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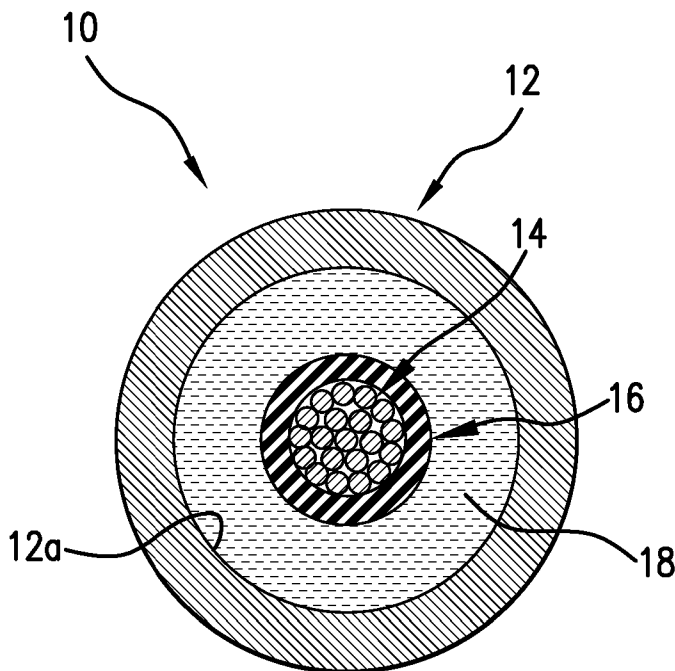


FIG. 1

(57) Abstract: A skin effect heating cable used to form a heat tracing circuit for heating a production pipe carrying process media. The skin effect heating cable includes a heating tube which includes a conductor, an insulating layer wrapped around the conductor and a dielectric fluid disposed between the insulating layer and the inner wall of the heating tube. The dielectric fluid increases the heat transfer characteristic from the conductor to the heating tube while providing mechanical load relief to the cable.

WO 2009/042575 A1

**SKIN EFFECT HEATING SYSTEM HAVING IMPROVED HEAT  
TRANSFER AND WIRE SUPPORT CHARACTERISTICS**

5 **FIELD OF THE INVENTION**

[0001] Embodiments of the invention relate to the field of heat tracing systems. More particularly, embodiments of the invention relate to a skin effect heating system and method having improved heat transfer characteristics and an associated support configuration.

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**DISCUSSION OF RELATED ART**

[0002] Heating systems are employed to facilitate the extraction of oil, gas and similar media from subterranean environments. For example, heating systems are used to prevent production losses resulting from paraffin deposits and hydrate formation in the extraction production tube as well as improving production of heavy oils by lowering the viscosity to provide better flow applications. One way to facilitate the heating of production pipes through which the media, such as oil, is extracted is to employ a heat tracing system. Electrical heat tracing systems are typically used in various industries including oil and gas, but may also be used in power, food and beverage, chemical and water industries. In these systems, a heating cable is connected or wrapped around a production or process pipe and power is supplied to the cable to form a heat tracing circuit.

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[0003] One type of pipe employed in heat tracing systems is a skin effect heat tracing pipe. Skin effect heat tracing pipes are preferred in many different pipeline

environments, including downhole or wellbore heating associated with oil extraction.

When this type of pipe is employed, the inner surface of a ferromagnetic pipe or tube is electrically energized (AC voltage) and an insulated, non-ferromagnetic return

conductor is used to complete the circuit. The inner surface of the pipe carries full

5 current and heats up, but the outer surface remains at ground potential. The path of the

circuit current is pulled to the inner surface of the heat tube by both the skin effect and

the proximity effect between the heat tube and the conductor. The skin effect circuit impedance is mainly resistive, thereby generating heat in the tube wall and, to a lesser

extent, in the insulated conductor. Additional heat transfer results from eddy currents

10 induced in the tube wall by the current flow through the conductor. These eddy currents

are the result of the changing magnetic field due to variations of the field over time

which causes a current within the conductor. In this manner, the skin effect pipes are in

contact with the outer surface of the delivery conduit and thermal conduction is used to

transfer the heat from the skin effect pipe to the delivery conduit and consequently to the

15 process media.

**[0004]** The size and depth of the skin effect heating system depends on the length of

the circuit within the subterranean application, the power output of the circuit, the tube

and conductor size as well as the process media pipe temperature. All of these factors

contribute to the efficiency and effectiveness of the heating system. However, a

20 drawback associated with these systems is that the heat transfer from the conductor to

the conduit or tube results in high conductor temperatures, thereby limiting the overall

power supplied by the heat tracing system. In addition, the mechanical tension on the

heat tracing cable within the conduit or tube, which increases with subterranean depth

due to gravitational forces, may compromise the integrity of the heating cable. Thus, there is a need for a skin effect heating system which provides improved heat transfer to the tube or conduit from the conductor and a tension management system which maintains the integrity of the cable within the wellbore.

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### **SUMMARY OF THE INVENTION**

[0005] Exemplary embodiments of the present invention are directed to a skin effect heat tracing system with improved heat transfer characteristics and an associated support configuration. In an exemplary embodiment, the skin effect heat tracing cable is positioned along a production pipe carrying process media and includes a heating tube, a conductor, an insulating jacket and a dielectric fluid. The heating tube is in contact with the production pipe to transfer heat thereto. The conductor is disposed within the heating tube and is connected to a power supply to supply current to the conductor. The power supply is also connected to the heating tube to complete a heat tracing circuit with the conductor. The insulating layer or insulating jacket is positioned around the conductor and the dielectric fluid is disposed between the heating tube and the insulating layer.

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### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0006] FIG. 1 is cross-sectional view of an exemplary embodiment of a heat tracing cable in accordance with the present invention.

[0007] FIG. 2 is a block diagram longitudinal cross-sectional view of a heat tracing cable installed within a well in accordance with the present invention.

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[0008] FIG. 3 is a longitudinal cross-sectional view of a heat tracing cable within a conduit or tube in accordance with the present invention.

#### DESCRIPTION OF EMBODIMENTS

5 [0009] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention, however, may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and  
10 complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements throughout.

[0010] Fig. 1 is a cross-sectional view of an exemplary embodiment of a skin effect heat tracing cable 10 in accordance with the present invention which includes a conduit or coiled tube 12, conductor 14, electrical insulation 16, and a dielectric fluid disposed  
15 between tube 12 and insulation 16. Heat tracing cable 10 may be used in various sub-sea and oilfield environments including bottom hole heating and reservoir stimulation, gas and water systems and other high pressure applications requiring skin effect heating cables. Conductor 14 is centrally positioned within the heat cable 10 and is comprised  
20 of a high strength conductor such as, for example, copper clad steel, high strength copper alloy, steel reinforced aluminum or other like material having sufficient strength and electrical conductivity. The conductor may be from about 0.25" to about 0.5" nominal dimensions, but can be larger or smaller depending on the particular application. Conductor 14 may be a solid conductor composed of multiple layers of

different materials. Alternatively, conductor 14 may be a stranded conductor composed of different designs and compositions including, for example, copper, aluminum, ferromagnetic steel, stainless steel, nickel plated copper, and the preferred material being copper.

5 [0011] Conductor 14 is surrounded by insulating layer 16 having a thickness, for example of from about 0.060" to about 0.120" and more preferably from 0.080" to about 0.100" and capable of withstanding temperatures from about  $\geq 100^{\circ}\text{C}$ . Insulating layer 16 may be comprised of, for example, a cross linked polyethelene formulation, fluoropolymers and the like. For example, polyethylene formulations are particularly  
10 applicable for higher voltage applications, whereas fluoropolymers are particularly useful for high temperature applications.

[0012] Conduit or tube 12 may be, for example, a coiled ferromagnetic steel tube and is non-porous to contain dielectric fluid 18. Conduit 12 may also be any ferromagnetic heatable encasement configuration such as steel pipe, coiled tube, roll  
15 formed tube, etc., which is capable of withstanding elevated temperatures found in wellbore applications. The diameter size of conduit 12 is dependent on the particular wellbore application, but may be, for example, from about 3" outer diameter (O.D.) to about 0.5" O.D. and preferably from about 2" O.D. to about 1" O.D. Conduit 12 has an inner wall surface 12a and a wall thickness from about 0.1" to about 0.5".

20 [0013] A dielectric fluid layer 18 is disposed between insulating layer 16 and conduit 12. In particular, dielectric fluid is filled into cable 10 between insulating layer 16 and the inner wall 12a of tube 12. Dielectric layer 18 wraps around conductor 14 and is used to reduce the gravitational tension and/or compression loads in the conductor 14.

The gravitational tension is reduced by decreasing the weight of the heating cable and thus the gravitational forces applied to the cable positioned within the wellbore. In addition, dielectric fluid layer 18 also improves the heat transfer characteristic from conductor 14 to conduit 12, while improving the dielectric capabilities to the insulation 16. Dielectric fluid 18 improves the heat transfer characteristic by eliminating air from around insulation layer 16. This minimizes the risk of partial discharge (PD) which is a particular concern for fluoropolymer insulations. In this manner, by adding dielectric fluid 18, an increase voltage may be employed for use with high temperature insulating layer 16. Representative dielectric fluids 18 may include, for example, mineral oils, organic based transformer oils and similar materials capable of providing sufficient dielectric strength and thermal stability to further electrically insulate the conductor 14 from tube or conduit 12. Representative dielectric fluids include SHELL DIALA® Oil HFX sold by Shell Oil Company of Houston, Texas (USA).

**[0014]** Fig. 2 generally illustrates an exemplary partial view of a downhole subterranean wellbore 100 having a well head section 110 and lower casing section 115. Wellhead section 110 includes a wellhead cap 130 and a wellhead cavity 135. The skin effect heating cable 105 is connected to one end of electrical penetrator power box 120 which provides AC power to the cable. Electrical penetrator box 120 extends through well head cap 130 and is connected at its other end to a power cable and transformer (not shown) at or near the surface of the well. Mandrel 140 is connected to, or extends through wellhead cap 130 for mechanical support for cable 105. Alternatively, mandrel 140 may also be located outside of wellhead section 110. Mandrel 140 is illustrated with a fishing neck portion 141, however a substantially cylindrical shaped mandrel may

also be employed. Cable 105 is wrapped around mandrel 140 in wellhead section 110 to provide mechanical load relief to electrical penetrator 120 and cable 105 as it extends into the depths of wellbore 100. In particular, by wrapping cable 105 around mandrel 140, the gravitational forces and load of the cable is dispersed across the mandrel. A tube hanger 150 is disposed within casing 115 and is used to provide mechanical holding strength to heating tube 180. A standard tube connector 190 is disposed between tube hanger 150 and heating tube 180. Heating cable 105 extends down through wellhead cavity 135, tube hanger 150, tube connection 190 and heating tube 180. The heating tube 180 extends along the production tube (not shown) down the wellbore to provide a heat tracing circuit to heat the process media flowing through the production tube. The heater cable may not extend down the entire length of the production tube depending on the extraction application. In addition, the production tube may also be diverted away from the electrical penetrator as it approaches the wellhead through a series of valves and piping connections.

**[0015]** Fig. 3 is a longitudinal cross-sectional view of a simplified wellbore to illustrate the use of heat tracing cable 105 in which the dielectric fluid 18 (shown in Fig. 1) is employed. In particular, wellhead section 110 receives skin effect heating cable 105 at one end which extends down into a portion of the wellbore by way of heating tube 180 along a production pipe carrying process media. An end seal 210 is located at the end of the heating tube 180 within the wellbore to provide a mechanical anchor and stop for the heating cable 105 within tube 180. In particular, the conductor 14 within tube 180 is typically a heavy steel or copper having significant weight with a downward gravitational force. End seal 210 located at the downward termination point of cable

Attorney Docket No. S-TC-00035

105 provides a “stop” for this downward force. In addition, end seal 210 provides a circuit connection between the conductor 18 (shown in Fig. 1) and the heating tube 180 to complete the heat tracing circuit. As explained with reference to Fig. 1, heating tube 180 includes a conductor section 14, insulating layer 16, dielectric layer 16 and tube or  
5 conduit 12. The conductor 14 and tube 12 are connected to a power supply via electrical penetrator 120 (shown in Fig. 2). Before or after installation of the heating cable 180 down the wellbore, tube 12 is filled with dielectric fluid 18. The dielectric fluid 16 fills around conductor 14 within tube 12 and is used to reduce the gravitational tension and/or compression loads in cable 180 within the wellbore. Dielectric fluid 18 improves  
10 the heat transfer characteristic from conductor 14 to conduit 12 and consequently to the production tube (not shown) through which process media, such as oil, flows toward wellhead 110. In this manner, a skin effect heating system is employed which improves the heat transfer characteristic from the heating tube to the production tube while providing a novel support mechanism to relieve the mechanical load on the cable as it is  
15 installed down the wellbore.

[0016] While the present invention has been disclosed with reference to certain embodiments, numerous modifications, alterations and changes to the described embodiments are possible without departing from the sphere and scope of the present invention, as defined in the appended claims. Accordingly, it is intended that the present  
20 invention not be limited to the described embodiments, but that it has the full scope defined by the language of the following claims, and equivalents thereof.

Attorney Docket No. S-TC-00035

What is claimed is:

1. A skin effect heating cable positioned along a production pipe carrying process media, said heating cable comprising:

a heating tube within or in contact with said production pipe to transfer heat thereto;

5 a conductor disposed within said heating tube, said conductor connected to a power supply to supply current to said conductor, said power supply connected to said heating tube to complete a heat tracing circuit with said conductor;

an insulating jacket positioned around said conductor; and

a dielectric fluid disposed between said heating tube and said insulating jacket.

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2. The heating cable of claim 1 wherein the dielectric fluid at least partially contains an organic based transformer oil.

3. The heating cable of claim 1 further comprising a seal located at the end of said  
15 heating cable, said seal configured to provide a mechanical anchor point for said conductor.

4. The heating cable of claim 1 further comprising a seal located at the end of said heating cable, said seal electrically connected to said conductor and said tube to complete  
said heat tracing circuit.

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5. The heating cable of claim 1 wherein said conductor is a high strength steel.

6. The heating cable of claim 1 wherein said conductor is a high strength copper.

Attorney Docket No. S-TC-00035

7. The heating cable of claim 1 wherein said conductor is a stranded conductor having a plurality of electrically conductive strand portions.

8. A skin effect heating system for installation within a subterranean well having a wellhead and a wellbore, said heating system comprising:

5 a skin effect heating cable positioned within or along and in contact with at least a portion of a production pipe disposed down said wellbore, said production pipe carrying process media up from said subterranean well, said heating cable having a first end connected to a power supply and a second end connected to a sealing portion, said second end and said sealing portion disposed within said wellbore;

10 a mandrel disposed within and connected to said wellhead, said heating cable wrapped around said mandrel and configured to relieve gravitational load stresses on said cable as it is positioned within said wellbore.

15 9. The skin effect heating system of claim 8 wherein said heating cable comprising:

a heating tube within or in contact with said production pipe;

20 a conductor disposed within said heating tube, said conductor connected to a power supply through said wellhead, said power supply configured to supply current to said conductor, said power supply connected to said heating tube to complete a heat tracing circuit with said conductor;

an insulating jacket positioned around said conductor; and

a dielectric fluid disposed between said heating tube and said insulating jacket.

Attorney Docket No. S-TC-00035

10. The skin effect heating system of claim 9 wherein said wellhead further comprises a wellhead cap, said heating system further comprising an electrical penetrator disposed through said wellhead cap and disposed between said power supply and said conductor.

5 11. The skin effect heating system of claim 8 wherein said wellhead further comprises a wellhead cap, said mandrel connected to said wellhead cap.

12. The skin effect heating system of claim 8 wherein said mandrel has a substantially cylindrical shape.

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13. The skin effect heating system of claim 9 further comprising:  
a tube hanger connected to said wellhead through which said heating cable extends;  
a tube connector having a first and second ends, said first end connected to said tube hanger, said second end connected to said heating tube.

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14. The skin effect heating system of claim 9 wherein said sealing portion electrically connects said conductor and said heating tube to complete a heat tracing circuit.

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15. A method for installing a skin effect heating cable within a well comprising:  
placing an insulated conductor within a tube;  
forming an electrically conductive connection between said conductor and said tube;  
inserting the tube containing the conductor into a wellbore; and  
filling the tube with a dielectric fluid.

Attorney Docket No. S-TC-00035

16. The method of claim 15 further comprising installing the tube along at least a portion of a production pipe within said wellbore.

17. The method of claim 15 wherein said wellbore includes a top portion located at the surface of said well, said method further comprising connecting said conductor and said tube to a power supply through an electrical penetrator positioned near the top of said wellbore.

18. The method of claim 15 wherein said wellbore includes a top portion located at the surface of said well, said method further comprising wrapping said cable around a mandrel located near the top of said well.

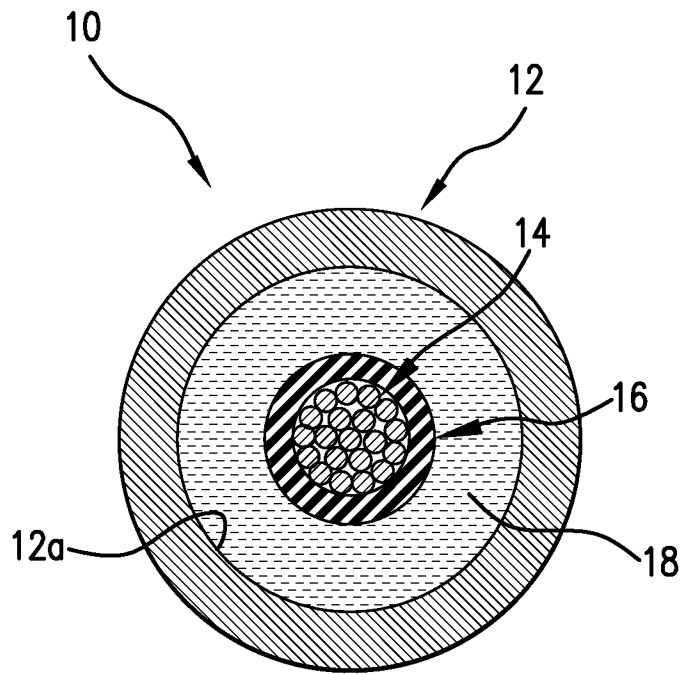


FIG. 1

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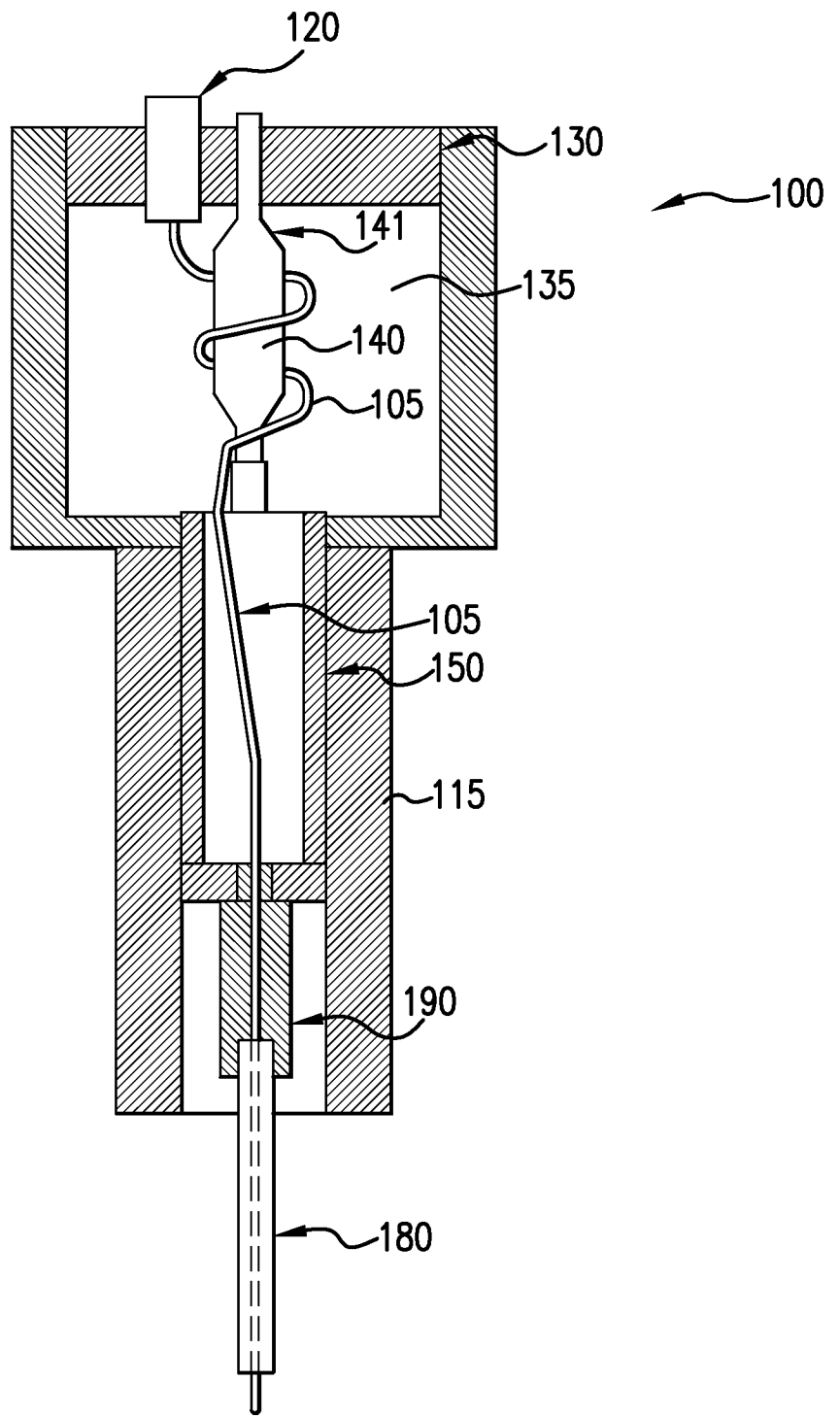


FIG. 2

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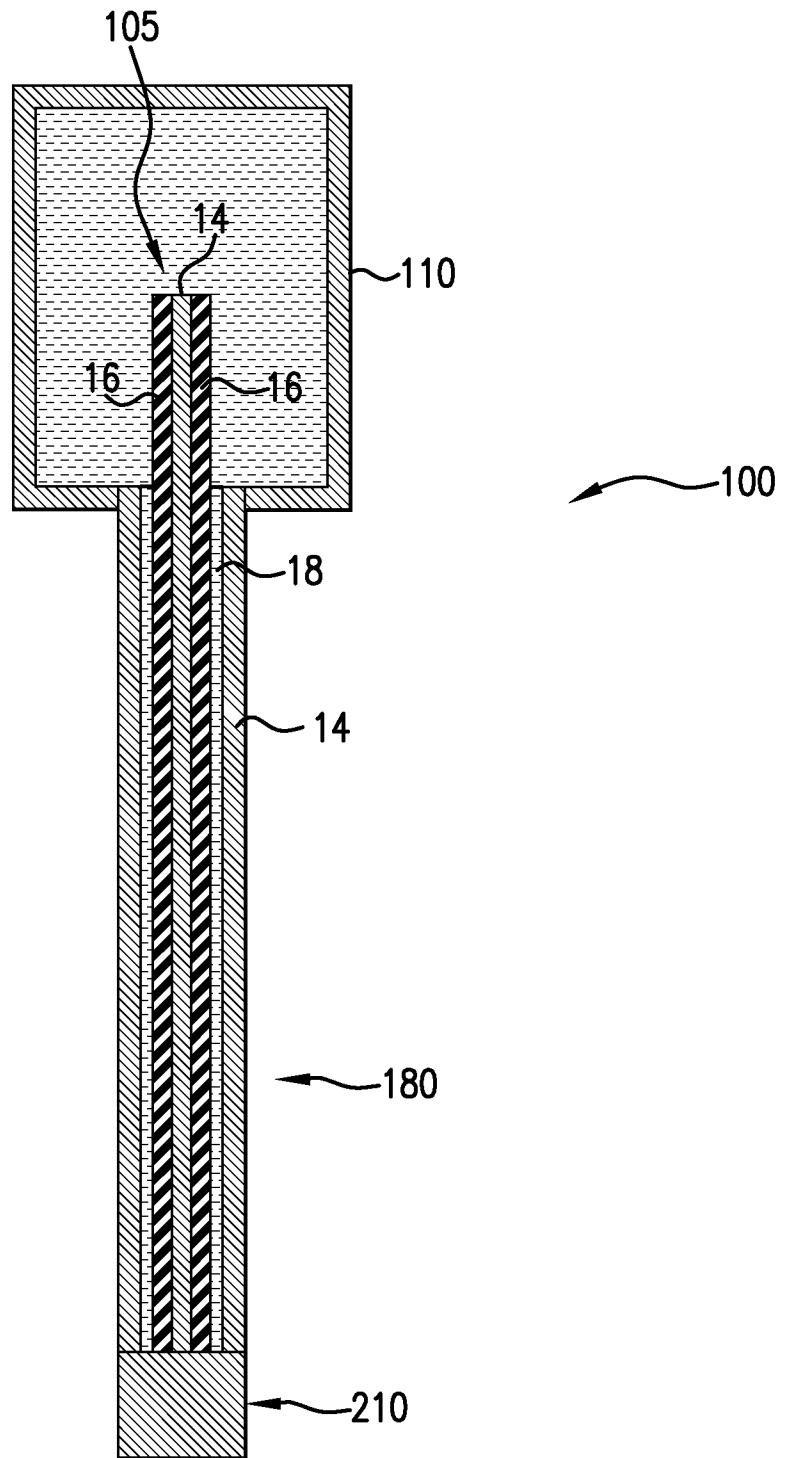


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 36/00 (2008.04)

USPC - 166/302

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(8) - E21B 36/00 (2008.04)

USPC - 166/302

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)

MicroPatent

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/023023 A2 (DE ST. REMEY) 02 March 2006 (02.03.2006) entire document	1, 3-5, 7-18
Y		2, 6
Y	US 2007/0127897 A1 (JOHN et al) 07 June 2007 (07.06.2007) entire document	2, 6

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Date of the actual completion of the international search

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