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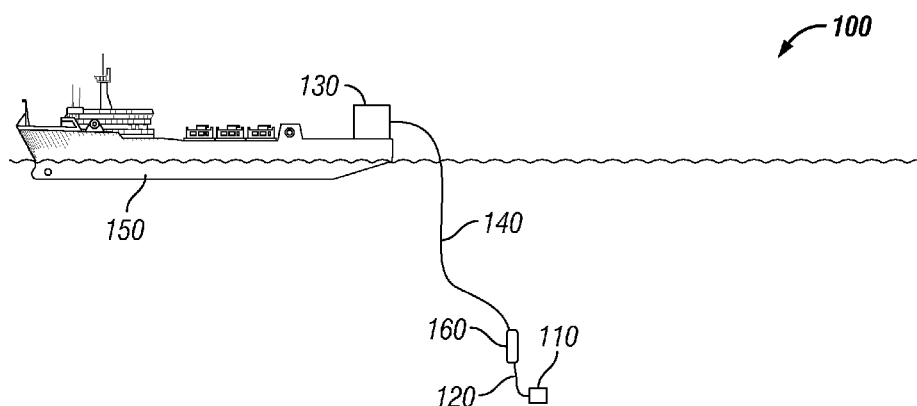


FIG. 1

(57) Abstract: A subsea power and control system comprising a subsea device and a mineral insulated cable, wherein the mineral insulated cable provides power or control signals to the subsea device.



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MINERAL INSULATED POWER AND CONTROL CABLES FOR SUBSEA APPLICATIONS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/520,006, filed June 15, 2017, which is incorporated herein by reference.

BACKGROUND

[0002] The present disclosure relates generally to power cables for subsea applications, and in particular, relates to the use of mineral insulated cables for electrical power and control of subsea equipment.

[0003] As offshore drilling operations progress into deeper waters, the use of fixed, bottom-supported drilling structures decreases. Instead, dynamically-positioned drilling vessels are commonly used in water depths usually greater than 1,000 feet (300 m). To drill a deepwater well, one of these drilling vessels is usually positioned above a subsea wellhead located upon the ocean floor and a pipe assembly, commonly called a riser, is extended downwardly from the vessel to the subsea wellhead.

[0004] The lower end of the riser usually contains hydraulically actuated well control valves and equipment coupling devices used to connect the lower end of the riser to the subsea wellhead. Pressurized hydraulic fluid supplied from the drilling vessel via hydraulic cables may be used to actuate these hydraulic devices.

[0005] At times, the hydraulic cables may be damaged during drilling operations, severing the source of pressurized hydraulic fluid that is supplied to the hydraulically-actuated devices. One solution to this problem is described in U.S. Patent No. 4,601,608, the entirety of which is hereby incorporated by reference.

[0006] Alternatively, polymer-based cables may be used to provide power and communications to subsea equipment. Examples of such polymer-based cables are described in US Patent Nos. 7,798,234 and US Patent Application Publication No. US 2017/0005468, the entireties of which are hereby incorporated by reference. These polymer-based cables however may not be suitable for extreme environments including the elevated temperatures and high pressures in deepwater application.

[0007] It is desirable to develop a system to more accurately and precisely control subsea electrical actuated valves and flow control devices compared to traditional hydraulically controlled system and develop a system that does not suffer degradation in deepwater environments.

5

SUMMARY

[0008] The present disclosure relates generally to power cables for subsea applications, and, in particular, relates to the use of mineral insulated cables for electrical power and control of subsea equipment.

[0009] In one embodiment, the present application provides a subsea power and control system comprising: a subsea device and a mineral insulated cable, wherein the mineral insulated cable provides power or control signals to the subsea device.

10

BRIEF DESCRIPTION OF THE FIGURES

[0010] A more complete and thorough understanding of the present embodiments and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings.

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[0011] FIG. 1 is an illustration of one embodiment of a subsea electrical power and control system according to the present invention.

[0012] FIG. 2 is an illustration of one embodiment of an example of a power cable according to the present invention.

[0013] FIG.3 is an illustration of one embodiment of a cross over system according to the present invention.

20

[0014] The features and advantages of the present disclosure will be readily apparent to those skilled in the art. While numerous changes may be made by those skilled in the art, such changes are within the scope of the disclosure.

25

DETAILED DESCRIPTION

[0015] The description that follows includes exemplary apparatuses, methods, techniques, and/or instruction sequences that embody techniques of the inventive subject

matter. However, it is understood that the described embodiments may be practiced without these specific details.

[0016] The present disclosure relates generally to power cables for subsea applications. More specifically, the present disclosure relates to the use of mineral insulated cables for
5 electrical power and control of subsea equipment.

[0017] Advantageously, the systems described herein serve as a direct replacement for hydraulic systems commonly used for subsea applications, thereby allowing for a reduction of the overall costs and the overall size and weight of those systems.

[0018] A further advantage is that the systems described herein can serve as a direct
10 replacement for polymer-based power and control cable systems. As the cables disclosed herein are suited for elevated temperatures and high pressures, unlike conventional polymer cables, they will not thermally degrade and are not susceptible to fluid permeating through the protective sheath or outer jacket. These properties of the present invention allow for the expansion of the current pressure and depth restriction due to the use of
15 conventional systems.

[0019] Another advantage is that the systems of the present invention allow for more accurate and precise control of subsea electrically actuated valves and flow control devices compared to traditional hydraulically controlled systems. Another advantage is that the systems of the present invention may be able to reduce costs in aging brownfield hydraulic
20 subsea systems.

[0020] The use of mineral insulated (MI) cables is advantageous because they are less susceptible to fluids permeating through the outer corrosion resistant sheath of the cables. Furthermore, the use of the MI cables has fewer complications related to splicing, interconnecting, and interfacing with subsea equipment as required for polymeric insulated
25 cables such as pressure compensated enclosures, dual process/fluid seals, and pressure rated splice bodies.

[0021] Referring now to Figure 1, a subsea power and control system 100 has a subsea device 110 and cable 120.

[0022] The subsea device 110 may be any conventional type of subsea equipment that requires electrical power or electrical control signals. Examples of the subsea device 110 requiring electric power include, without limitation, mudline pumping systems, transformers, flowline heating systems, trace heating systems, power supplies for control
5 systems, chemical pumping systems, and motor operated valves. Examples of the subsea device 110 that require electrical control signals include, without limitation, flow control valves, solenoid operated valves, wellhead chokes, manifold electrically operated valves, and sensing devices.

[0023] Another type of subsea device 110 includes a piece of subsea equipment
10 conventionally operated with hydraulics, such as, for example, without limitation, blowout preventers, subsurface safety valves, flow control valves, solenoid operated valves, wellhead chokes, manifold valves, and injection pumps.

[0024] Still another type of subsea device 110 includes a piece of subsea equipment typically provided with power and/or communicators via a conventional subsea power
15 cable, such as, for example, without limitation, flow control valves, solenoid operated valves, wellhead chokes, manifold electrically operated valves, sensing devices, mudline pumping systems, transformers, flowline heating systems, trace heating systems, power supplies for control systems, chemical pumping systems, and motor operated valves.

[0025] The cable 120 is a mineral insulated cable. The cable 120 may be arranged in a
20 single phase or a three-phase configuration.

[0026] Referring now to Figure 2, the mineral insulated cable 200 has one or more electrical conductors 238, preferably one, two, three, four, or five individual single electrical conductors 238. In the embodiment shown in Figure 2, the mineral insulated cable 200 has three single electrical conductors 238. In other embodiments, not illustrated
25 in Figure 2, the mineral insulated cable 200 may comprise only a single electrical conductor 238. The mineral insulated cable 200 preferably has a single phase, single cable design, a single phase, dual cable design, or a three phase, three cable design. The mineral insulated cable 200 may comprise a single electrical circuit or multiple electrical circuits. In a particular example, the mineral insulated cable 200 has a dual cable and three cable
30 design and is installed within a carrier tubing, such as a coiled tube.

[0027] Each of the individual single electrical conductors 238 illustrated in Figure 2 has conductive cores 228, mineral insulation 230, and a protective sheath 232. The conductive cores 228 are formed of an electrically conductive material, for example, without limitation, copper or aluminum. For example, a first portion of conductive cores
5 228 may be formed of a different conductive material than a second portion of conductive cores 228.

[0028] The mineral insulation 230 is preferably a high temperature insulator material, including, without limitation, magnesium oxide (MgO) or a derivative thereof. Preferably, the mineral insulation 230 is constructed of inorganic material to avoid damaging
10 carbonization in high temperature and/or high pressure environments. As shown in the embodiment of Figure 2, the mineral insulation 230 preferably surrounds the conductive cores 228, for example, by direct contact with conductive cores 228.

[0029] As illustrated in Figure 2, the protective sheath 232 surrounds the mineral insulation 230, preferably in direct contact with the mineral insulation 230. The protective
15 sheath 232 is formed of a material suited for protecting the conductive core 228 in the environment in which it is deployed. For example, the protective sheath 232 in the illustrated examples is constructed of a material that can provide physical protection to the conductive core 228 in a wellbore environment and in a high temperature environment. The protective sheath 232 may be constructed of a metallic material, such as, without
20 limitation, stainless steel, duplex stainless steel, nickel iron, INCOLOY 825, INCOLOY 800, MONEL, carbon steel, lead or the like. In a preferred embodiment, the protective sheath 232 may be a seam welded metal jacket or may have similar construction. The protective sheath 232 is preferably constructed of inorganic material to avoid damaging carbonization in high temperature and/or high pressure environments.

25 [0030] In the embodiment illustrated in Figure 2, the protective sheath 232 is of unitary construction. Alternatively, the protective sheath 232 may be constructed of multiple sheaths, e.g., an inner sheath and an outer sheath. The inner sheath and the outer sheath may be formed of the same or of different materials. When multiple sheaths are used, each sheath may be constructed of an inorganic material to avoid damaging carbonization in
30 high temperature and/or high pressure environments.

[0031] As depicted in Figure 2, the mineral insulated cable 200 has an outer jacket 234. The outer jacket 234 may be constructed of a metallic material, such as, without limitation, stainless steel, duplex stainless steel, nickel iron, INCOLOY 825, INCOLOY 800, MONEL, carbon steel, lead or the like. Preferably, the outer jacket 234 is constructed out of a material that is corrosion resistant and temperature compatible. As illustrated in Figure 2, the outer jacket 234 surrounds each of the electrical conductors 238, for example, as shown by wrapping several electrical conductors 238 with the outer jacket 234. Alternatively, each of the single electrical conductors 238 may be joined by spiraling the individual single electrical conductors 238 in a helical fashion and/or wrapping with the outer jacket 234. The outer jacket 234 advantageously provides additional corrosion resistance while the protective sheath 232 provides additional axial strength or vice versa. In other embodiments, for example when mineral insulated cable 200 comprises only a single electrical conductor 238, mineral insulated cable 200 may not comprise an outer jacket 234.

[0032] In the embodiment illustrated in Figure 2, each of the individual single electrical conductors 238 are shown positioned and joined to form a power cable 200 that has a planar shape. In other embodiments, not illustrated in Figure 2, each of the individual single electrical conductors 238 may be positioned relative to each other in a non-planar shape, for example triangular or cylindrically shaped power cable 200.

[0033] The mineral insulated cable 200 may be a high voltage, medium voltage, or low voltage cable.

[0034] Referring to Figure 1, the cable 120 preferably has features discussed above with respect to mineral insulated cable 200 shown in Figure 2.

[0035] In the embodiment shown in Figure 1, the subsea power and control system 100 has a power source 130 and an umbilical 140. Preferably, a portion of the cable 120 may be disposed within the umbilical 140. In another embodiment, when the umbilical 140 is an umbilical cable, the cable 120 may be connected to the umbilical 140.

[0036] The power source 130 supplies power to cable 120. As illustrated, the power source 130 is located on a floating vessel 150. Alternatively, the power source 130 may be located on a fixed facility.

[0037] The cable 120 may be connected directly to the power source 130. Alternatively, as shown in Figure 1, when the umbilical 140 is an umbilical cable, the umbilical cable may be utilized to connect the mineral insulated cable 120 to the power source 130.

5 [0038] The umbilical cable 140 may be any type of conventional umbilical cable. For example, the umbilical cable 140 may be a multi-conductor power cable that can utilized to transmit the electrical power from the power source 130 to cable 120. The umbilical cable 140 may comprise one or more single or three phase power circuits. Preferably, the umbilical cable 140 may be a dynamic type cable that can withstand constant movement in
10 the subsea due the wave and current forces acting on the surface.

[0039] In the embodiment of Figure 1, the umbilical cable 140 is connected to the mineral insulated cable 120 using a cross over system 160.

[0040] Referring now to Figure 3, a cross over system 160 has an umbilical cable 140, a wet-mate plug 161, a flex lead 162, and an umbilical crossover 163.

15 [0041] The wet-mate plug 161 is any electrical connector that can be connected and disconnected under water for connecting the umbilical cable 140 to the flexible lead 162.

[0042] The flexible lead 162 is a flexible cable for connecting the wet-mate plug 161 to the cable 120.

20 [0043] The umbilical cross over 163 is used to connect the flexible lead 162 to the cable 120. The umbilical cross over 163 may be a 3-way umbilical cross over. Preferably, the umbilical cross over 163 may be an oil filled device. In certain embodiments, umbilical cross over 163 may comprise an MI (mineral insulated) connector for connecting the mineral insulated cable 120 to the flexible lead 162.

25 [0044] In another embodiment, the flexible lead 162 may be connected directly to the mineral insulated cable 120.

[0045] From the foregoing, detailed description of specific embodiments, it should be apparent that a system for a high temperature power cable that is novel has been disclosed. Although specific embodiments have been disclosed herein in some detail, this has been

done solely for the purposes of describing various features and aspects and is not intended to be limiting with respect to the scope of the claims herein. It is contemplated that various substitutions, alterations, and/or modifications, including but not limited to those implementation variations which may have been suggested herein, may be made to the
5 disclosed embodiments without departing from the scope of the appended claims which follow.

CLAIMS

1. A subsea power and control system comprising a subsea device and a mineral insulated cable, wherein the mineral insulated cable provides power or control signals to the subsea device.
- 5 2. The subsea power and control system of claim 1, wherein the mineral insulated cable is arranged in a single-phase configuration.
3. The subsea power and control system of claim 1 or 2, wherein the mineral insulated cable comprises a conductive core, a mineral insulation surrounding the conductive core, and a protective sheath surrounding the mineral insulation.
- 10 4. The subsea power and control system of claim 3, wherein the mineral insulate cable further comprises an outer jacket surrounding the protective sheath.
5. The subsea power and control system of any one of claims 1-4, wherein the subsea device comprises a piece of subsea equipment that requires electrical power or electrical control signals.
- 15 6. The subsea power and control system of any one of claims 1-5, further comprising a power source.
7. The subsea power and control system of any one of claim 6, wherein the mineral insulated cable is connected directly to the power source.
8. The subsea power and control system of any one of claims 1-7, further comprising
20 an umbilical.
9. The subsea power and control system of claim 8, wherein the mineral insulated cable is disposed within the umbilical.
10. The subsea power and control system of claim 8, wherein the mineral insulated cable is connected to the umbilical using a cross over system.

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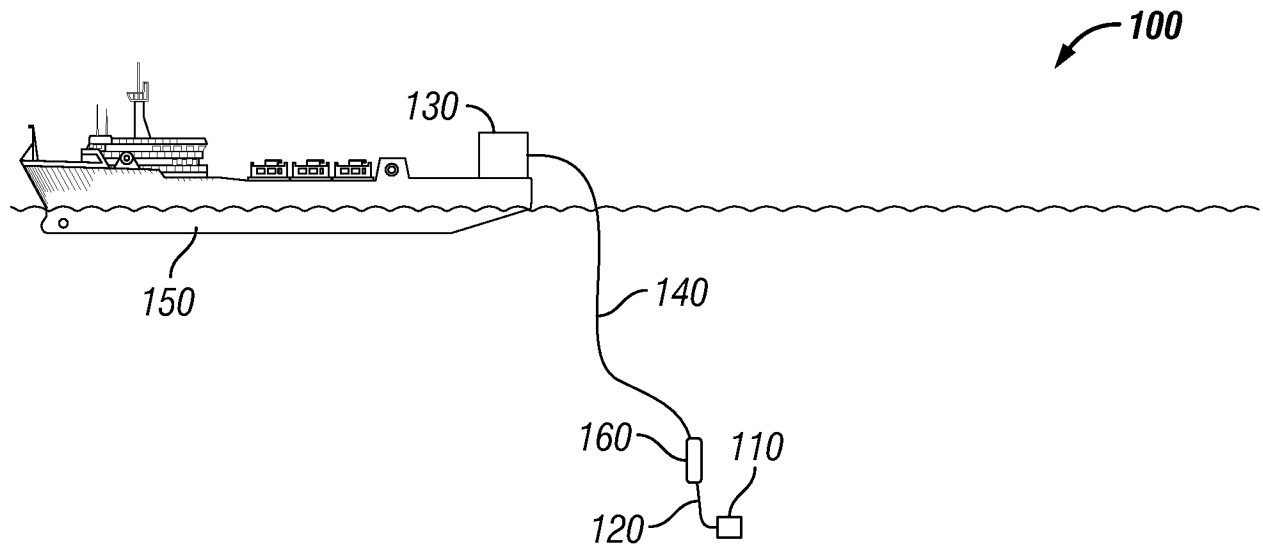


FIG. 1

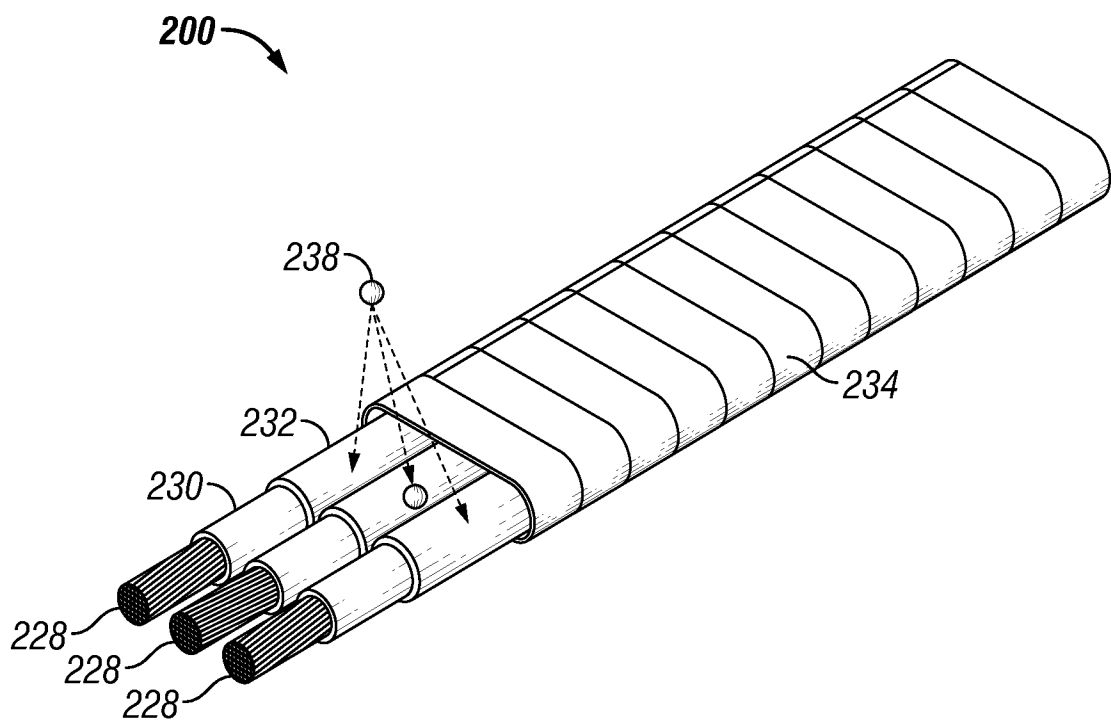


FIG. 2

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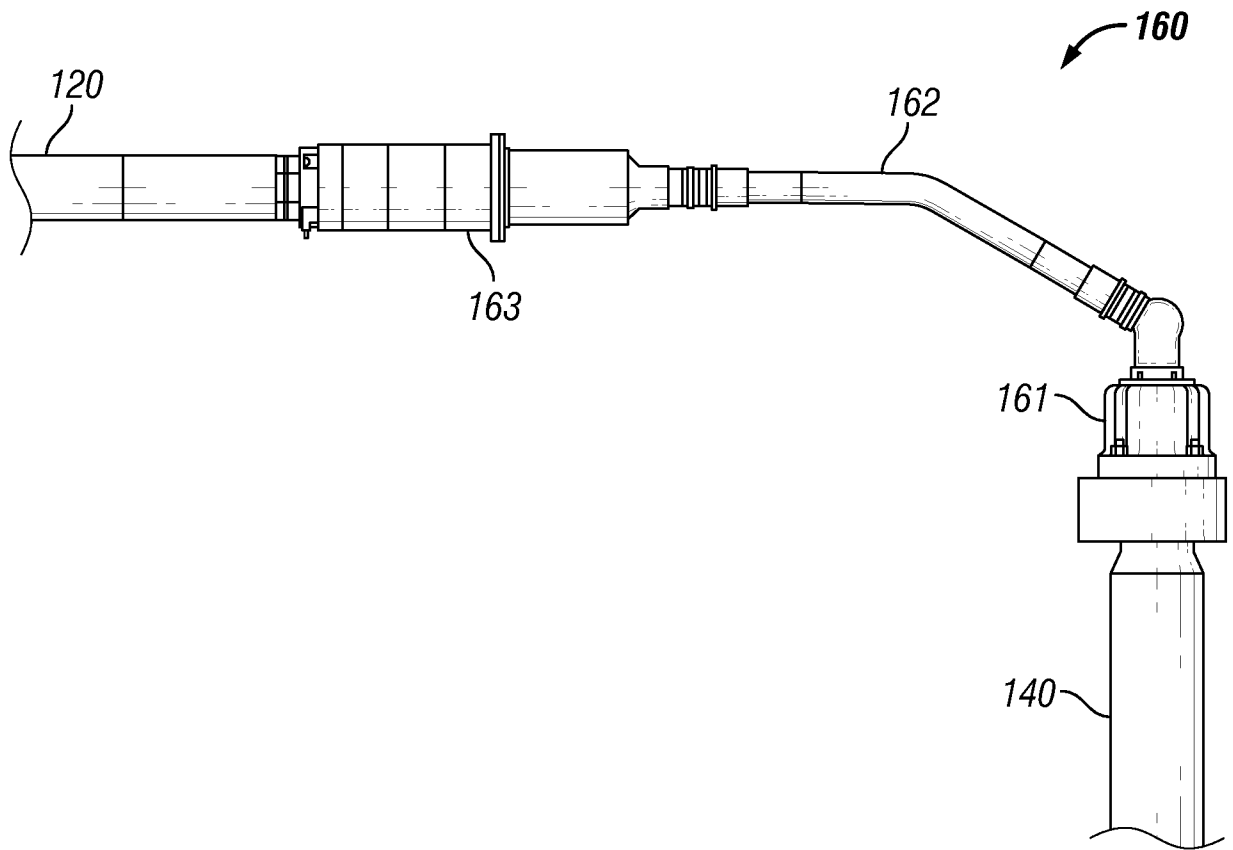


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/037320

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B41/00 F16L11/00 H01B7/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01B F16L E21B H02G

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017/058647 A1 (SCHLUMBERGER TECHNOLOGY CORP [US]; SCHLUMBERGER CA LTD [CA]; SERVICES) 6 April 2017 (2017-04-06)	1-7,9,10
Y	abstract figures 1-3,7 paragraph [0028] paragraph [0043] - paragraph [0044] paragraph [0047] paragraph [0074] paragraph [00104] paragraph [00128] paragraph [00147]	8
Y	US 2009/120632 A1 (WORMAN PETER J [US] ET AL) 14 May 2009 (2009-05-14)	8
A	abstract figure 1 paragraph [0026]	1-7,9,10
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/037320

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/114547 A1 (TYCO THERMAL CONTROLS LLC [US]; PARMAN DAVID G [US]; WHITE LAWRENCE [U] 7 October 2010 (2010-10-07) abstract figures 1-2 paragraph [0010] - paragraph [0012] paragraph [0020] - paragraph [0021] -----	1-10
A	Kme Germany Gmbh & Co Kg: "MINERAL INSULATED CABLES : KME - Engineering Copper Solutions", 24 May 2017 (2017-05-24), XP055502216, Retrieved from the Internet: URL:https://web.archive.org/web/20170524072404/https://www.kme.com/copper-division/mic/ [retrieved on 2018-08-24] the whole document -----	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/037320

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