



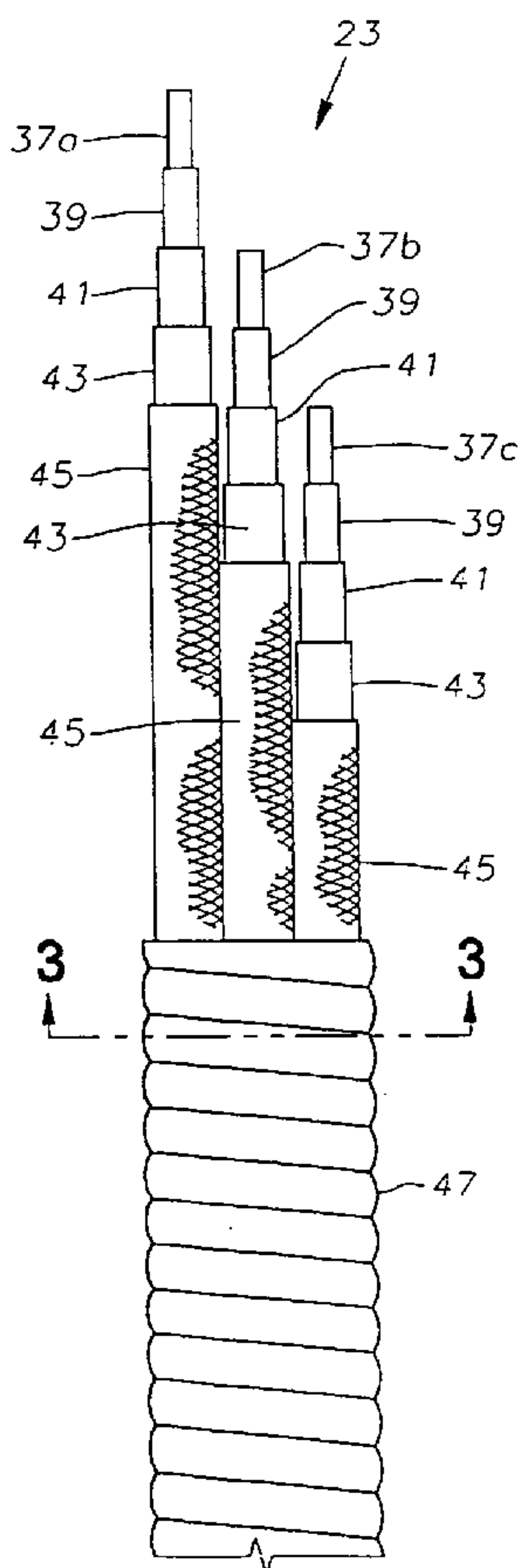
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(54) **CABLE DE POMPE ELECTRIQUE SUBMERSIBLE RESISTANT
A LA CORROSION POUR UTILISATION DANS DES Puits
AUX CONDITIONS EXTREMES**

(54) **CORROSION RESISTANT ELECTRICAL SUBMERSIBLE PUMP
CABLE FOR USE IN EXTREME WELL CONDITIONS**



(57) A cable for a submersible pump has three power conductors. The power conductors are surrounded by an elastomeric insulation. A lead sheath surrounds the elastomeric insulation. A barrier layer is extruded over the lead sheath to protect the lead sheath, the elastomeric insulation and the conductors from highly corrosive well fluids. A cable armor surrounds these insulated and protected power conductors.



ABSTRACT

A cable for a submersible pump has three power conductors. The
5 power conductors are surrounded by an elastomeric insulation. A lead sheath
surrounds the elastomeric insulation. A barrier layer is extruded over the lead sheath
to protect the lead sheath, the elastomeric insulation and the conductors from highly
corrosive well fluids. A cable armor surrounds these insulated and protected power
conductors.

**CORROSION RESISTANT ELECTRICAL SUBMERSIBLE
PUMP CABLE FOR USE IN EXTREME WELL CONDITIONS**

Technical Field

This invention relates in general to power cables for electrical submersible pumps, and in particular to a power cable having an barrier layer
5 extruded over the power conductors to protect the conductors from highly corrosive environments.

Background Art

In an electrical submersible pump installation for an oilwell, the pump
10 is driven by a downhole AC motor. The downhole pump assembly is suspended on the end of a string of tubing. The power cable extends from the surface alongside the tubing down to the motor.

Two types of power cable are in general use. Each type utilizes three insulated conductors for transmitting three phase AC power. In one type, the
15 insulated conductors are assembled in a cylindrical or round configuration, each 120 apart from the other and located within an elastomeric jacket. An outer armor comprising a metal strip wraps helically around the round configuration of the jacket.

In the other type of cable, the conductors are assembled in a flat configuration. The insulated conductors are located side by side, touching each other
20 and with their axis in a common plane. An armor comprising a metal strip wraps helically around the assembled insulated conductors. Flat cable is particularly useful where there is insufficient clearance for round cable. In wells having a corrosive environment, such as when H₂S is present, the cable of choice for such environments has been a lead cable. A typical lead cable consists of a plurality of conductors

surrounded by an elastomeric insulation such as EPDM. The elastomeric insulation is surrounded by a lead sheath. A metallic outer armor is wrapped around the assembled lead sheaths. The lead sheath protects the copper conductors from attack and degradation in the form of copper sulfide. Because of lead's excellent barrier
5 properties, the lead protects the underlying insulation material from chemical and decompression damage, therefore providing good performance in harsh well environments.

Although lead cable has been successfully used for many years, there are situations where highly corrosive environments can corrode the lead and cause
10 ultimate failure of the cable. In such cases, the lead may be severely pitted, which leads to cable failure. Examples of highly corrosive environments that may lead to pitting of the lead layer and subsequent cable failure include wells having H₂S and high concentrations of brine or chloride. It is theorized that the lead corrosion results from galvanic coupling and/or crevice corrosion between the lead and the steel armor
15 in the presence of H₂S and chlorides.

Summary of the Invention

A power cable is provided for an electrical submersible pump assembly that preferably has three power conductors. The power conductors are typically
20 copper. An elastomeric insulation such as EPDM surrounds each of the power conductors. A lead sheath surrounds the elastomeric insulation of each of the conductors. An extruded barrier layer is provided over each of the lead sheaths. Examples of acceptable extruded fluoropolymer barrier layers include polyvinylidene fluoride (PVDF), fluorinated ethylene propylene (FEP), or a co-polymer of

tetrafluoroethylene and perfluoromethylvinylether (MFA). The extruded barrier layer provides protection to the lead sheath and the insulated power conductors from corrosive well fluids. The extruded barrier layer is preferably 5 - 50 mils in thickness.

A metallic armor is wrapped around the assembled conductors, the armor being
5 separated from the lead sheaths by the barrier layers.

Brief Description of the Drawings

Figure 1 is a schematic drawing of a typical submersible pump assembly installed in a well.

10 Figure 2 is a cut-away view showing a portion of a cable for an electrical submersible pump constructed in accordance with this invention.

Figure 3 is a sectional view of the cable taken along the line 3-3 of Figure 2.

Detailed Description of the Invention

15 Referring now to Figure 1, well casing 11 is located within a well in earth formation 13 and also passes through a producing zone 15. Perforations 17 formed in the well casing 11 enable the fluid in the producing zone 15 to enter the casing 11.

20 The submersible pump assembly includes an electrical motor 19 that is located in the well. Electrical motor 19 receives power from a power source 21 via power cable 23. The shaft of motor 19 extends through a seal section 25 and is connected to a centrifugal pump 27. Pump 27 is connected to tubing 29 for conveying well fluid 31 to a storage tank 33 at the surface. The casing 11 will contain an

operating fluid level 35 in the annulus of the casing 11. The pump 27 must be capable of delivering fluid for the distance from level 35 to the surface tank 33.

Referring to Figures 2 and 3, power cable 23 has three power conductors 37a, 37b, and 37c, which are assembled side by side. Although a flat power cable 23 is shown in the drawings it should be understood that the invention is applicable to round power cables or other types of power cables. Power conductor 37a is on one side of the configuration, power conductor 37b is located in the middle, and power conductor 37c is on the other side. Each power conductor 37a, 37b, and 37c is preferably made of copper. The power conductors 37a, 37b and 37c are surrounded by an elastomeric insulation 39. Elastomeric insulation 39 is typically made of ethylene-propylene-diene-monomer rubber (EPDM). The insulation 39 is encased within a sheath 41 that may be of lead and is typically about 0.030 to 0.060 inches thick, and is preferably 0.040 inches thick. An extruded barrier layer 43 surrounds sheath 41. Extruded barrier layer 43 provides a hermetic seal to prevent corrosive well fluids from contacting the elastomeric insulation 39 and power conductors 37a, 37b and 37c. Preferably, barrier layer 43 is between 5 - 50 mils in thickness. Examples of acceptable materials for extruded barrier layer 43 include polyvinylidene fluoride (PVDF) for anticipated downhole temperatures of up to 300F. For anticipated downhole temperatures of up to 400F, it has been found that fluorinated ethylene propylene (FEP) is preferred. Finally, for higher temperature applications of up to 500F, it has been found that a copolymer of tetrafluoroethylene and perfluoromethylvinylether (MFA) is preferred. MFA may be obtained from Ausimont USA, Inc. in Thorofare, New Jersey and is available under the trademark Hyflon®. A fabric wrap 45 may be provided around extruded layer 43. A cable

armor 47 surrounds extruded barrier layers 43. Armor 47 holds the conductors 37 in a flat or side by side configuration. Armor 47 is typically a metal strip that wraps helically around the assembled conductors 37a, 37b and 37c. The metal strip is overlapped at each wrap.

5 During manufacture, after the lead sheath 41 has been extruded over the elastomeric insulation 39, the insulation 39 and sheath 41 are taken through a separate extrusion operation when an appropriate barrier material 43 is extruded over the lead sheath 41. The temperature of the barrier material 43 is raised to the melting point of the barrier material 43 by applying heat as the barrier material 43 passes
10 through an extruder. The molten barrier material 43 is then formed into a continuous tubular form over the lead sheath 41.

In the preferred embodiment, extrusion tooling is selected to optimize the physical properties of the barrier layer material 43 and to yield an average thickness of approximately .020 inches. The elastomeric insulation 39 and sheath 41
15 are pulled forward as the barrier material 43 is extruded so that the lead sheath 41 is coated with a continuous fluid repelling barrier layer 43. The resulting barrier layer 43 prevents well fluids from coming into contact with the lead sheath 41, thereby preventing the onset of galvanic corrosion.

In practice, the power cable 23 of the invention may be used in highly
20 corrosive well environments. The extruded barrier layer prevents corrosive well liquids, which may contain high concentrations of brine or chlorides, from coming in contact with the underlying lead sheath 41. Extruded barrier layer 43 prevents lead corrosion in sheaths 41, which may be the result of galvanic coupling and/or crevice corrosion between the lead sheath 41 and cable armor 47.

Advantages of the invention include the prevention of chemical reactions from taking place between a lead sheath and cable armor. An extruded barrier layer forms a seal over the sheath. Additionally, the insulation quality of the barrier material reduces galvanic currents that may result in corrosion of the lead sheath. The barrier layer also serves to protect the soft lead sheath from mechanical damage and may eliminate the requirement for a bedding tape, which is typically used to protect the lead sheath from damage during manufacture. Unlike bedding tape, which is destroyed during service, the extruded barrier layer remains intact throughout the life of the cable.

10 While the invention has been shown in only one of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention.

We claim:

1. A cable for a submersible well pump, comprising:
three power conductors;
5 an elastomeric insulation surrounding each of said power conductors;
a lead sheath surrounding said elastomeric insulation of each of said
power conductors;
a continuous barrier layer over said lead sheath of each of said power
conductors, said continuous layer being substantially impermeable to fluids; and
10 a metallic cable armor wrapped around said extruded barrier layers.
2. The cable according to claim 1 wherein said continuous layer is an
extruded layer.
- 15 3. The cable according to claim 1 wherein said extruded barrier layer is
between approximately 5 to 50 mils in thickness.
4. The cable according to claim 1 wherein said extruded barrier layer is a
material selected from a group consisting of polyvinylidene fluoride, fluorinated
20 ethylene propylene, and a co-polymerization of tetrafluoroethylene and
perfluoromethylvinylether.

5. In a well pump assembly having a downhole pump driven by a downhole motor, an improved power cable for supplying power to the motor comprising:
- three power conductors;
 - 5 an elastomeric insulation surrounding each of said power conductors;
 - a lead sheath surrounding said elastomeric insulation of each of said power conductors;
 - a continuous thermoplastic barrier layer over said lead sheath of each of said power conductors, said barrier layer being substantially impermeable to fluids;
 - 10 and
 - a metallic cable armor wrapped around said extruded barrier layers.
6. The cable according to claim 5 wherein said continuous layer is an extruded layer.
- 15
7. The power cable according to claim 5 wherein said thermoplastic barrier layer is a material selected from a group consisting of polyvinylidene fluoride, fluorinated ethylene propylene, and a co-polymerization of tetrafluoroethylene and perfluoromethylvinylether.
- 20
8. A method of protecting a power conductor of a submersible well pump cable from a corrosive environment comprising the steps of:
- applying an elastomeric insulation around each of said power conductors;

surrounding said elastomeric insulation of each of said power
conductors with a lead sheath;

applying a continuous barrier layer over said lead sheath of each of
said power conductors, said continuous barrier layer being substantially impermeable
5 to fluids; and

wrapping a metallic cable armor around said continuous barrier layers.

9. The method according to claim 8 wherein said step of applying said
continuous barrier layer comprises extruding said continuous said barrier layer.

10

10. The method according to claim 8 wherein said continuous barrier layer
is polyvinylidene fluoride, fluorinated ethylene propylene, and a co-polymerization of
tetrafluoroethylene and perfluoromethylvinylether.

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Fig. 1

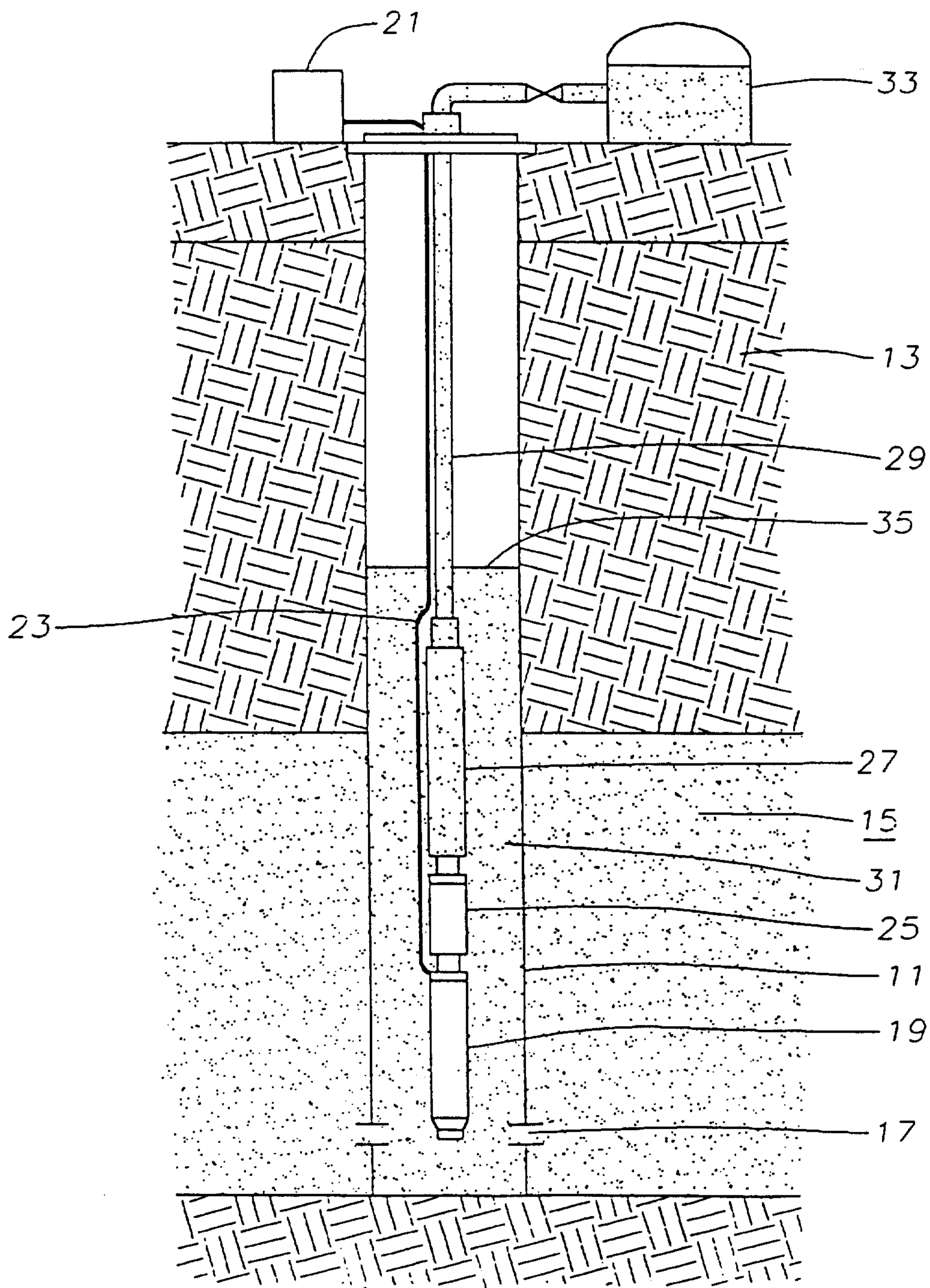


Fig. 2

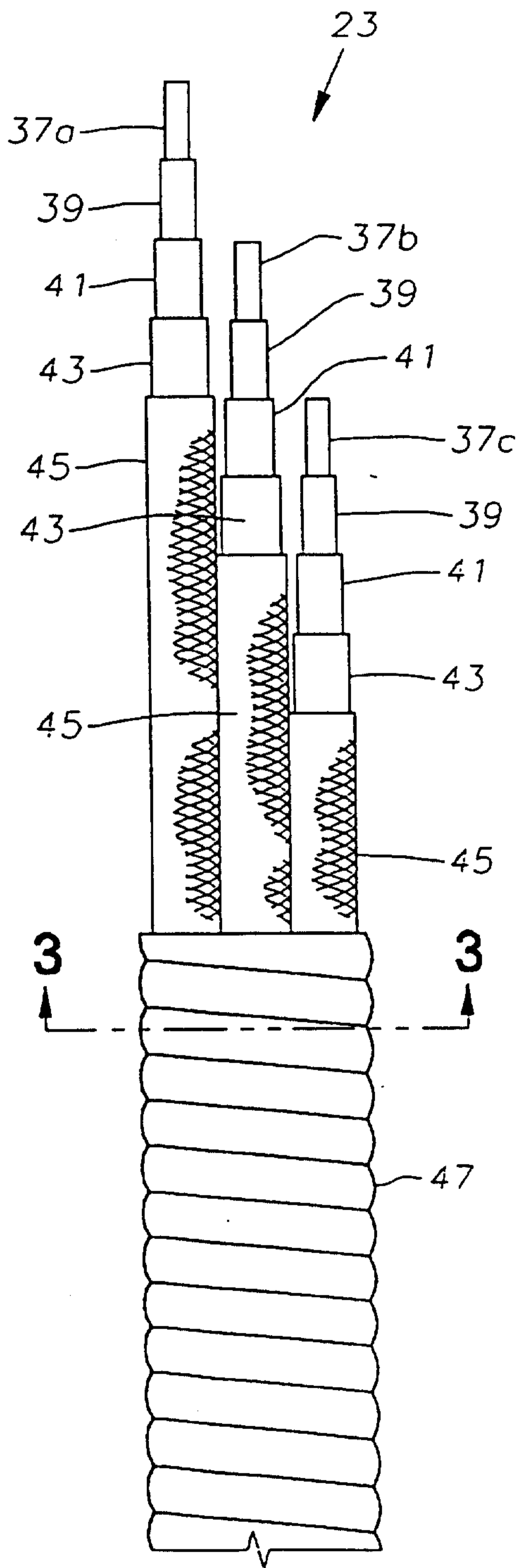


Fig. 3

