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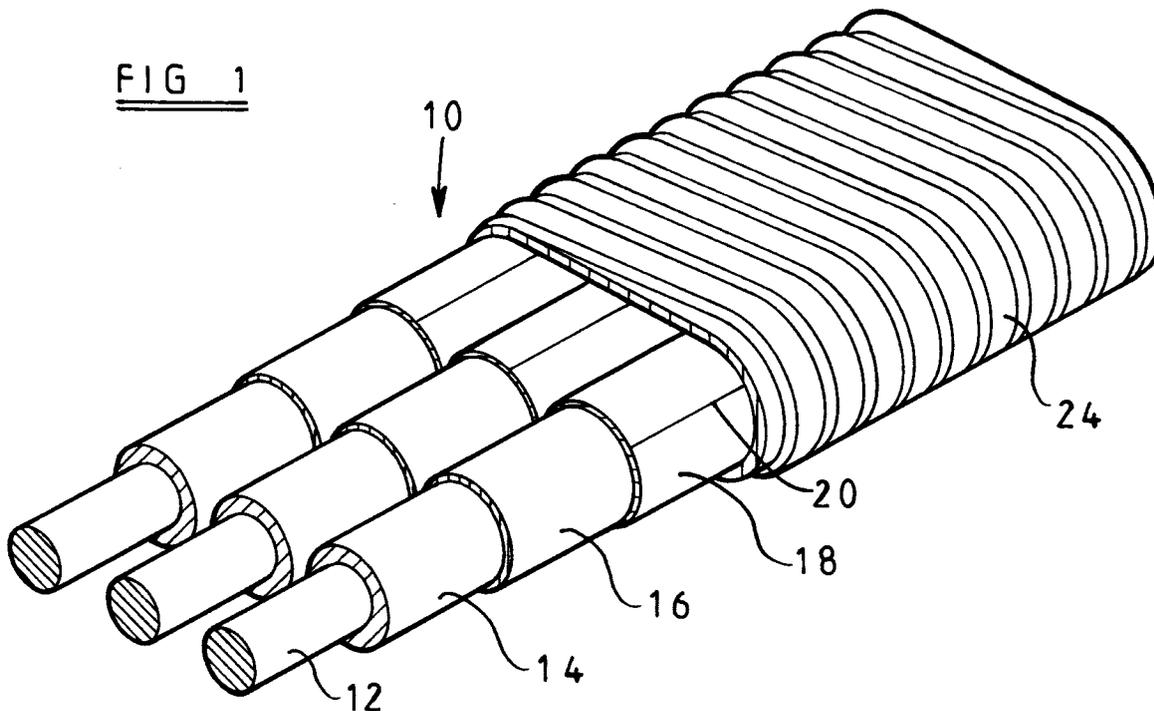
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(54) **Multiconductor electrical cable**

(57) A multiconductor electrical cable (10) for use in a subterranean wellbore includes at least one electrical conductor (12) surrounded by one or more layers (14) of insulating material, such as EPDM. A fluid barrier, such as an extruded layer (16) of lead or a lead alloy, surrounds the insulating material. To protect the fluid

barrier from damage during the subsequent armouring process, a non-braided material (18) is applied, as an extrusion or a tape. The non-braided material can be applied immediately after the fluid barrier is applied, not as a separate process, thereby reducing the risk of damage to the fragile fluid barrier, and at a cost less than the braided materials used in the past.

FIG 1



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Description

The present invention relates to multiconductor electrical cables and, more particularly, to multiconductor electrical cables for use in subterranean wellbores.

Multiconductor electrical cables that are used to power wellbore equipment, such as electrical submersible pumping systems, must be capable of withstanding the high temperatures, high pressures and/or corrosive fluids often encountered within subterranean wellbores. As used herein, the term "high temperature" means temperatures of greater than about 180 F and as high as about 500 F. The term "high pressure" means pressures as high as about 5,000 psi. Further, the term "corrosive fluids" means liquids and gases which can cause degradation to cable insulating materials and/or corrosion to the electrical conductors, such as liquids and/or gases containing hydrogen sulphide, carbon dioxide, brine, water, and the like.

Subterranean wellbore cables include several layers of different materials to either protect the copper conductors from mechanical damage and/or from damage from corrosive fluids. Usually, the copper conductors are sheathed in one or more layers of insulating materials, such as ethylene propylene diene methylene terpolymer ("EPDM"), and a thin sheath of extruded lead to act as a fluid barrier. As a final protection, a metal armour is applied over the electrical conductors.

To protect the thin sheath of extruded lead from mechanical damage, such as cracks from bending and scratches from abrasion, a protective braid is woven around the electrical conductors. When the electrical conductors leave the metal extruder, where the fluid barrier is applied, they are reeled onto a spool, transported to the braiding machines, fed through the braiding machines, and then transported to the armouring machines. Each of these steps greatly increases the chances for the fluid barrier to be damaged, which directly results in power cable failures.

If damage does occur in the manufacturing process, then once the power cable is installed and a failure occurs, then, the fluid production from the wellbore is ceased, resulting in lost revenue to the operator. In addition, expensive and time-consuming cable retrieval, repair and reinstallation procedures must be undertaken.

There is a need for a multiconductor power cable, and methods of manufacture thereof, for use in subterranean wellbores that eliminates the braiding process to form a protection of the metallic fluid barrier.

The present invention has been contemplated to overcome the foregoing deficiencies and meet the above described needs. Specifically, the present invention is a multiconductor electrical cable for use in a subterranean wellbore that includes at least one electrical conductor surrounded by one or more layers of insulating material. A fluid barrier, such as an extruded layer of lead or tin alloy, surrounds the insulating material. To

protect the fragile fluid barrier during the subsequent armouring process, a non-braided protective material is applied as an extrusion or a tape. The non-braided protective material can be applied immediately after the fluid barrier is applied, not as a separate process as in the past with braided materials, thereby reducing the risk of damage to the fragile fluid barrier during manufacturing. In addition, the non-braided protective material can be applied with simple forms or wrapping machines that are less complex and less costly than the prior braiding machines.

Brief description of the drawings:

Figure 1 is a cross-sectional, perspective view of one preferred embodiment of a multiconductor electrical cable of the present invention, with a longitudinal wrap of non-braided material above the fluid barrier.

Figure 2 is a cross-sectional, perspective view of an alternate preferred embodiment of a multiconductor electrical cable of the present invention, with a spiral wrap of non-braided material.

Figure 3 is a cross-sectional, perspective view of an alternate preferred embodiment of a multiconductor electrical cable of the present invention, with an extruded layer of non-braided material.

Figure 4 is a cross-sectional, perspective view of an alternate preferred embodiment of a multiconductor electrical cable of the present invention.

As described above, the present invention comprises a multiconductor electrical cable for use in a subterranean wellbore. The cable includes at least one electrical conductor surrounded by one or more layers of insulating material, with a fluid barrier surrounding the insulating material. To protect the fragile fluid barrier during the subsequent armouring process, a non-braided protective material is applied as an extrusion or a tape. The non-braided protective material can be applied immediately after the fluid barrier is applied, not as a separate process as in the past with braided materials, thereby reducing the risk of damage to the fragile fluid barrier.

While the power cable of the present invention can be used in many differing power transmission environments, for the purposes of the present discussion it will be assumed that the power cable is used to supply electricity to an electric submersible pumping system ("ESP"). As is well known to those skilled in the art, the ESP is set within a casing that is cemented within a subterranean wellbore that penetrates one or more subterranean earthen formations. Typical ESP's comprises an elongated electric motor, an oil-filled motor protector, and a multistage pump connected to a production tubing. The electrical cable extends from a surface power source downwardly within the casing and is operatively connected to the electric motor.

The electrical cable of the present invention is made to withstand relatively high temperatures, high pres-

tures and corrosive fluids encountered within subterranean wellbores; however, it should be understood that the electrical cable of the present invention can also be used in less difficult applications, such as surface power transmission, under water uses, and the like. As used herein, the term "high temperature" means temperatures of greater than about 180 F and as high as about 500 F. The term "high pressure" means pressures as high as about 5,000 psi. Further, the term "corrosive fluids" means liquids and gases which can cause degradation to insulating materials and/or corrosion to the electrical conductors, such as liquids and/or gases containing hydrogen sulphide, carbon dioxide, water, and the like.

To aid in the understanding of the features of the present invention, reference is made to the accompanying drawings. Figure 1 shows one preferred embodiment of an electrical cable 10 of the present invention of a relatively flat configuration, with three electrical conductors 12 in parallel and side-by-side relationship. The electrical conductors 12 are single drawn wires of copper or copper alloys, as shown in Figures 1-3, or from a twist of several wires, as shown in Figure 4. For typical wellbore applications, the conductors 12 are single drawn wires having a diameter or gauge thickness of from about 0.160" (6 AWG) to about 0.414" (2/0 AWG). If the cable 10 is to be used in extremely corrosive environments, the conductors 12 may have a relatively thin coating (not shown) of lead, tin or alloys thereof, hot dipped, heat extruded, or electroplated thereon. One or more ground wires (not shown) may be included, as well as other wires, conductors, conduits, fibre optics, and the like, as may be used to transmit fluids and/or information and command signals through the power cable 10.

At least one of the electrical conductors 12, and preferably all of the conductors 12, is sheathed in at least one layer of an insulating material 14 selected from the group consisting of ethylene propylene diene methylene, ethylene propylene rubber, polychloroprene, polyimide, fluoroelastomers, polypropylene, polyethylene, polyether, and copolymers, mixtures, blends and alloys thereof. If a polyether insulating material is selected, then preferred materials are selected from the group consisting of polyetherketone (PEK), polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyetherketoneetherketoneketone (PEKEKK), and mixtures, blends and alloys thereof. The insulating material 14 is applied to the conductor 12 by spiral or longitudinal wrapping, or preferably by heat extrusion, as is well known to those skilled in the art.

To protect the conductors 12 and the insulation material 14 from damage caused by corrosive fluids, a fluid barrier 16 is applied to the outer surface of the insulating material 14. The fluid barrier 16 is preferably one or more extruded layers of a metal, such as lead, tin, and/or alloys thereof.

As described previously, the fluid barrier 16 is fragile

and very susceptible to cracking and abrasion damage during the manufacturing process. Therefore, a braid of nylon threads has been applied to protect the fluid barrier during subsequent transport and armouring process. As described previously, this braiding process is relatively expensive as compared to extruding processes, uses relatively complex machines as compared to extruding machines, and requires the insulated and sheathed conductors to be spooled onto a reel, moved to the braiding machines, spooled through the braiding machines, respooled onto a reel, and then moved to the armouring machines. All of this spooling and transport can lead to damage to the fluid barrier.

To eliminate or at least to greatly reduce the chances of damage to the fluid barrier 16 during the manufacturing process, with the present invention the prior nylon braid is eliminated and a new non-braided protective material 18 is applied in one or more layers to the fluid barrier 16 as a tape or as an extrusion. The protective material 18 is selected from the group comprising fibreglass, nylon, ethylene propylene copolymer, ethylene vinyl acrylate copolymer, ethylene ethyl acrylate copolymer, ethylene propylene diene methylene terpolymer, polychloroprene, polyolefin elastomer, and copolymers, mixtures, blends and alloys thereof.

To assist in dissipating static electrical charges within the cable 10 to the outer metallic armour, and to provide a grounding of the armour when the cable 10 is installed in a wellbore, the non-braided protective material 18 is selected to be itself semi-conductive, i.e., have a resistivity less than about 10 K ohm/meter, or include one or more threads and/or fibres of semi-conductive materials, such as carbon impregnated nylon threads or other similar material.

One or more layers of the non-braided protective material 18 can be applied to the insulated and sheathed conductors 12 as a separate process, as before with the nylon braid, or preferably as a process that is in-line and immediately adjacent to the machinery that applies the fluid barrier 16. Specifically and for example, the protective material 18 can be in the form of a tape that is passed through a conical form and longitudinally wrapped around the insulated and sheathed conductor 12, as shown in Figure 1. The tape of protective material 18 can be thermoplastic or thermoset, and as such a seam 20 of the protective material 18 can be sealed by the external application of heat to seal the seam. In place of the application of heat or in addition thereto, a solvent or glue can be used along the seam 20 to create a seal.

When the fluid barrier 16 is a heat extruded layer of metal, the fluid barrier 16 exits that extrusion machinery is at about 300 degrees F to about 400 degrees F. Preferably, the seam 20 is sealed simply by applying the tape of protective material 18 immediately thereafter so that the residual heat from the immediately prior metal extrusion will cause the seam 20 to seal.

The tape of the protective material 18 can be applied

as a spiral wrap, as shown in Figure 2, and as one or more extruded layers, as shown in Figure 3. The cable 10 can also include a jacket of elastomeric material 22, as shown in Figure 4, that surrounds the insulated and sheathed conductors 12. This jacket 22 can be formed from tapes and/or one or more extruded layers of elastomeric material selected from the group consisting of nitrile rubber, ethylene propylene, ethylene propylene diene methylene terpolymer, polychloroprene, polyolefin elastomer, polyethylene, polypropylene, polyethylene, polyether, and copolymers, mixtures, blends and alloys thereof. After the protective material 18 has been applied, an outer protective armour 24 is spirally wrapped there around, as is well known to those skilled in the art.

As can be understood from the previous discussion, the present invention provides an electrical cable that does not need a separate braiding process, with its inherent risks of damage to the fragile fluid barrier, and uses material and processes that are less expensive than the prior braided material.

Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modifications, apart from those shown or suggested herein, may be made within the scope of the present invention as defined in the claims

Claims

1. A multiconductor electrical cable for use in a subterranean wellbore, comprising: at least one electrical conductor; at least one layer of insulating material surrounding the at least one electrical conductor; a fluid barrier surrounding the insulating material; an extruded protective material surrounding the fluid barrier; and an outer protective armour.
2. A multiconductor electrical cable for use in a subterranean wellbore, comprising: at least one electrical conductor; at least one layer of insulating material surrounding the at least one electrical conductor; a fluid barrier surrounding the insulating material; a tape of protective material surrounding the fluid barrier; and an outer protective armour.
3. A multiconductor electrical cable for use in a subterranean wellbore, comprising: at least one electrical conductor; at least one layer of insulating material surrounding the at least one electrical conductor; a fluid barrier surrounding the insulating material; a non-braided material surrounding the fluid barrier; and an outer protective armour.
4. A multiconductor electrical cable of Claim 3, wherein the insulating material is selected from the group consisting of tapes and extruded layers of ethylene propylene diene methylene, ethylene propylene rubber, polychloroprene, fluoroelastomers, polypropylene, polyethylene, polyimide, polyether, and copolymers, mixtures, blends and alloys thereof.
5. A multiconductor electrical cable of Claim 4 wherein the polyether insulating material is selected from the group consisting of polyetherketone (PEK), polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyetherketoneetherketoneketone (PEKEKK), and mixtures, blends and alloys thereof.
6. A multiconductor electrical cable of any of Claims 3 to 5, wherein the fluid barrier is selected from the group consisting of extruded layers of lead and alloys thereof.
7. A multiconductor electrical cable of any of Claims 3 to 6, wherein the non-braided material includes at least one thread of semi-conducting material.
8. A multiconductor electrical cable of any of Claims 3 to 7, wherein the non-braided material is selected from the group consisting of fibreglass, nylon, ethylene propylene copolymer, ethylene vinyl acrylate copolymer, ethylene ethyl acrylate copolymer, ethylene propylene diene methylene terpolymer, polychloroprene, polyolefin elastomer, and copolymers, mixtures, blends and alloys thereof.
9. A multiconductor electrical cable of any of Claims 3 to 8, and further comprising a jacket of elastomeric material surrounding the non-braided material.
10. A multiconductor electrical cable of Claim 9, wherein the jacket of elastomeric material is selected from the group consisting of nitrile rubber, ethylene propylene, ethylene propylene diene methylene terpolymer, polychloroprene, polyolefin elastomer, polyethylene, polypropylene, polyether, and copolymers, mixtures, blends and alloys thereof.
11. A multiconductor electrical cable for use in a subterranean wellbore, comprising: at least one electrical conductor; at least one layer of insulating material surrounding the at least one electrical conductor, the insulating material selected from the group consisting of tapes and extruded layers of ethylene propylene diene methylene, ethylene propylene rubber, polychloroprene, polyimide, fluoroelastomers, polypropylene, polyethylene, polyether, and copolymers, mixtures, blends and alloys thereof; a metallic fluid barrier surrounding the insulating material selected from the group consisting of extruded layers of lead and alloys thereof; a non-braided material surrounding the metallic fluid barrier selected from the group consisting of fibreglass, nylon, eth-

ylene propylene copolymer, ethylene vinyl acrylate copolymer, ethylene ethyl acrylate copolymer, ethylene propylene diene methylene terpolymer, polychloroprene, polyolefin elastomer, and copolymers, mixtures, blends and alloys thereof; and an outer protective armour.

12. A method of making a multiconductor electrical cable, comprising:

- (a) surrounding at least one electrical conductor with at least one layer of insulating material;
- (b) surrounding the insulating material with a fluid barrier;
- (c) surrounding the fluid barrier with a non-braided material; and
- (d) surrounding the at least one electrical conductor with an outer protective armour.

13. The method of Claim 12, wherein the insulating material is heat extruded onto the at least one electrical conductor.

14. The method of Claim 13, wherein the insulating material is selected from the group consisting of ethylene propylene diene methylene, ethylene propylene rubber, polychloroprene, polyimide, fluoroelastomers, polypropylene, polyethylene, polyether, and copolymers, mixtures, blends and alloys thereof.

15. The method of any of Claims 12 to 14, wherein the metallic fluid barrier is heat extruded onto the insulating material.

16. The method of any of Claims 12 to 15, wherein the metallic fluid barrier is selected from the group consisting of lead and alloys thereof.

17. The method of any of Claims 12 to 16, wherein a tape of the non-braided material is spirally wrapped around the metallic fluid barrier.

18. The method of any of Claims 12 to 16, wherein a tape of the non-braided material is longitudinally wrapped around the metallic fluid barrier.

19. The method of Claim 18 and further comprising sealing a seam of the tape of non-braided material by applying heat thereto.

20. The method of Claim 18 and further comprising heat extruding the metallic fluid barrier to surround the insulating material, and wrapping a tape of non-braided material around the metallic fluid barrier so that residual heat therein will seal a seam of the tape of non-braided material.

21. The method of any of Claims 12 to 20, wherein the non-braided material is selected from the group consisting of fibreglass, nylon, ethylene propylene copolymer, ethylene vinyl acrylate copolymer, ethylene ethyl acrylate copolymer, ethylene propylene diene methylene terpolymer, polychloroprene, polyolefin elastomer, and copolymers, mixtures, blends and alloys thereof.

22. The method of any of Claims 12 to 21, wherein the non-braided material includes at least one thread of semi-conductive material.

FIG 1

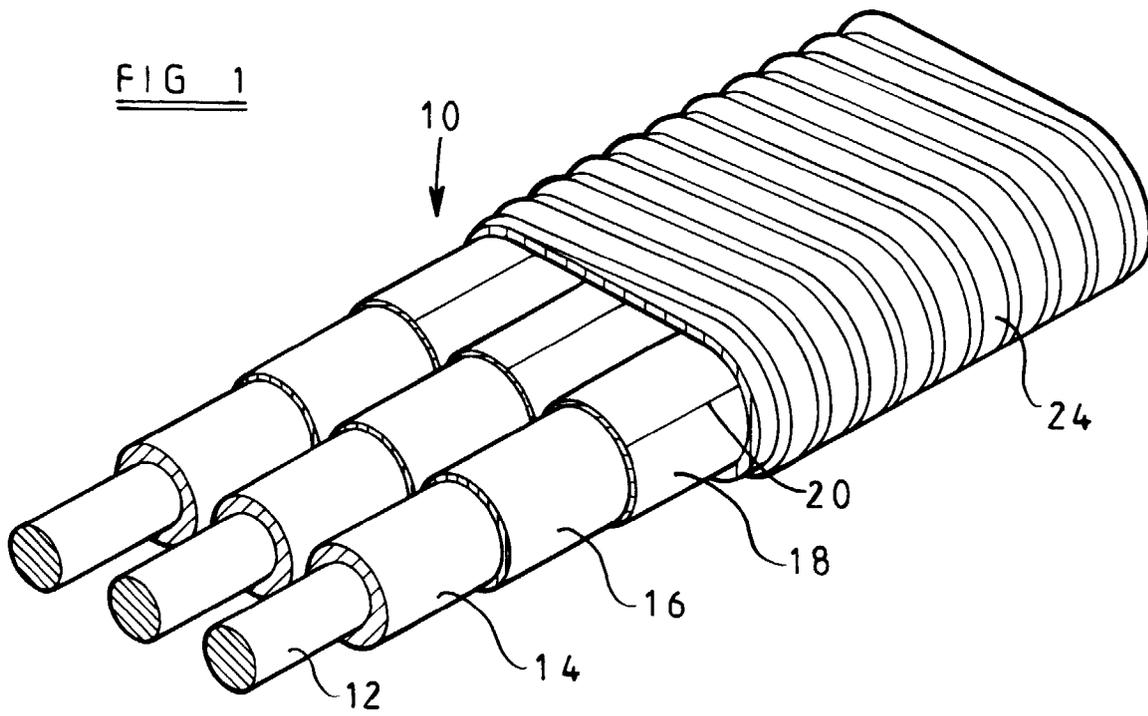
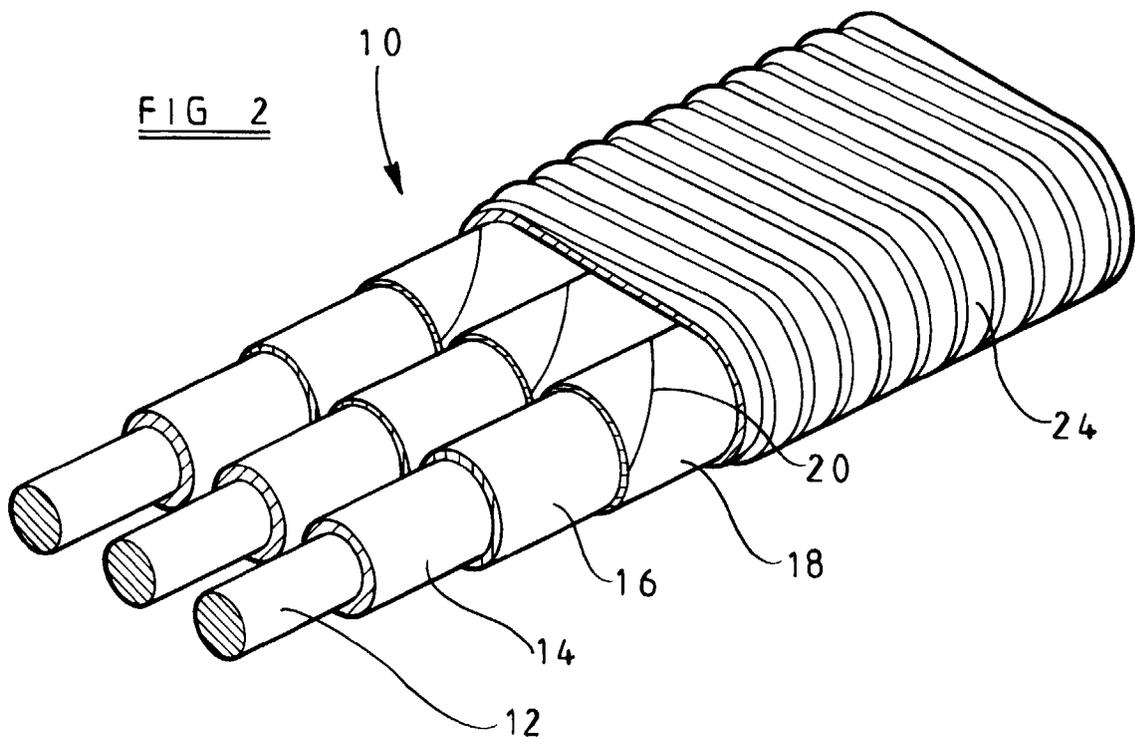
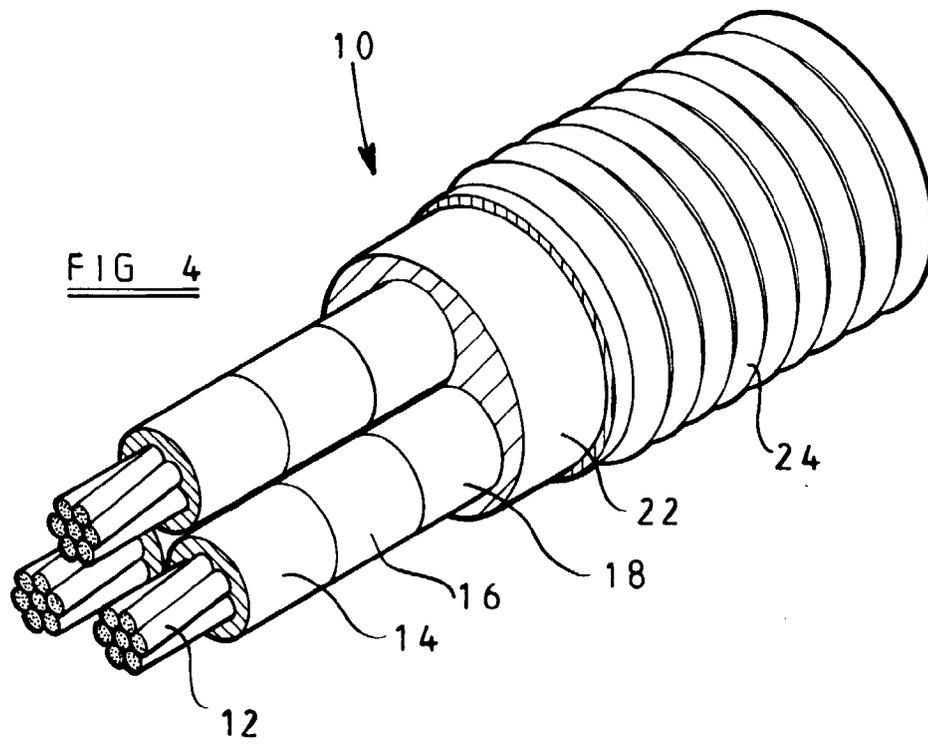
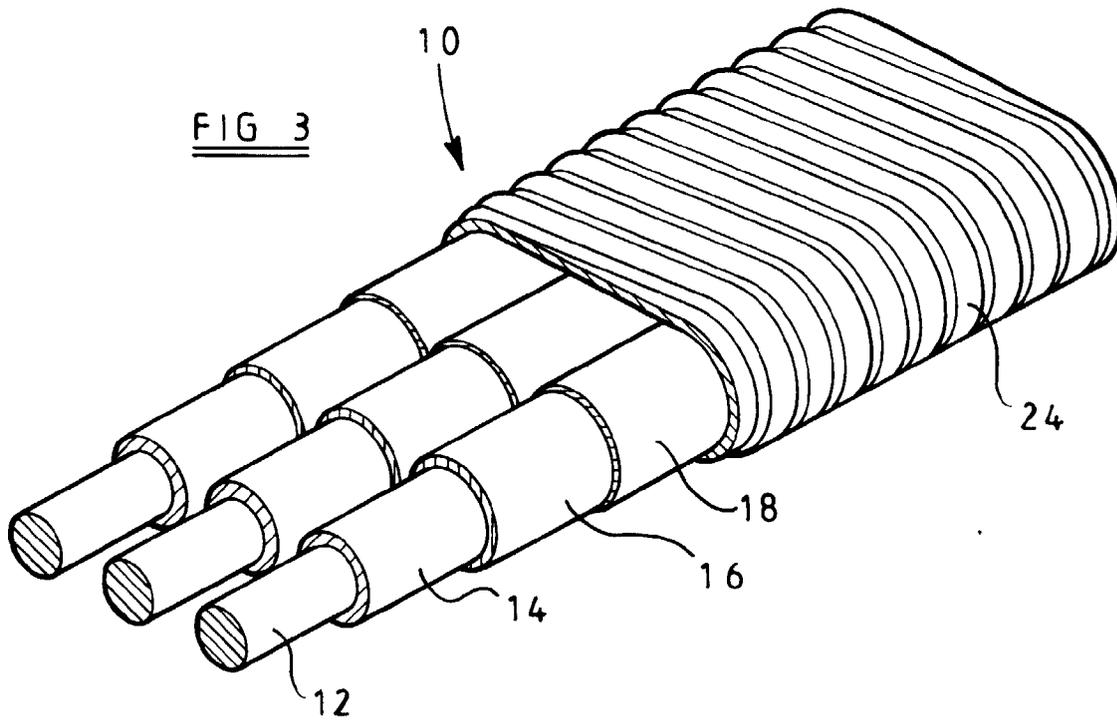


FIG 2







European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 1353

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 5 300 733 A (UEMATSU TADAYUKI) 5 April 1994 * column 1, line 1 - column 5, line 9 * ---	1-3,11, 12	H01B7/28 H01B7/20
X	US 4 626 619 A (UEMATSU TADAYUKI) 2 December 1986 * column 1, line 1 - column 6, line 7 * ---	1-3,11, 12	
X	US 4 780 574 A (NEUROTH DAVID H) 25 October 1988 * figures 1,2 * ---	1-3,11, 12	
X	US 5 414 217 A (NEUROTH DAVID H ET AL) 9 May 1995 * the whole document * ---	1-3,11, 12	
X	EP 0 122 954 A (DAINICHI NIPPON CABLES LTD) 31 October 1984 * the whole document * -----	1-3,11, 12	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		18 September 1998	Shade, M
CATEGORY OF CITED DOCUMENTS			
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