylate or acrylate additives (such as TMPTMA, SR350 or similar), and also materials such as polyoctenamer (VestanamerTM products from StruktolTM). There are various other additives that can be used to accomplish improved cross-linking at the material interface.

[0040] Further protection of the electrical cable 24 also may be provided by armor layer 66 which can be formed of a variety of suitable materials selected for a given application. By way of example, the armor layer 66 may be formed of galvanized steel, stainless steel, MonelTM, or other suitable metal, metal alloy, or non-metal material resistant to downhole conditions. In some applications, the armor layer 66 also may be formed as a composite layer having a plurality of materials.

[0041] Depending on the application, the electrical cable 24 may have a variety of shapes and/or components. For example, the electrical cable may have a variety of layers formed of various materials in various orders within the external elastomeric jacket. Additionally, various layers may be disposed around the corresponding conductors individually or collectively. The number, type, and arrangement of electrical conductors also may be selected according to the parameters of a given application and environment. For example, the electrical cable may have a round configuration, a rectangular configuration, or a flat configuration to accommodate certain spatial constraints. Various additives and materials may be mixed with or otherwise added to materials forming the various layers of the electrical cable 24. The electrical cable 24 may be in the form of a power cable which provides electrical power to downhole systems, e.g. electric submersible pumping system, however the electrical cable may be used in a variety of other types of applications.

[0042] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

- 1 1. A system for conducting electricity in harsh environments, comprising:
2
3 a power cable, comprising::
4 a plurality of conductors for conducting electricity;
5 a primary insulation layer disposed around each conductor of the
6 plurality of conductors;
7 a fluid barrier located around each primary insulation layer;
8 an internal elastomeric jacket disposed around the plurality of
9 conductors collectively and externally of the fluid barrier;
10 an external elastomeric jacket disposed around the internal
11 elastomeric jacket, the external elastomeric jacket having a nitrile rubber
12 (NBR or HNBR) portion cross-linked and bonded with an ethylene
13 propylene diene monomer (EPDM) portion; and
14 a metallic armor surrounding the external elastomeric jacket.
- 1 2. The system as recited in claim 1, wherein the plurality of conductors comprises
2 three conductors.
- 1 3. The system as recited in claim 1, wherein each conductor of the plurality of
2 conductors comprises copper.
- 1 4. The system as recited in claim 1, wherein the primary insulation layer comprises
2 EPDM.
- 1 5. The system as recited in claim 1, wherein the fluid barrier comprises
2 polytetrafluoroethylene (PTFE).

- 1 6. The system as recited in claim 1, wherein the internal elastomeric jacket
2 comprises EPDM.
- 1 7. The system as recited in claim 1, wherein the metallic armor comprises steel.
1
- 1 8. The system as recited in claim 1, wherein the external elastomeric jacket is
2 constructed with the nitrile rubber portion and the EPDM portion formed as
3 simultaneously extruded layers.
- 1 9. The system as recited in claim 1, wherein the external elastomeric jacket
2 comprises a cross-linking additive to improve cross-linking between the nitrile
3 rubber and the EPDM.
1
- 1 10. The system as recited in claim 1, wherein the power cable further comprises a
2 conductor shield layer formed of a semi-conductive material disposed along an
3 exterior of each conductor.
1
- 1 11. The system as recited in claim 1, wherein the power cable further comprises an
2 insulation shield layer formed of a semi-conductive material disposed along an
3 exterior of the primary insulation layer.
- 1 12. The system as recited in claim 11, wherein the power cable further comprises a
2 ground plane formed as a metallic layer located externally of the insulation shield
3 layer.
- 1 13. A method, comprising:
2
3 forming a power cable with a conductor for conducting electricity;
4 insulating the conductor with a primary insulation layer;
5 providing a fluid barrier layer around the insulation layer;

6 placing an internal elastomeric jacket around the conductor externally of
7 the fluid barrier; and

8 locating an external elastomeric jacket, formed of a nitrile rubber portion
9 and an EPDM portion, around the internal elastomeric jacket.

1

1 14. The method as recited in claim 13, further comprising cross-linking the nitrile
2 rubber portion and the EPDM portion; and protecting the external elastomeric
3 jacket with a metallic armor layer.

1 15. The method as recited in claim 13, wherein locating comprises forming the nitrile
2 rubber portion and the EPDM portion as layers in which the nitrile rubber portion
3 is located along an exterior of the EPDM portion.

1 16. The method as recited in claim 15, further comprising forming the layers via
2 simultaneous extrusion.

1 17. The method as recited in claim 16, further comprising cross-linking the layers
2 during the simultaneous extrusion.

1 18. The method as recited in claim 17, wherein forming comprises forming the power
2 cable with at least three of the conductors, and coupling the power cable with an
3 electric submersible pumping system.

1 19. A system, comprising:

2

3 a power cable having: a conductor for conducting electricity; an internal
4 elastomeric jacket disposed around the conductor and formed of EPDM; an
5 external elastomeric jacket disposed around the internal elastomeric jacket and
6 formed of bonded layers of nitrile rubber and EPDM; and an armor layer disposed
7 around the external elastomeric jacket.

1

20. The system as recited in claim 19, wherein the layers of nitrile rubber and EPDM of the external elastomeric jacket are in the form of a cross-linked extrusion.

FIG. 1

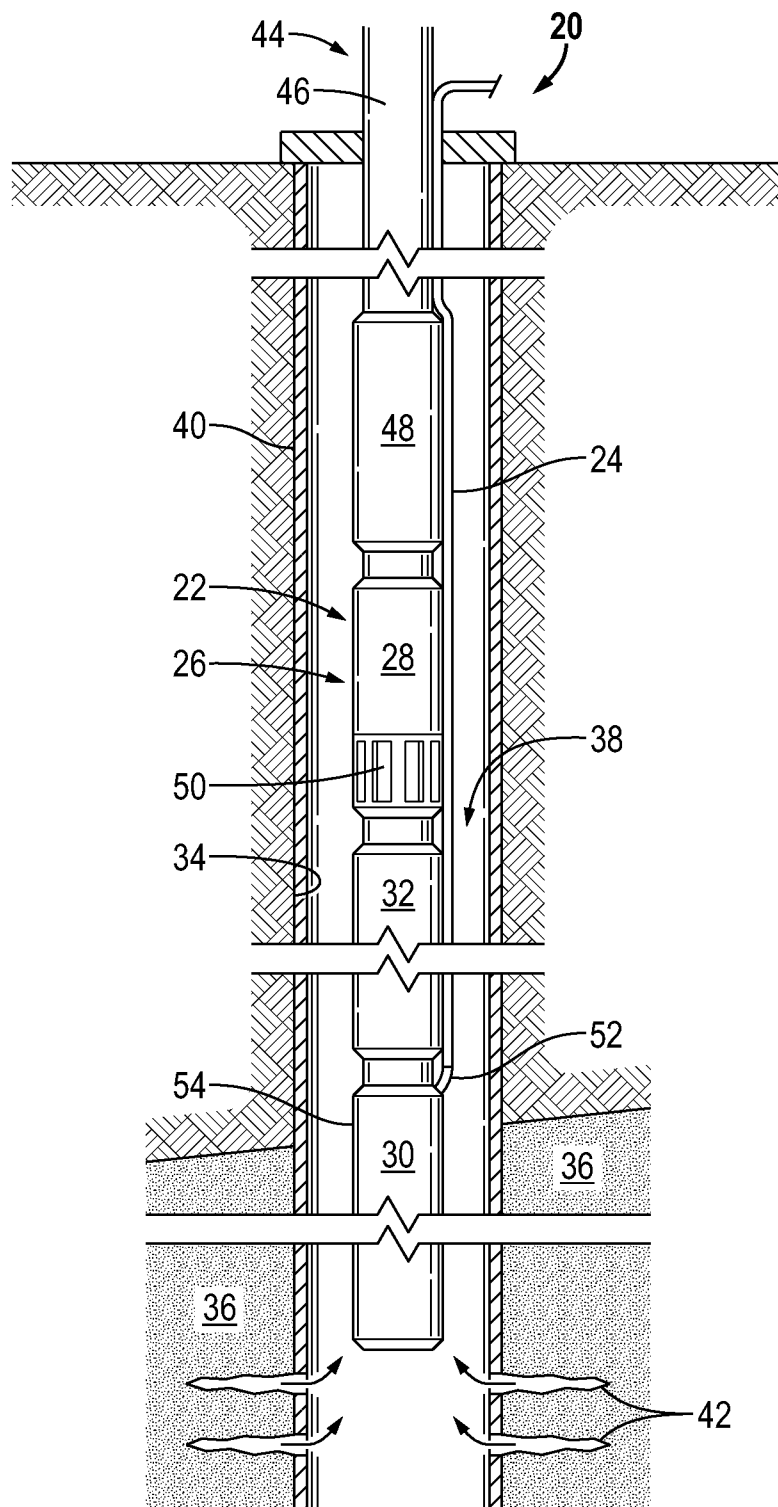


FIG. 2

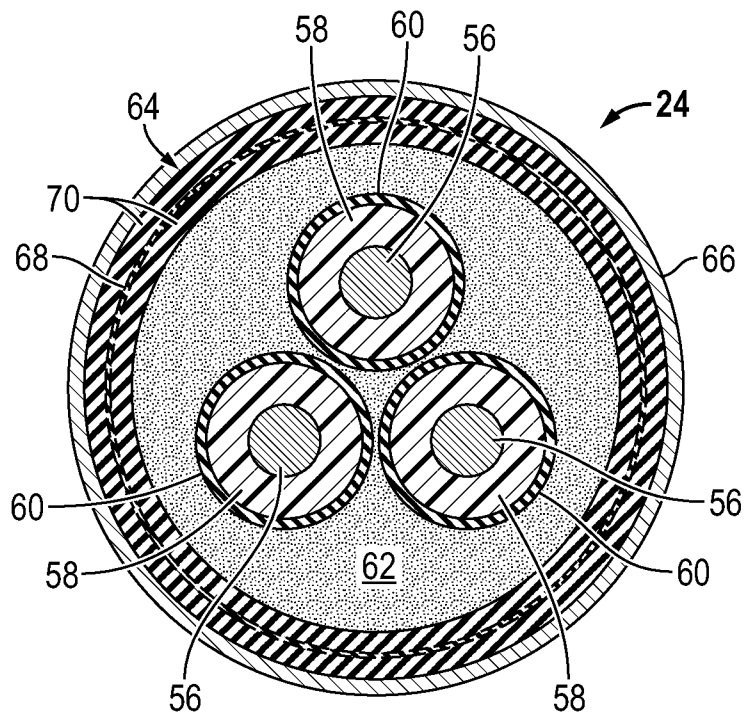
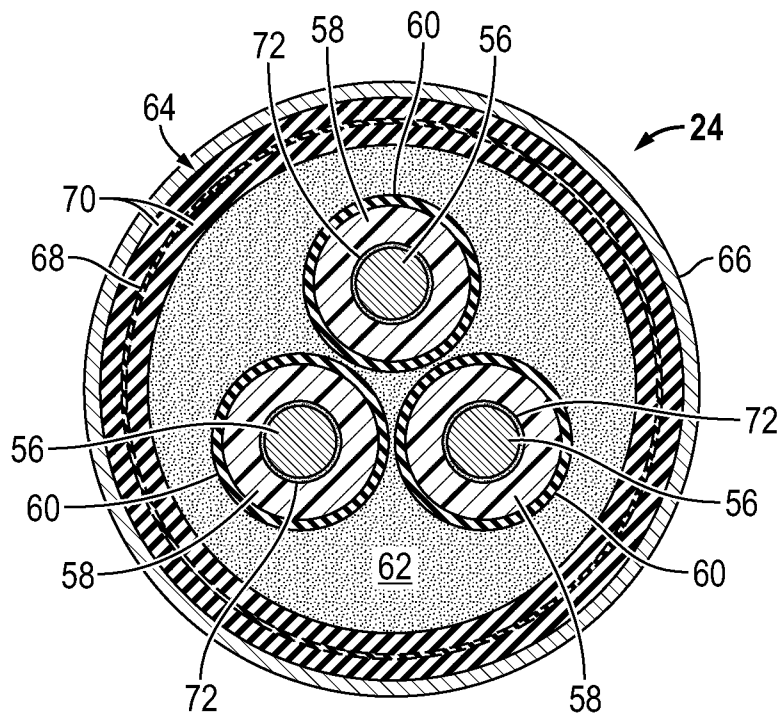


FIG. 3



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FIG. 4

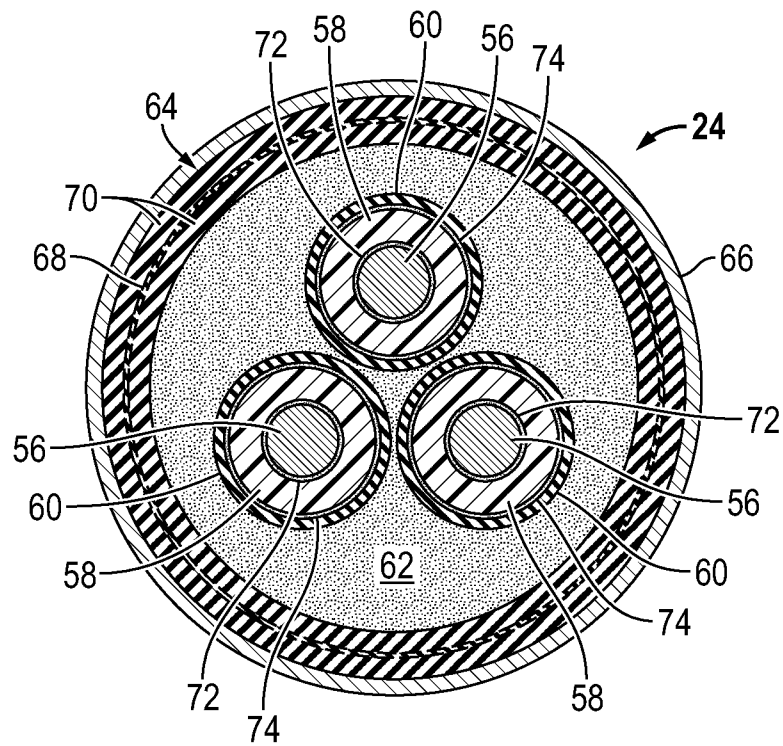
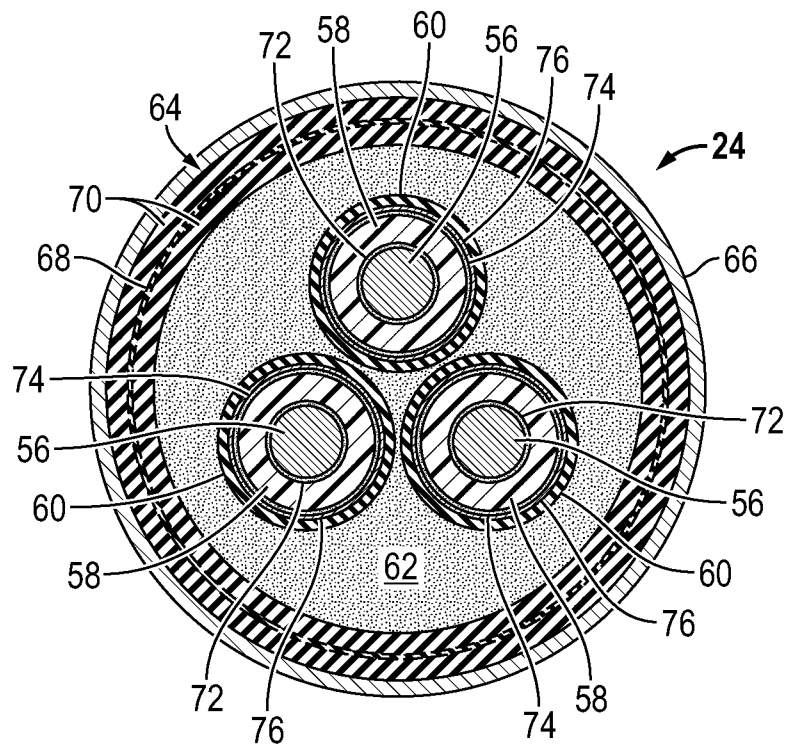


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/020387**A. CLASSIFICATION OF SUBJECT MATTER****H01B 7/17(2006.01)i, H01B 7/14(2006.01)i, H01B 13/012(2006.01)i, H01B 13/22(2006.01)i**

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)

H01B 7/17; H01B 7/22; H01B 7/18; H01B 7/00; H01B 9/02; G02B 6/44; H01B 7/14; H01B 13/012; H01B 13/22

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: insulation, power cable, jacket, nitrile rubber, ethylene propylene diene monomer, crosslink

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0306348 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 21 November 2013 See abstract, paragraphs [0032], [0050]-[0051], claims 1, 6, 20 and figure 5.	1-20
A	US 2012-0279750 A1 (SJUR KRISTIAN LUND et al.) 08 November 2012 See abstract, paragraphs [0022]-[0024], claim 1 and figure 1.	1-20
A	US 8204348 B2 (DAVID KELLER et al.) 19 June 2012 See abstract, column 3, lines 7-23, claim 1 and figures 2-4D.	1-20
A	US 7989700 B2 (HIROTAKA ESHIMA) 02 August 2011 See abstract, claims 1, 5, 7 and figures 1B, 2B, 5B.	1-20
A	US 8653371 B2 (TAMOTSU KIBE et al.) 18 February 2014 See abstract, claims 1, 3, 6, 9, 11 and figure 2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

04 December 2015 (04.12.2015)

Date of mailing of the international search report

07 December 2015 (07.12.2015)

Name and mailing address of the ISA/KR

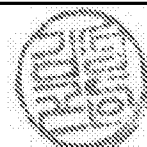
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/020387

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