Title: LOW-PROFILE MOTOR LEAD TRANSITION FOR AN ELECTRIC SUBMERSIBLE PUMP (ESP)

Abstract: A low-profile motor lead transition for an electric submersible pump (ESP) is provided. In an implementation, a flat motor lead extension (MLE) for an ESP has conductors that branch out into three separate legs from a single power cable, with each conductor in the MLE individually wrapped in a respective armor sheath. The MLE is made flat to reduce impacts and abrasions in the limited cross-sectional space of a wellbore. The transition in outer armor from the MLE to the single power cable is protected, aligned, and anchored by a low-profile housing member that provides mechanical cover to the joint. The low-profile housing member aligns and secures the armor transition while protecting the transition segment from impacts, abrasions, bending, and aggressive chemicals in a wellbore.
Agents: STONEBROOK, Michael et al; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).


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LOW-PROFILE MOTOR LEAD TRANSITION FOR AN ELECTRIC SUBMERSIBLE PUMP (ESP)

CROSS-REFERENCE TO RELATED APPLICATIONS
[0001] The present document is based on and claims priority to U.S. Provisional Application Serial No.: 62/037,420 filed August 14, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND
[0002] A power cable and motor lead extension (MLE) for connecting power to the motor of an electric submersible pump (ESP) may include single-phase or three-phase electrical conductors. The terminations of the MLE are fastened to the ESP by hardware called a pothead connector. The pothead connector may have an exterior flange and several mechanisms or components designed to prevent well fluid and gas from traveling through the connector and into the motor during operation.

[0003] The installation and operation of the ESP, power cable, and MLE in the confined and harsh environment of a well can result in damage to the power cable and MLE. A damaged power cable or MLE may result in interruption of the ESP. Moreover, the deployment of the ESP or its subsequent operation may subject the power cable or MLE to abuse from the interior surface of the wellbore or from other objects being raised and lowered in the wellbore. These objects can strike or detrimentally slide against the power cable and MLE. Aggressive chemicals in the well environment can also attack and penetrate the power cable and MLE.
SUMMARY

A motor lead extension (MLE) transition for an electric submersible pump (ESP) can include a housing member to cover a joint between a first outer armor of a motor lead extension and a second outer armor of a single power cable, the housing member protecting the joint from an impact, an abrasion, and an aggressive chemical action in a wellbore. An alignment feature can be included in the housing member to maintain the motor lead extension and the single power cable in a collinear alignment while protecting the joint from bending. At least one fastener can secure the housing member to the ESP to secure the joint in between the housing member and the ESP. In an implementation, an apparatus can include an ESP, a power cable for the ESP, an outer armor to protect the power cable from impact, abrasion, and aggressive chemical action in a well. Three conductors within the power cable provide three-phase power to a motor of the ESP. A bundled segment of the power cable has the three conductors bundled together within the outer armor. An unbundled segment of the power cable has the three conductors separated from each other and each individually disposed within a respective branch of the outer armor. A transition segment of the power cable has a first end with an outer armor contiguous with the outer armor of the bundled segment and a second end with an outer armor contiguous with each respective branch of the outer armor of the unbundled segment. A protective member covers the transition segment and protects the transition segment from impact, abrasion, and aggressive chemical action in the well. An
alignment feature of the protective member maintains the bundled segment of
the power cable and the unbundled segment of the power cable in collinear
alignment to protect the transition segment from bending. At least one
fastener anchors the protective member to the ESP, also securing the
transition segment to the ESP. An example method for constructing a power
cable and motor lead extension (MLE) for an ESP can include configuring a
plurality of conductors into a single bundled segment of the power cable and
an unbundled segment providing the motor lead extension composed of a
plurality of separate cables, each separate cable including a respective single
conductor. An armor sheath can be applied about the bundled segment and
the unbundled segment, transitioning the armor sheath from the single
bundled segment to the plurality of separate cables of the unbundled
segment. A housing member covers at least part of a joint where the
transitioning occurs. The housing member aligns, anchors, and protects the
joint from impact, abrasion, and bending action.

[0004] This summary is not intended to identify key or essential features of
the claimed subject matter, nor is it intended to be used as an aid in limiting
the scope of the claimed subject matter.
BRIEF DESCRIPTION OF THE DRAWINGS

[0005] 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.

[0006] Fig. 1 is a diagram of an example ESP system including a low-profile motor lead transition.

[0007] Fig. 2 is a diagram of an example power cable and motor lead extension (MLE) including a transitioned outer armor.

[0008] Fig. 3 is diagram of an example pothead environment of a low-profile MLE.

[0009] Fig. 4 is a diagram of example pothead connections of an example low-profile MLE.

[0010] Fig. 5 is a diagram of an example single branch of an example low-profile MLE.

[0011] Fig. 6 is a diagram of an example low-profile motor lead transition for an ESP.

[0012] Fig. 7 is a flow diagram of an example process of constructing a power cable and low-profile motor lead extension (MLE) for an electric submersible pump (ESP), including a low-profile transition segment between the power cable and the MLE.
DETAILED DESCRIPTION

Overview

[0013] 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.

[0014] This disclosure describes low-profile motor lead transitions for electric submersible pumps (ESPs). A three-phase power cable and a connected motor lead extension (MLE) that divides into three separate legs to attach to an ESP may be encased in an impervious outer armor against impact, abrasion, and aggressive chemical action in a wellbore. But the outer armor must transition between the single power cable and the three separate legs, which are also encased in the outer armor. In an implementation, a low-profile, flat motor lead extension for an ESP has conductors that branch out into three separate legs from the single power cable, with each of the three conductors in the MLE individually wrapped in a respective armor sheath. The MLE is made flat to reduce impacts and abrasions in the limited cross-sectional space of a wellbore. Then, the transition or joint in the outer armor between the MLE and the single power cable is aligned, anchored, and protected by a low-profile housing member that provides mechanical cover to the joint. The low-profile housing member may be a plate, cover, bracket,
flange, shield and so forth. The low-profile housing member aligns and secures the armor transition while protecting the transitional joint in the outer armor from impacts, abrasions, and aggressive chemicals in a wellbore.

Example Well Environments

[0015] The geologic environments of wells in which ESPs operate usually include harsh features. For example, a wellbore is often at high pressure and high temperature. Usual pressures may be around 140 MPa (e.g., about 20 ksi or 20,000 psi) and temperatures around 205 degrees C (i.e., about 400 degrees F). Ultra high temperature and high pressure well environments may have pressures as high as 240 MPa (e.g., about 35 ksi or 35,000 psi) or higher, and temperatures as high as 260 degrees C (i.e., about 500 degrees F) or higher.

[0016] Harsh environments may also include aggressive chemicals with corrosive properties increased by the above pressures and temperatures. For example, well environments may contain hydrogen sulfide (H₂S) and carbon dioxide (CO₂), corrosive to certain materials. The well environment may also have particulates in the well fluid which cause abrasion to hardware, including power cables and MLEs.

[0017] Fig. 1 shows an example wellbore 100 that includes an ESP 102, a power cable 104 to the ESP 102, and a motor lead extension (MLE) 106 between the power cable 104 and the ESP 102. The ESP 102, power cable 104, and MLE 106 may be expected to function in a harsh environment of the
wellbore 100 over an extended period of time (e.g., on the order of years). Example ESPs 102 may generate pump rates above 4,000 barrels per day while lifting the fluid being pumped up to 3.6 km (e.g., about 12,000 feet) or more from the ESP 102 to the surface.

[0018] When a power cable 104 or MLE 106 is placed within a harsh geologic environment, the longevity of this equipment can depend on characteristics of the environment and, for example, duration of use of the power cable 104 and MLE 106. A high-voltage power cable 104 and MLE 106 may pose challenges regardless of the environment into which they are placed. When the power cable 104 and MLE 106 are to endure a harsh environment over an extended period of time on the order of decades, the power cable 104 and MLE 106 are preferably constructed with materials that can endure the harsh environmental conditions.

[0019] In an implementation, an example power cable 104 and MLE 106 are encased in respective outer armors 108 & 109 against the harsh environmental conditions of the wellbore 100. The outer armors 108 & 109 may be sheath or armor layer made from a metal, for example, a steel, aluminum, alloy, or polymer, such as a polyvinylidene fluoride fluoroplastic, a polyvinyl fluoride (PVF), an ethylene tetrafluoroethylene (ETFE), a chlorotrifluoroethylene (CTFE), a polyaryletherketone polymer, a polyetherketone (PEK), a polyether ether ketone (PEEK), and a polyetherketone-etherketoneketone (PEKEKK). The outer armors 108 & 109 may be applied as a wrap, an extruded layer, or by folding an armor sheet
over the bundle or cable lengthwise with the opposing edges of the armor sheet crimped, sealed, or welded together to form a lengthwise seam. In other embodiments, the outer armors 108 & 109 may be tubes into which the conductors are inserted.

[0020] The outer armor 108 has a transition segment 110, or joint, from the outer armor 108 of the single power cable 104 to the outer armor 109 of the MLE 106, which may have three separate armored branches to deliver each phase of a three-phase electrical power, each separate leg encased in an individual outer armor 109. A housing member 112 is disposed on or near the joint or transition segment 110 in the outer armors 108 & 109, to align and stabilize the transition in the outer armors 108 & 109 between the power cable 104 and the MLE 106, protecting the joint or transition segment 110 and anchoring the joint to a casing of the ESP 102. The housing member 112 may also keep the outer armor 108 from unwrapping, loosening, or unraveling.

[0021] The example ESP 102 may include a variety of sections and components depending on the particular application or environment in which the system is used. Examples of components utilized in submersible pumping system 102 include at least one motor 114, one or more submersible pumps 116, and one or more motor protectors 118 coupled together to form stages, sections, or segments of the ESP 102, also referred to as an ESP string.

[0022] The example ESP 102 is designed for deployment in the wellbore 100 within the geological formation 120 containing desirable production fluids, such as petroleum. A wellbore 100 is drilled into the formation 120 and in at
least some applications is lined with a wellbore casing 122. Perforations 124 are formed through wellbore casing 122 to enable flow of fluids between the surrounding formation 120 and the wellbore 100.

[0023] The example submersible pumping system 102 may be deployed in the wellbore 100 by a deployment system 126 that may have a variety of configurations. For example, deployment system 126 may consist of tubing 128, such as coiled tubing or production tubing 128, connected to the ESP 102 by a connector 130 section. Power is provided to one or more ESPs 102 via the power cable 104 and MLE 106. A power supply on the surface 134 may supply a voltage of, for example, about 4.16-4.55 kV at approximately 200 amps to one or more motors 114 that operate at 4.16-4.55 kV. Each ESP motor 114 may be a three-phase induction motor. Each ESP motor 114 may generate approximately 1220 horsepower for pumping the well fluid.

[0024] The submersible motor 114, in turn, powers the pump section 116, which can be used to draw in well fluid through a pump intake 132. Within the pump section 116, multiple impellers may rotate to pump or produce the well fluid through tubing 128 to a desired collection location which may be at the surface 134 of the Earth.

[0025] The example ESP 102 is only one example of many types of electric submersible pumps or pumping systems that may use a power cable 104 and MLE 106. Multiple stages that utilize multiple pumps 116 and multiple motors 114 can be added to the ESP lineup to make a longer string. The submersible pump or pumps 116 can also utilize different types of stages,
such as centrifugal, mixed flow, radial flow stages, and so forth, or other types of pumps such as hydraulic diaphragm electric submersible pumps, for example, which are positive-displacement, double-acting diaphragm pumps with down hole motors.

[0026] Fig. 2 shows an example power cable 104 with an armor sheath or outer armor 108 terminating in a motor lead extension (MLE) 106 with three separate legs individually clad in an outer armor 109. The three legs of the MLE 106 may each provide one phase of a three-phase power being provided to an ESP motor 114. A bundled segment 202 of the power cable 104 has the three conductors bundled together within the outer armor 108 of the bundled segment 108.

[0027] An unbundled segment 204 of the power cable 104 has the three conductors separated from each other and each leg of the power cable 104 individually disposed within a respective branch of their outer armor 109. The unbundled segment 204 may comprise an MLE 106 for connecting to the ESP motor 114.

[0028] A transition segment 110 of the power cable 104 may have a first end contiguous with the outer armor 108 of the bundled segment 202 and a second end contiguous with each respective branch of the outer armor 109 of the unbundled segment 204. Thus, the transition segment 110 is a joint between the outer armors 108 & 109 of the bundled segment 202 and unbundled 204 segment of the power cable 104. In an implementation, the transition segment 110, or joint, is where the outer armor 108 of the single
power cable 104 ends, revealing individual conductors separated from each other, with each individual conductor individually clad in its own outer armor 109.

[0029] The transition segment 110 of the power cable 104 may use various materials and devices to seal the termination of the outer armor 108 of the bundled segment 202, to keep the end of the outer armor 108 of the bundled segment 202 from unwrapping or loosening, and or to seal and secure the joint between the outer armors 108 & 109 of the bundled 202 and unbundled 204 segments. For example, a material for plugging, sealing, and securing the joint may be a plastic, polymer, rubber, braid, metal, solder, or weld.

[0030] For connection to a power cable 104 or to motor lead extensions (MLEs) 106, a motor 114 may include a pothead for receiving connection of the MLEs 106. Such a pothead may, for example, provide for a tape-in connection with metal-to-metal seals (e.g., to provide a barrier against fluid entry). A motor 114 may include one or more types of potheads or connection mechanisms. As an example, a pothead unit may be provided as a separate unit configured for connection, directly or indirectly, to a motor housing.

[0031] The individual conductors may be configured relative to one another in any configuration, for example, a planar configuration or a stacked configuration. The outer armor 109 serves to protect the encased electric components from damage should the power cable 104 be physically struck by another object or be moved to slide against another object, such as the
interior surface of the wellbore 100. Proximate one end of the power cable 104, the transition segment 110 occurs where the individual conductors cease being commonly covered together in the outer armor 108 but instead are individually protected by individual armor sheaths 109 providing motor lead extension 106. Each leg of the motor lead extension 106 may be provided with a mechanical connector 208 adapted, via threads or other structure, to mate with a pothead connector. Each conductor of motor lead extension 106 may terminate in a plug 210 adapted to mate, for example, by insertion into a socket, with the pothead.

[0032] Fig. 3 shows various examples of motor equipment associated with an example power cable 104 and MLE 106. Such equipment includes various components (e.g., units, cables, plugs, etc.) where two or more of the components may be joined to form a joint or joints. As an example, one or more seal elements may be disposed at a joint to form a seal. For example, a seal may be an internal seal, disposed within the cable 104 or piece of equipment. As an example, a seal may be at a location that may be exposed to an external environment, for example, an environment exposed to well fluid(s).

[0033] As shown in Fig. 3, an ESP motor pothead unit 301 includes opposing ends 302 and 304 and a through bore, for example, defined by a bore wall 305. As shown, the ends 302 and 304 may include flanges configured for connection to respective other units (e.g., a protector unit at the
end 302 and a motor unit at the end 304). As an example, the pothead 301 may be part of a pump (e.g., an ESP, etc.).

[0034] In the example of Fig. 3, the pothead unit 301 includes cable passages 307-1, 307-2 and 307-3 (e.g., cable connector sockets) configured for receipt of cable connectors 316-1, 316-2 and 316-3 of respective cables 314-1, 314-2 and 314-3. As shown, the pothead unit 301 can include test ports 309-1, 309-2 and 309-3, for example, to introduce fluid to test respective seals (e.g., seal elements, seating of seal elements, etc.) for plug portions of the cable connectors 316-1, 316-2 and 316-3 as received in the cable passages 307-1, 307-2 and 307-3 (e.g., cable connector sockets). As shown, the cable connectors 316-1, 316-2 and 316-3 can include test ports 319-1, 319-2 and 319-3, for example, to introduce fluid to test respective seals (e.g., seal elements, seating of seal elements, etc.) for respective cable portions of the cables 314-1, 314-2 and 314-3 as received in the cable connectors 316-1, 316-2 and 316-3. As an example, one or more seal elements may be disposed in a test port, for example, fitted in a test port and/or fitted on a test port plug (e.g., optionally about a shaft portion or extension of a plug, etc.). In such an example, one or more seals formed may seal a region of a component or components from an external environment in which the component or components are located.

[0035] As an example, the cables 314-1, 314-2 and 314-3 and/or the cable connectors 316-1, 316-2 and 316-3 may include one or more polymers. For example, a cable may include polymer insulation while a cable connector
may include polymer insulation, a polymer component (e.g., a bushing), etc. As an example, the cables 314-1, 314-2 and 314-3 may be coupled to a single larger cable. The single larger cable 104 may extend to a connector end for connection to a power source or, for example, equipment intermediate the cable and a power source (e.g., an electrical filter unit, etc.). As an example, a power source may be a VSD unit that provides three-phase power for operation of the motor 114.

[0036] Referring to Fig. 4, each of the three individually armored legs of the MLE 106 (each respectively carrying a separate phase of a three-phase power system) are connected to a respective pothead connection 404 to deliver three-phase power to the ESP motor 114. Connector members 402 secure the individual armor wrapped conductors of motor lead extension 106 to the pothead 404.

[0037] Fig. 5 shows an interior of one conductor leg in the unbundled segment 204 providing a motor lead extension 106 portion of the power cable 104. In an implementation, each leg of the MLE 106 has a conductor core 502, an insulation layer 504, a metallic layer 506, and a protective layer 508, each of which may have different sizes and configurations. Conductor core 502 may be formed from copper or other conductive material. Insulation layer 504 may be formed from an electrically insulating material, for example, extruded PEEK insulation. Metallic layer 506 may be a braided metal hose or a solid flexible metal tube. The metallic layer 506 may be extruded atop the insulation layer 504 or co-extruded therewith. The metallic layer 506 may
provide protection from the deployment environment, e.g., an oil-field services well. The protective layer 508 may overlay the metallic layer 506 to provide mechanical protection. Protective layer 508 may be formed from a polyester yarn braid, for example. The outer armor 109 encases each individual conductor leg of the MLE 106.

[0038] Fig. 6 shows an example low-profile motor lead extension transition 110 for an ESP 102. In an implementation, an example housing member 112 secures the power cable 104 to the exterior of an ESP case such that the example motor lead extension (MLE) 106 segment of the power cable 104 is positioned proximate to pothead 404 to facilitate the connection of the power cable 104 with the pothead 404. The example housing member 112 may be a plate, cover, bracket, flange, shield and so forth. In some embodiments, more than one housing member 112 may be used to secure the power cable 104 to a casing of an ESP segment, such as the ESP motor 114.

[0039] In an implementation, a low-profile motor lead extension (MLE) transition 110 for an ESP 102 includes the example housing member 112 to cover at least part of the joint 110 between an outer armor 108 of a single power cable 104 and an outer armor 109 of a motor lead extension 106, the housing member 112 protecting the joint 110 from an impact, an abrasion, and an aggressive chemical action in a wellbore 100.

[0040] At least an alignment feature 602 or alignment member may be included in the housing member 112 to maintain the motor lead extension 106 and the single power cable 104 in a collinear alignment and to protect the joint
from bending. At least one fastener 604 may be included to secure the housing member 112 to the ESP 102 and to secure the joint 110 in between the housing member 112 and the ESP 102.

[0041] In an implementation, the motor lead extension (MLE) 106 and the outer armor 109 of the motor lead extension 106 are made flat. The example housing member 112 is also flat to provide a low-profile transition 110 between the outer armor 109 of the flat motor lead extension 106 and the outer armor 108 of the single power cable 104.

[0042] The example housing member 112 may be a formed housing member, a machined housing member, a molded housing member, an extruded housing member, a 3D-printed housing member, a soldered housing member, a welded housing member, a rolled housing member, or a folded-and-seam-welded housing member, for example.

[0043] The example housing member 112 may be composed of a material, such as a steel, a stainless steel, an aluminum, a MONEL metal, an INCONEL metal (Special Metals Corporation, New Hartford, New York), a nickel-based alloy, a composite, a fiber-reinforced composite, a polyaryletherketone polymer, a polyetherketone (PEK), a polyether ether ketone (PEEK), and a polyetherketone-etherketoneketone (PEKEKK), a polyether ketone ketone (PEKK), a poly (aryl) ether ether ketone (PEEKK), a polyvinylidene fluoride fluoroplastic, a polyvinyl fluoride (PVF), an ethylene tetrafluoroethylene (ETFE), a chlorotrifluoroethylene (CTFE), a fluorinated ethylene propylene (FEP), a polytetrafluoroethylene (PTFE), an expanded
polytetrafluoroethylene (ePTFE), a perfluoroalkoxy polymer (PFA), or an epitaxial co-crystallized alloy (ECA).

[0044] The example housing member 112 may secure the transition 110 between outer armors 108 & 109 by at least one fastener, for example a screw, pin, bolt, spring washer, anchor, strap, cable, clamp, clasp, solder, or weld.

[0045] The joint 110 or transition between outer armors 108 & 109 may further include a material or feature to seal the outer armor 108 and to prevent the outer armor 108 from unwrapping, such as a plastic, a polymer, a rubber, a metal, a solder, or a weld.

[0046] In an implementation, an apparatus may include the ESP 102, the power cable 104 for the ESP 102, and the outer armor 108 to protect the power cable 104 from an impact, abrasion, or aggressive chemical action in the wellbore 100. The three conductors 502 within the power cable 104 provide three-phase power to a motor 114 of the ESP 102. The bundled segment 202 of the power cable has the three conductors 502 bundled together within the respective outer armor 108, while the unbundled segment 204 of the power cable 104 has the three conductors 502 separated from each other and each individually disposed within a respective branch of the respective outer armor 109. The transition segment 110 may include the outer armor 108 of the power cable 104 transitioning into the outer armor 109 of the unbundled segment 204, or MLE 106. Such a transition segment 110 has a first end with an outer armor 108 contiguous with the outer armor 108 of the
bundled segment 202 and a second end with an outer armor 109 contiguous with each respective branch of the outer armor 109 of the unbundled segment, with no break or discontinuity in the outer armors 108 & 109.

[0047] The housing member 112, a protective member, covers at least part of the transition segment 110 and protects the transition segment 110 from impact, abrasion, and aggressive chemical action in a wellbore 100. The alignment feature 602 of the protective housing member 112 maintains the bundled segment 202 of the power cable 104 and the unbundled segment 204 of the power cable 104 in a collinear alignment and protects the transition segment 110 from bending. At least one fastener 604 anchors the protective member 110 to the ESP 102, and the protective member 112 also secures the transition segment 110 to the ESP 102.

[0048] In an implementation, at least the unbundled segment 204 and the transition segment 110 have a flat geometry to provide the low-profile motor lead transition 110 that avoids impact and abrasion in the wellbore 100.

[0049] The transition segment 110 between the power cable 104 and the MLE 106 may further include a strap, tape, or film of a material applied as a winding or wrap to provide a transition 110 of the outer armors 108 & 109. In an implementation, the outer armors 108 & 109 may be tubes, with the three conductors 502 inserted into tubes of the outer armors 108 & 109 and the tubes of the armors 108 & 109 connected to each other at the transition segment 110.
In an implementation, the outer armor 109 may individually surround each individual conductor 502 along an entire length of the power cable 104, but the bundled segment 202 further includes the additional outer armor 108 surrounding the individually armored 109 individual conductors 502, the additional outer armor 108 of the bundled segment 202 ending at the transition segment 110. In another implementation, the individual armor 109 for each leg of the MLE 106 may extend a distance under the outer armor 108 of the single power cable 104.

In various implementations, there may be one or more intermediate layers in the bundled segment 202, with an intermediate layer disposed between the three conductors 502 and the outer armor 108, the intermediate layer also transitioning in the transition segment 110 to respective intermediate layers for each of the three separated conductors 502 in the unbundled segment 204. Such an intermediate layer may be, for example, an insulation, a protective metal, a filler, or a braid.

In an implementation, the protective member may interface with one or more features disposed on the exterior of the ESP in such fashion as to secure the protective member to the ESP without an additional fastener. By way of example, a portion of the protective member may be inserted into a channel disposed on the exterior of the ESP thereby securing the protective member to the ESP. In another implementation, a portion of the protective member may be received by a complimentary feature on the exterior of the ESP to secure the protective member to the ESP.
In some implementations, the protective member may be a plate, a cover, a bracket, a flange, a shield, or a housing.

In some implementations, the joint between the outer armor of the MLE and the outer armor of a power cable may include a length of unarmored MLE and/or power cable. In some implementations, the outer armor of the MLE is contiguous to the outer armor of the power cable.

Example Method

Fig. 7 shows an example method 700 of constructing a power cable and low-profile motor lead extension (MLE) for an electric submersible pump (ESP), with a low-profile transition segment between the power cable and the MLE. In the flow diagram, each operation is shown as an individual block.

At block 702, a plurality of conductors are configured into a bundled segment of a single power cable, and an unbundled segment of a motor lead extension composed of multiple separate cables, each separate cable including a respective single conductor.

At block 704, an armor sheath is applied about the bundled segment and the unbundled segment.
At block 706, the armor sheath is transitioned from the single cable of the bundled segment to the plurality of separate cables of the unbundled segment.

At block 708, a joint where the transitioning occurs is covered at least in part with a housing member to align, anchor, and protect the power cable and the motor lead extension at the joint from impact, abrasion, and bending.

The example method 700 may further include applying the housing member in a manner such as molding the housing member about the joint, fusing the housing member about the joint, folding and seam-welding a sheet of the housing member about the joint, wrapping or winding a strap, tape, strip, or film of the housing member about the joint, extruding the housing member about the joint, and 3D-printing at least part of the housing member about the joint.

The example method 700 may include constructing a flat geometry for the motor lead extension, the transitional joint, and the housing member. The example method 700 may include fastening the housing member to the ESP to anchor the housing member and to secure and permanently align the joint.

In the specification and appended claims: the terms "connect", "connection", "connected", "in connection with", and "connecting" are used to mean "in direct connection with" or "in connection with via one or more elements"; and the term "set" is used to mean "one element" or "more than
one element”. Further, the terms "couple", "coupling", "coupled", "coupled together", and "coupled with" are used to mean "directly coupled together" or "coupled together via one or more elements". As used herein, the terms "up" and "down", "upper" and "lower", "upwardly" and downwardly", "upstream" and "downstream"; "above" and "below"; and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly describe some embodiments of the disclosure.

[0063] While the present disclosure has been disclosed with respect to a limited number of embodiments, those skilled in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations there from. It is intended that the appended claims cover such modifications and variations as fall within the true spirit and scope of the disclosure.
CLAIMS

1. A motor lead extension (MLE) transition for an electric submersible pump (ESP), comprising:
   a housing member to cover at least part of a joint between a first outer armor of a motor lead extension and a second outer armor of a single power cable, the housing member protecting the joint from an impact, an abrasion, and an aggressive chemical action in a wellbore;
   at least an alignment member included in the housing member to maintain the motor lead extension and the single power cable in a collinear alignment to protect the joint from bending; and
   at least one fastener to secure the housing member to the ESP and to secure the joint in between the housing member and the ESP.

2. The motor lead extension (MLE) transition of claim 1, wherein the motor lead extension and the first outer armor of the motor lead extension are flat; and
   wherein the housing member is flat to provide a low-profile transition between the flat first outer armor of the flat motor lead extension and the second outer armor of the single power cable.
3. The motor lead extension (MLE) transition of claim 1, wherein the housing member is selected from the group consisting of a formed housing member, a machined housing member, a molded housing member, an extruded housing member, a 3D-printed housing member, a soldered housing member, a welded housing member, a rolled housing member, and a folded-and-seam-welded housing member.

4. The motor lead extension (MLE) transition of claim 1, wherein at least the housing member comprises a material selected from the group consisting of a steel, a stainless steel, an aluminum, a MONEL metal, an INCONEL metal, a nickel-based alloy, a composite, a fiber-reinforced composite, a polyaryletherketone polymer, a polyetherketone (PEK), a polyether ether ketone (PEEK), and a polyetherketone-etherketoneketone (PEKEKK), a polyether ketone ketone (PEKK), a poly (aryl) ether ether ketone (PEEK), a polyvinylidene fluoride fluoroplastic, a polyvinyl fluoride (PVF), an ethylene tetrafluoroethylene (ETFE), a chlorotrifluoroethylene (CTFE), a fluorinated ethylene propylene (FEP), a polytetrafluoroethylene (PTFE), an expanded polytetrafluoroethylene (ePTFE), a perfluoroalkoxy polymer (PFA), and an epitaxial co-crystallized alloy (ECA).

5. The motor lead extension (MLE) transition of claim 1, wherein the at least one fastener is selected from the group consisting of a
screw, a pin, a bolt, a spring washer, an anchor, a strap, a cable, a clamp, a clasp, a solder, and a weld.

6. The motor lead extension (MLE) transition of claim 1, wherein the motor lead extension includes multiple conductors each individually enclosed in an armor sheath of the first outer armor;

wherein the single power cable includes the multiple conductors each wrapped inside an armor sheath of the second outer armor; and

wherein the joint between the first outer armor and the second outer armor further includes a material to seal an outer armor and to prevent the outer armor from unwrapping, the material selected from the group consisting of a plastic, a polymer, a rubber, a braid, a metal, a solder, and a weld.

7. An apparatus, comprising:

an electric submersible pump (ESP);

a power cable for the ESP;

an outer armor to protect the power cable from an impact, an abrasion, and an aggressive chemical action in a well;

three conductors within the power cable for providing three-phase power to a motor of the ESP;
a bundled segment of the power cable comprising the three conductors bundled together within the outer armor;

an unbundled segment of the power cable comprising the three conductors separated from each other and each individually disposed within a respective branch of the outer armor;

a transition segment of the power cable having a first end with an outer armor contiguous with the outer armor of the bundled segment and a second end with an outer armor contiguous with each respective branch of the outer armor of the unbundled segment;

a protective member to cover at least part of the transition segment and to protect the transition segment from an impact, an abrasion, and an aggressive chemical action in the well, wherein the protective member secures the transition segment to the ESP; and

an alignment feature of the protective member to maintain the bundled segment of the power cable and the unbundled segment of the power cable in a collinear alignment to protect the transition segment from bending.

8. The apparatus of claim 7, wherein a material of at least the protective member is selected from the group consisting of a steel, a stainless steel, an aluminum, a MONEL metal, an INCONEL metal, a nickel-based alloy, a composite, a fiber-reinforced composite, a polyaryletherketone polymer, a polyetherketone (PEK), a polyether ether ketone (PEEK), and a
polyetherketone-etherketoneketone (PEKEKK), a poly ether ketone ketone (PEKK), a poly (aryl) ether ether ketone ketone (PEEKK), a polyvinylidene fluoride fluoroplastic, a polyvinyl fluoride (PVF), an ethylene tetrafluoroethylene (ETFE), a chlorotrifluoroethylene (CTFE), a fluorinated ethylene propylene (FEP), a polytetrafluoroethylene (PTFE), an expanded polytetrafluoroethylene (ePTFE), a perfluoroalkoxy polymer (PFA), and an epitaxial co-crystallized alloy (ECA).

9. The apparatus of claim 7, wherein at least the unbundled segment and the transition segment have a flat geometry to provide a low-profile motor lead transition to avoid an impact, an abrasion, and an aggressive chemical action in the well.

10. The apparatus of claim 7, additionally comprising a fastener securing the protective member to the ESP.

11. The apparatus of claim 7, wherein the protective member is selected from the group consisting of a formed protective member, a machined protective member, a molded protective member, an extruded protective member, a 3D-printed protective member, a soldered protective member, a welded protective member, a rolled protective member, and a folded-and-seam-welded protective member.
12. The apparatus of claim 7, wherein the transition segment further comprises a material applied as a sheet and then folded and seam-welded to provide a transition of the outer armor from the bundled segment to the unbundled segment.

13. The apparatus of claim 7, wherein the transition segment further comprises a strap, tape, or film of a material applied as a winding or wrap to provide a transition of the outer armor from the bundled segment to the unbundled segment.

14. The apparatus of claim 7, wherein the power cable comprises the three conductors inserted into tubes of the outer armor, wherein a tube of the bundled segment is connected to tubes of the unbundled segment at the transition segment.

15. The apparatus of claim 7, wherein the outer armor individually surrounds each individual conductor along an entire length of the power cable and the bundled segment further comprises an additional outer armor surrounding the individually armored individual conductors, the additional outer armor of the bundled segment ending at the transition segment.
16. The apparatus of claim 7, further comprising an intermediate layer in the bundled segment, the intermediate layer disposed between the three conductors and the outer armor, the intermediate layer transitioning in the transition segment to an intermediate layer for each of the three separated conductors in the unbundled segment, the intermediate layer selected from the group consisting of an insulation, a protective metal, a filler, and a braid.

17. A method for constructing a power cable and motor lead extension (MLE) for an electric submersible pump (ESP), comprising:

configuring a plurality of conductors into a single bundled segment of the power cable and an unbundled segment providing the motor lead extension composed of a plurality of separate cables, each separate cable including a respective single conductor;

applying an armor sheath about the bundled segment and the unbundled segment;

transitioning the armor sheath from the single bundled segment to the plurality of separate cables of the unbundled segment; and

covering at least part of a joint where the transitioning occurs with a housing member to align, anchor, and protect the joint from at least an impact, an abrasion, and a bending action.
18. The method of constructing a power cable of claim 17, further comprising applying a process selected from the group consisting of molding the housing member about the joint, fusing the housing member about the joint, folding and seam-welding a sheet of the housing member about the joint, wrapping or winding a strap, tape, strip, or film of the housing member about the joint, extruding the housing member about the joint, and 3D-printing at least part of the housing member about the joint.

19. The method of constructing a power cable of claim 17, further comprising constructing a flat geometry of the motor lead extension, the joint, and the housing member.

20. The method of constructing a power cable of claim 17, further comprising fastening the housing member to the ESP to anchor the housing member and secure the joint to the ESP.
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Configure a plurality of conductors into a single bundled segment of a power cable and into an unbundled segment of the power cable composed of a plurality of separated cables

702

Apply an armor sheath about the bundled segment and the unbundled segment

704

Transition the armor sheath from the bundled segment to the plurality of separated cables of the unbundled segment

706

Cover at least part of a joint where the transitioning occurs with a housing member to align, anchor, and protect the joint

708

Fig. 7
A. CLASSIFICATION OF SUBJECT MATTER
F04D 13/10(2006.01)i, F04D 29/00(2006.01)i, HOIR 13/533(2006.01)i, H02K 5/132(2006.01)i, H02K 5/22(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)
F04D 13/10; H02K 5/02; F04B 35/04; H01R 13/53; F04B 39/00; H02K 5/22; H02B 1/00; H02K 5/124; F04D 29/00; H01R 13/533; H02K 5/132

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: electric submersible pump, power cable, motor lead extension, armor, sheath, cover, protect, shield, alignment, impact, abrasion, and bending

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>A</td>
<td>US 4128735 A (ZEHREN, JAMES N.) 05 December 1978 See abstract, column 2, line 15 - column 3, line 49, and figures 1-4.</td>
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Further documents are listed in the continuation of Box C.

See patent family annex.

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Authorized officer
LEE, Chang Ho

Telephone No. +82-42-481-8398
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