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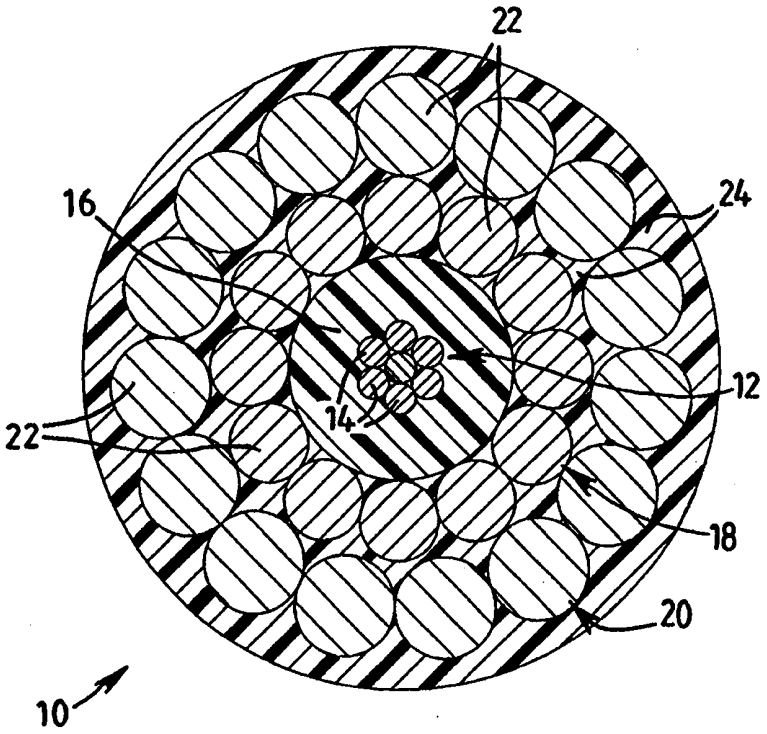
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(54) Title: CONDUCTIVE SLICKLINE CABLE

(57) Abstract

A cable (10) for use in the deployment of services in a well-bore as described which comprises a conductive core (12) which is insulated from at least one layer (18, 20) of armour wires by an insulating layer (16). To control the migration of well fluids through the pressure control equipment, the voids (24) between the armour wires (22) are filled with a resilient material to prevent well fluids from seeping into the voids (24) between the armour wires causing damage to the cable (10). The resilient material binds strongly to the armour wires (22) preventing the armour wires from separating, even after repeated use or loss of tension. Thus, the armour filled with resilient material provides satisfactory mechanical strength for bearing relatively large loads. The resilient material also provides the cable with a smooth outside surface.



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CONDUCTIVE SLICKLINE CABLE

The present invention relates to a cable, and particularly but not exclusively, to a cable for use in the deployment of services in a well bore.

Various cable assemblies have been proposed for the deployment of services in a well bore. Typical cable assemblies include electric lines and slickline cables.

An electric line comprises a central conductive core formed from between one and seven electrical conductors. The core is surrounded by a layer of insulating material, which in turn, is surrounded by an inner layer and an outer layer of armour wires. The armour wires of the inner layer are wrapped around the longitudinal axis of the cable in the opposite direction to the armour wires of the outer layer. The arrangement provides the cable with mechanical strength and helps to prevent the cable from untorquing during use.

Such electric lines may be used to deploy relatively large loads in wellbores and may be used to communicate with and power downhole equipment in real-time. However, electric lines have an uneven surface which requires the use of pressure control equipment incorporating grease control flowtubes, which prevent the migration of well fluids and gases through the voids between the cable armours. A further disadvantage is that the armour wires may separate with repeated use or loss of tension. In such situations, special techniques are required to allow safe recovery of the line from the well bore.

A slickline comprises a single strand of alloy or steel wire used for the mechanical manipulation of various equipment in a well bore. The outside surface of a slickline is smooth; thus, the frictional force in raising or lowering a slickline is relatively low. In addition, the complexity of pressure control equipment used to deploy slickline is considerably less than that which is necessary to deploy an electric line. Slicklines, however, cannot be used to transmit

electricity and, accordingly, cannot be used to communicate electrically, and, accordingly, cannot be used to power downhole equipment.

It is among the objects of embodiments of the present invention to obviate or mitigate at least one of the disadvantages associated with the existing cable assemblies.

It is a further object of embodiments of the present invention to provide a conductive cable having a smooth outside surface, high mechanical strength and which is resistant to damage by well fluids.

This is achieved by providing a cable comprising a conductive core which is insulated from at least one layer of armour wires by an insulating layer. To control the migration of well fluids through the pressure control equipment, the voids between the armour wires are filled with a resilient material to prevent well fluids from seeping into the voids between the armour wires causing damage to the cable. The resilient material binds strongly to the armour wires preventing the armour wires from separating, even after repeated use or loss of tension. Thus, the armour filled with resilient material provides satisfactory mechanical strength for bearing relatively large loads. The resilient material also provides the cable with a smooth outside surface.

According to the present invention, there is provided a cable comprising:

a conductive core,

at least one layer of insulating material surrounding said conductive core,

at least one layer of armour wires disposed around said layer of insulating material, said wires defining voids therebetween, and

a resilient material disposed in said voids between said armour wires.

The cable of the present invention may be used for the deployment of services in a wellbore, and is

suitable, for example, for communicating electrically and powering downhole tools in real time. Additionally and/or alternatively, the cable may be used to raise or lower relatively large loads in a wellbore. The resilient material fills the voids between the wires so that the armour wires are bound together and are resistant to separation, even after repeated use. The outside surface of the cable is relatively smooth; thus, the frictional losses involved in raising and lowering the cable are relatively low. The cable has a high degree of mechanical strength and is resistant to damage by well fluids and permits deployment utilising the minimum of pressure control equipment.

Preferably, the cable comprises an even number of armour wire layers. Preferably also, each layer is wrapped around the longitudinal axis of the cable in an opposite direction to the layer immediately adjacent to it. In a preferred embodiment, the cable comprises an inner layer and an outer layer of armour wires. The armour wires of the inner layer are wrapped around the longitudinal axis of the cable in the opposite direction to the armour wires of the outer layer. The arrangement provides the cable with mechanical strength and helps to prevent the cable from untorquing during use.

The conductive core may be formed of one or more electrical conductors. Any suitable metal or metal alloy wire may be used as an electrical conductor. In one embodiment, the conductive core comprises a bundle of seven copper conductors. In a preferred embodiment, a single conductor comprising a bundle of seven #20AWG, 7/,126"BCu copper strands is employed.

The conductive core is insulated by a layer of, for example, a plastics material. Suitable plastics insulators include, for example, EPC, PVC and PTFE. In a preferred embodiment, a layer of 0.05842cm (0.023") Wall EPC is used.

The armour wires may be formed from Incalloy,

stainless steel or carbon steel.

Preferably, the armour wires are formed from galvanised improved plough steel (IPS). In a preferred embodiment, an inner armour layer of 12/0.024" wire and an outer armour layer of 15/0.03" wire are used.

The voids between the armour wires are filled with any resilient material, for example, a plastics material. Suitable plastics include polypropylene, TPX, Tefzel and Teflon PTFE. Most preferably, however, the voids are filled with polytetrafluoroethylene (PTFE). Polytetrafluoroethylene molecularly bonds to the armour wires, preventing the wires from separating even after extensive use. The polytetrafluoroethylene also provides the cable with a protective seal and a smooth outside surface. The resulting cable withstands conditions, for example, of pressure and temperature within a well bore, and is resistant to damage by well fluids. The cable is also suitable for supporting relatively large loads by virtue of its high mechanical strength, and permits deployment utilising the minimum of pressure control equipment.

Advantageously, the bond formed between the resilient material bonds to the armour wires is consistent throughout the length of the cable. In one embodiment, this is achieved by applying the resilient material to the cable at the time of applying the armour wires. Alternatively, the resilient material may be applied using a pressurised die process similar to that employed in the construction of heavy duty marine umbilicals.

Preferably, the cable is surrounded by a further protective layer.

Advantageously, each kilometre length of cable weighs approximately between 60 and 120 kg. Typically, each kilometre length of cable weighs approximately 80 to 100 kg. In a preferred embodiment, the mass of the cable is 94kg per km.

Conveniently, the breaking strength of the cable is in excess of approximately 9 kN, typically above 12 kN and preferably, in excess of 17 kN. Conveniently also, the cable has a working load of above approximately 3 kN, and preferably, above 6 kN.

These and other aspects of the present invention will now be described, by way of example, with reference to the accompanying drawing which is a cross sectional view of the cable according to a preferred embodiment of the present invention.

The drawing depicts a conductive slickline cable in accordance with a preferred embodiment of the present invention. The cable has overall dimensions (OD) of 4.95mm (0.195"). Certain characteristics of the conductive slickline cable are comparable to those of armour cables of, for example, the Rochester stock type 1-H-18LA10 (Rochester Corporation, Virginia, USA).

The conductive slickline cable 10 comprises a conductive core 12 formed of a bundle of seven copper strands 14 (#20 AWG, 7/.126"BCu), each strand 14 measuring 0.32 mm (0.0126") in diameter. The core 12 is surrounded by a layer of insulating material 16 (0.5842mm (0.023") Wall EPC), which in turn, is surrounded by an inner layer 18 and outer layer 20 of armour wires 22 (spec.galv. IPS).

The inner layer 18 is formed of 12/0.024" wire and the outer layer is formed of 15/0.03" wire. The inner layer 18 is wrapped around the longitudinal axis of the cable 10 in the opposite direction to the outer layer 20. The arrangement provides the cable 10 with mechanical strength and helps to prevent the cable 10 from untorquing during use. The PTFE also prevents the armour wires 22 from separating with repeated use or loss of tension, and permits deployment utilising the minimum of pressure control equipment.

Voids 24 between the armour wires 22 are filled with polytetrafluoroethylene (PTFE). PTFE is resilient and

chemically bonds on a molecular level to the armour wires 22 to provide the cable 10 with a smooth outside surface and to protect the cable 10 from damage caused by well fluids and permits deployment utilising the minimum of pressure control equipment.

The cable 10 is suitable for the deployment of services in wellbores. The cable 10 may be used to communicate electrically and power downhole tools in real time. The cable 10 is also is resistant to damage by well fluids and may be used to support large loads. By virtue of the cable's 10 smooth outside surface, the frictional losses involved in raising and lowering the cable 10 in a wellbore are relatively low.

The physical, mechanical and electrical properties of the cable 10 are listed in Tables 1 to 3 below:

Table 1

Physical Properties and Characteristics of Cable 10

Diameter of conductor 14	0.97mm
thickness of insulating layer 16	2.13mm
diameter of armour wires 22 in inner layer 18	3.18mm
diameter or armour wires 22 in outer layer 20	4.70mm
weight of cable 10 in air	94kg/km
weight of cable 10 in water	79kg/km
temperature rating of cable 10 (normal)	136°C
temperature rating of cable 10 (intermittent)	149°C

Table 2

Mechanical Properties of Cable 10

Breaking strength	17.3kN
Working load	6.4kN
Bend diameter	30cm
Elongation	0.9m/km/kN

Table 3

Electrical Properties of Cable 10

Voltage Rating of cable 10	1000Vdc
Resistance of insulating layer 16	15000MΩ/km
dc Resistance at 20°C copper conductor 14	32.2 Ω/km
dc Resistance at 20°C armour wires 22	21.0 Ω/km
capacitance at 1kHz of copper conductor:armour	164pF/m
velocity of propagation at 1MHz	67%

Various modifications may be made to the embodiment described above without departing from the scope of invention. For example, a plurality of layers of armour wire may be employed. Also, the PTFE elastomer may be replaced by any resilient material which will bind to the armour wires. Suitable materials include polypropylene, TPX, Tefzel and Teflon PTFE. In a further modification, the conductive slickline cable is surrounded by a sheath of stainless steel, Inconel or another elastomer.

The conductive slickline cable is applicable to a wide range of cable sizes.

CLAIMS

1. A cable comprising:

a conductive core,

at least one layer of insulating material surrounding said conductive core,

at least one layer of armour wires disposed around said layer of insulating material, said wires defining voids therebetween, and

a resilient material disposed in said voids between said armour wires.

2. A cable as claimed in claim 1 wherein the resilient material fills the voids between the wires.

3. A cable as claimed in claim 1 or claim 2 wherein the outside surface of the cable is relatively smooth.

4. A cable as claimed in any preceding claim wherein the cable comprises an even number of armour wire layers.

5. A cable as claimed in any preceding claim wherein each layer is wrapped around the longitudinal axis of the cable in an opposite direction to the layer immediately adjacent to it.

6. A cable as claimed in any preceding claim wherein the cable comprises an inner layer and an outer layer of armour wires.

7. A cable as claimed in claim 6 wherein the armour wires of the inner layer are wrapped around the longitudinal axis of the cable in the opposite direction to the armour wires of the outer layer.

8. A cable as claimed in any preceding claim wherein the conductive core is formed of one or more electrical conductors.

9. A cable as claimed in claim 8 wherein the conductive core comprises a bundle of seven copper conductors.

10. A cable as claimed in any preceding claim wherein the conductive core is insulated by a layer of plastics material.

11. A cable as claimed in claim 10 wherein plastic insulator material may be selected from the group

consisting of EPC, PVC and PTFE.

12. A cable as claimed in any preceding claim wherein the armour wires are formed from galvanised improved plough steel (IPS).

13. A cable as claimed in any preceding claim wherein the inner armour layer is 12/0.024" wire and the outer armour layer is 15/0.03" wire.

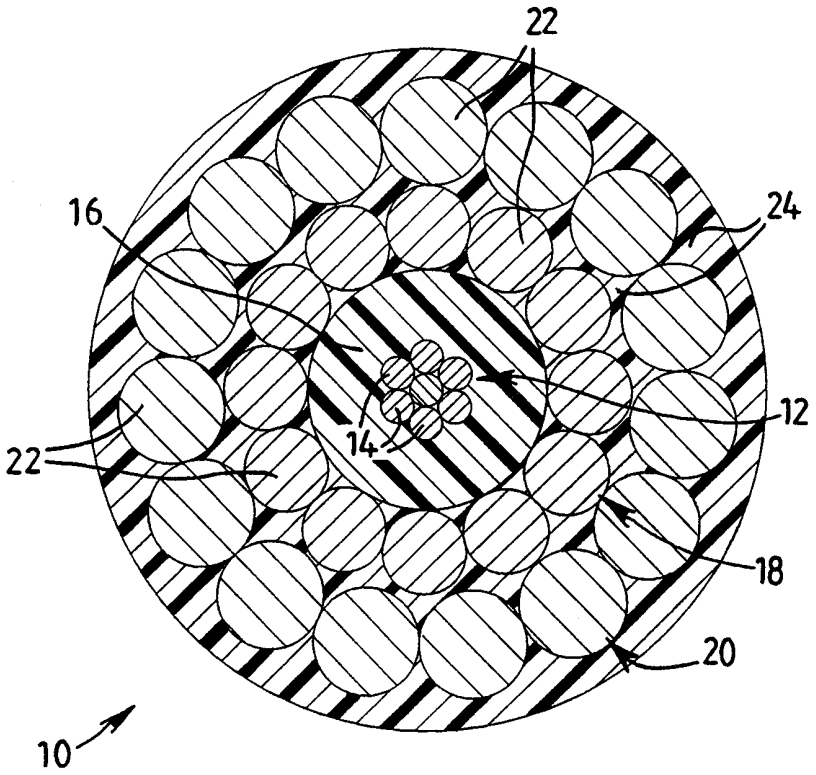
14. A cable as claimed in any preceding claim wherein the voids re filled with polytetrafluoroethylene (PTFE).

15. A cable as claimed in any preceding claim wherein the resilient material bonds to the armour wires throughout the length of the cable.

16. A cable as claimed in any preceding claim wherein the cable is surrounded by a further protective layer.

17. A cable as claimed in any preceding claim wherein each kilometre length of cable weighs approximately 80 to 100 kg.

18. A cable as claimed in any preceding claim wherein the breaking strength of the cable is in excess of approximately 9 kN, typically above 12 kN and preferably, in excess of 17 kN.


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INTERNATIONAL SEARCH REPORT

Interr ıal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01B7/22 H01B7/04

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)
IPC 6 H01B

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

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 131 757 A (FELKEL) 26 December 1978 see column 4, line 33 - column 12, line 42; figures 1-5	1-8,10, 15
X	EP 0 471 600 A (SCHLUMBERGER) 19 February 1992 see page 4, line 38 - page 6, line 55; figures 1-3	1,2,4-8, 10,11

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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